EPA/540/8-91/012
OSWER DIRECTIVE #9355.8-01
MAY 1991

Design And Construction Issues At Hazardous Wastes Sites

CONFERENCE PROCEEDINGS

HYATT REGENCY AT REUNION, DALLAS, TEXAS
MAY 1-3, 1991

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Emergency and Remedial Response
Harzardous Site Control Division
Washington, D.C. 20460

Printed on Recycled Paper

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ACKNOWLEDGEMENT

The U.S. Environmental Protection Agency (EPA) wishes to thank all of those who participated in the development of the Agenda, Proceedings Manual, and attended the first "Conference on Design and Construction Issues at Hazardous Waste Sites", held between May 1-3, 1991 at the Downtown Hyatt Regency at Reunion in Dallas Texas. The feedback received during and after the conference was extremely positive; it is EPA's plan to sponsor this conference on an annual or biennial basis over the next several years until a 'steady-state' in design and construction at hazardous waste sites is reached.

Several individuals played an important role in making the conference the success it was. In particular, Kenneth Ayers, William Zobel, and Edward Hanlon of USEPA, and Michael Blackmon and Chris Fafard of PEER Consultants, and the PEER Consultants Word Processing staff, should be recognized. We thank these individuals, the Conference Abstract Review Committee, and the authors, speakers, panel members, and conference participants for a job well done. Their efforts will help insure that design and construction efforts during hazardous waste site remediation will continue to see quality improvements in future years.

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PREFACE

CONFERENCE ON DESIGN AND CONSTRUCTION ISSUES AT HAZARDOUS WASTE SITES MAY 1-3, 1991, HYATT REGENCY AT REUNION, DALLAS

The first U.S. Environmental Protection Agency (EPA)-sponsored national conference on design and construction issues at hazardous waste sites occurred between May 1-3, 1991 at the Downtown Hyatt Regency at Reunion in Dallas Texas. Ninety-five presentations of technical papers with three panel discussions on technical/policy issues and case studies were held.

Included in this publication are questions and answers from the panel discussions, as well as text of the technical papers. In some cases, the authors' names and addresses are included at the end of their respective papers. This 'Conference Proceedings' culminates and memorializes the significant efforts made at and for this conference.

This national conference was warranted and timely due to the increased complexity of issues related to this subject area and the growing number of hazardous waste sites entering design and construction. The conference also had a different intent, agenda and format than other major hazardous waste conferences. An open exchange of ideas to promote formal and informal discussion of design and construction issues was planned, in order to encourage national consistency, help develop more efficient and practical means to move design and construction projects through the pipeline, and augment EPA's current efforts to revise its Superfund design and construction guidance and policies.

Topics covered a range of issues, including pre-design activities, construction administration and claims, community relations, health and safety, and government policy. Participants include the U.S. Department of Energy (DOE), Department of Defense (DOD), Bureau of Reclamation, and Army Corps of Engineers, as well as EPA, numerous design and construction contractors and State agencies.

EPA wishes to thank all of those who participated in the first "Conference on Design and Construction Issues at Hazardous Waste Sites". It is EPA's plan to sponsor this conference on a regular basis over the next several years. The next conference is tentatively planned for early April, 1992 in Chicago.

Future inquiries regarding this conference and next year's planned conference are encouraged to be made in writing to the attention of: Kenneth Ayers, Chief, Design and Construction Management Branch, U.S. Environmental Protection Agency, 401 M Street, SW, Mailcode OS-220W, Washington DC 20460, or by contacting EPA's Design and Construction Management Branch at (703) 308-8393.

SUMMARY OF QUESTIONS AND RESPONSES FROM THE PANEL SESSIONS

DESIGN AND CONSTRUCTION POLICY PANEL SESSION

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USEPA

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USACE

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Chief, Superfund and Emergency Response Section
Texas Water Commission

Doug Smith
U.S. Department of Energy

John J. Smith
Acting Branch Chief
Remedial Operations and Guidance Branch
USEPA

James Moore
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1. **QUESTION:** What support is available through the Corps of Engineers or the Bureau of Reclamation for RCRA-lead actions?

   RESPONSE: The Corps and Bureau of Reclamation are available and have done support of RCRA actions.

2. **QUESTION:** How are lessons learned at remediation sites in Texas shared?

   RESPONSE: Papers are presented at Conferences such as this. The State is open to provide any information they have to interested parties.

3. **QUESTION:** With regard to Texas State Enforcement actions, how do you view cost recovery and what documentation is acceptable with the courts?

RESPONSE: Cost recovery on non-NPL sites has been successful on solid waste enforcement sites. On NPL sites the recovery is conducted in conjunction with the EPA. The State Superfund program has not proceeded far enough to start recovery.

4. **QUESTION:** With the new shift to PRP lead RD/RAs, we need to evaluate what the PRPs are like; some may be trusted, some not. This may be determined in the negotiation process. It should be considered that the public does not trust the PRPs.

RESPONSE: A draft PRP Oversight Guidance Document has been prepared and distributed to RPMs. Current EPA staffing and funding will not be able to handle oversight of a large number of new sites. The amount of liability that the EPA will assume in PRP oversight must be evaluated. Possibly each enforcement action needs to be evaluated, case by case, and as little oversight as necessary be used. Begin with high oversight and, if the PRP is determined to be performing acceptably, reduce the amount of oversight. This approach is presented in the guidance which is still out in draft form, awaiting feedback. The guidance is flexible, based on the RPM's evaluation of the PRP performance. Part of the guidance was to have the PRP provide an Independent Quality Assurance Team provide QA data to the RPM for review. This point is still in contention.

5. **QUESTION:** When can we expect an agreement between EPA, Corps and Bureau of Rec on data validation?

RESPONSE: EPA Region 2 does have an agreement with the Corps, and a national agreement has been proposed. Current trends are shifting toward more autonomy to the EPA Regions, and fewer national agreements are being signed. EPA Regions and the respective Corps and Bureau of Reclamation representatives need to determine, on a Region-specific basis, whether such agreements are necessary. If so, meetings should be set, and decisions made, on this issue.

6. **QUESTION:** What is the status of "Lessons Learned"? What is the direction for distribution?

RESPONSE: A computerized "Lessons Learned" system was developed at the Corps which every field office could input to and be read at headquarters. The current status of the system was not available. It is not currently being used for the Superfund Program, but it will be adopted.

7. **QUESTION:** One of the problems many RPMs run into is the acquisition of property during a Remedial Action. Many Remedial Actions have been halted to allow time to acquire a piece of property, property easement or long-term lease. Under SARA, the law requires that any property acquisition during a Remedial Action must be accepted by the State after the action is complete.

In Pennsylvania, the Commonwealth has refused to accept any of the acquired properties. Since an agreement with the Commonwealth has to be in place prior to the property acquisition, projects in Pennsylvania are stifled at the time. Is anything being done to deal with the States' concerns that they will be liable for any contamination remaining on the site after the Remedial Action?

RESPONSE: It is a requirement under the law; we can't get around this. EPA's tentative understanding is that states may not be considered liable for any contamination remaining on the site after remedial action. However, if only an easement is needed which will expire at the end of the Remedial Action, State approval is not required. If we are buying property and the lease actually comes to the EPA, an agreement for transfer to the State is required. In regard to the liability issue, in the Superfund contract the States have agreed to operate and maintain long-term remediation after the EPA completes its efforts. We don't understand or know all the details of why Pennsylvania has taken this stand at the this time.

8. **QUESTION:** The States are mainly fearful of "owner liability" for property which they must take over after the Remedial Actions. Is there any effort at Headquarters to relieve the States of this potential liability in the future?

RESPONSE: As discussed above, EPA's tentative understanding is that states may not be considered liable for any contamination remaining on the site after remedial action. EPA is still investigating this issue. However, it was never fully understood why Pennsylvania was not willing to accept the property acquisitions. This can be discussed with Headquarters Council to see if there is some wording which may assist in the negotiations with Pennsylvania.

9. **QUESTION:** Do you think the Federal Government could be a central data-gathering point for "Lessons Learned" within the Corps, and States as well, and could there be a publication of this data for those who need this information?

RESPONSE: This would be the optimum; however, resources are not available at this time to facilitate this large an effort. For a computer database of "Lessons Learned", significant screening of the data to be input must be done. "Lessons Learned" may become purely emotional or personal, which are not the intent of this type of database. Information which is not clearly worded and analyzed could be misinterpreted or lead to liability. This will require mature screening.

RESPONSE: The EPA Design and Construction Management Branch produces a bimonthly flyer, "RD/RA Update", which provides current information and "lessons learned" on RD/RAs.

10. **QUESTION:** In regard to setting design parameters, I understand that there is a lack of data available to make site decisions. When you get into the construction phase, you need to take the opportunity to seek the data to verify the design parameters that you have designed with and make necessary adjustments. Is the Corps of Engineers putting into place any mechanism to keep the Designer involved during construction to verify design parameters?

RESPONSE: Absolutely. An agreement is made with the designer for involvement throughout construction to discuss problems, etc.

11. **QUESTION:** In regard to AE liability, could this point be expanded on?

RESPONSE: In just the last few years the EPA has gotten heavily involved in design, and we are now seeing designs being implemented. EPA's REM contracts had the standard AE liability clause, which states that if there is an error or omission that the AE firm will go back and correct this error or omission at no cost, and if the error or omission was caused by negligence and the error caused significant increased costs the AE firm will be liable for these costs (rough interpretation). If the EPA gives the designer definitive direction, more than likely the EPA is assuming liability for the affects of that direction.

The guidance given to the AE determines if the AE is liable for errors. An AE liability clause is being drafted specifically for the ARCs contracts. However, the negligence standard, Section 119 set up for indemnification, may conflict with the liability clause; it is not a clear-cut issue.

12. **QUESTION:** What are the differences between the two liability clauses?

RESPONSE: Section 119 imdemnification addresses third party liability associated with releases or threatened releases. AE liability is two party, which focuses on design errors or omissions. The clause being drafted for the ARCs contracts is not substantially different. It clarifies that for a cost reimbursement contract, if an error or omission occurs the EPA is only asking for the error or omission to be corrected at no cost; EPA is not asking for additional design work to be performed gratis. Also, it clarifies negligence portions so there is not a conflict with the negligence standard, Section 119.

13. **QUESTION:** What efforts have been made by the Corps of Engineers to involve small, disadvantaged or women-owned business in your contracts?

RESPONSE: Efforts are being made to track small and disadvantaged business (SDB) contracts and insure the set-aside levels are met. Future effort will be made to track the amount of subcontracts which are awarded to SDBs.

14. **QUESTION:** Should private industry be performing site clean-up with the question of clean-up sufficiency? Could other mechanisms be used to achieve clean-up? Could the property be given to the AE firm in return for the clean-up? The EPA providing funds to the Corps who then pays an AE does not seem efficient.

RESPONSE: An "orphan" site is a site which does not have a viable PRP. This does not necessarily mean there is not an owner; it means that the PRP does not have the funds or ability to do the remediation. The EPA cannot just take possession of the property. The legal ramifications would be extensive.

In regard to efficiency, the decision was made to get the most technically qualified people working on Superfund site remediations due to the potential risks posed at these sites. Costs were not the central factor. The Corps was determined to have the technically qualified personnel needed. Efficiency, strictly in regard to profit margin, is not the whole picture.

15. **QUESTION:** In Navy programs there is not enough contract oversight available. The oversight official cannot keep up with the amount of data and information generated by several contractors at several sites. The contractors then operate with minimal oversight. I think the Government or the EPA's time would be better spent on enforcement.

RESPONSE: That is one of the problems focused on by EPA Administrator William Reilly - enforcement first; however, resolving this problem will not occur overnight.

The EPA has had a preponderance of excellent contractors and encourages initiative by contractors. It depends on your outlook and how you want to use a contractor. Overall the products received by the EPA have been excellent. However, the EPA would prefer to have 100% enforcement actions and not spend any of the Superfund.

16. **QUESTION:** Any lessons learned from Value Engineering Studies?

RESPONSE: We are very receptive to contractors proposals on how to better clean up sites. At the Sikes project, a major revision is underway. Under State law, however, we cannot share the savings.

There is a Federal value engineering clause in which savings achieved through a value engineering study are shared with the contractor. The Bridgeport, New Jersey site had a value engineering proposal which was accepted by the government during construction.

17. **QUESTION:** I understand there is an interagency agreement between the EPA and the Corps that states any contract that is more than $5 million will go to the Corps. I recommend that this limitation be extended from $5 million to $10 million. There are 45 ARCs contractors, and you will achieve your goals more quickly and efficiently.

RESPONSE: There is no dollar value specified in the interagency agreement. It was strictly a policy call on EPA's part. Any projected remedial action of less than $5 million, the Regions have their choice of using the Corps, bureau of Rec or an ARCs contractor for either or both Design and Construction. For contracts between $5 million and $15 million, the Regions haves the choice of using an ARCs contractor or Corps of Engineers for design and implementing the construction through the Corps or Bureau of Rec. Anything over $15 million is to be designed and constructed by the Corps of Engineers or Bureau of Rec.

A policy letter has been drafted to consider exceptions to this policy on a case-by-case basis. The Regions would have to make a strong argument to waive this criteria.

COMMUNITY RELATIONS PANEL SESSION

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Betty Williamson
Community Relations Coordinator
USEPA, Region VI

George Hanley, USACE

Pat Ferrebee
U.S. Navy

1. **QUESTION:** Regarding your comments about not responding argument by argument in the Responsiveness Summary, how do we have a complete Responsiveness Summary if we have, say, forty arguments in the formal comments and do not address them individually?

RESPONSE: There are situations where the arguments get so outside of the reality of the project that they start creating problems that do not exist, be it a hypothetical question or whatever. Instead of being in a response mode where we literally go through the arguments and respond sentence by sentence, we got back to the basics of "did we consider reduction of volume, toxicity and mobility". We focused on those issues that they were trying to attack, rather than getting into a point by point discussion in the response.

2. **QUESTION:** My understanding of the Responsiveness Summary is that you can take the comments and group them into general points, as opposed to addressing specifics to the letter.

ANSWER: Correct.

3. **QUESTION:** Concerning sending documents out to the TAG group (Technical Assistant Grant group of the New Bedford Community Environmental Awareness Group), they were sent out as draft documents -- were they EPA internally reviewed, or what do you mean by "draft"? Were they documents that actually came from the RI consultant?

RESPONSE: The documents the TAG group received from their own consultant were final documents; the group had hired this consultant to generate their documents. The TAG group received from EPA draft RI documents prepared by EPA's RI consultant.

4. **QUESTION:** I assumed that EPA had a consultant doing the RI/FS; did the TAG people see documents directly from that consultant, or did EPA internally review these documents, with their technical people, before they went to the TAG group?

RESPONSE: EPA reviewed them first, they were draft final versions.

5. **QUESTION:** Did you find, when you first started working with the Community Group, that they were organized to the point that they were ready to apply for the Technical Assistance Grant, or anxious to do so, or was it something that had to be worked with?

RESPONSE: No, the group had to be formed. Going back to the initial meeting they had, there was difficulty because the area was settled with Portuguese with little English speaking ability. EPA community relations coordinators went out with bilingual material trying to generate interest for the group. At an early meeting with the City of New Bedford, one woman requested to be the project manager. She organized sign up sheets which were taken to the community.

6. **QUESTION:** Did you provide assistance or background for the incorporation process which the Community Group went through?

RESPONSE: They did that on their own. Problems developed with attaining Non-Profit Organization status through the IRS.

7. **QUESTION:** When initial newspaper articles (regarding a hazardous waste site) came out, was there any sort of direct response by the Navy, or did you just kind of let them go and continue with your community relations?

RESPONSE: We did a press release, and we also prepared several fact sheets which we took to the community. We put them in the post office, library, etc. We had already set up an information repository -- we had done a few of the preliminary things we would do for a CR. We did not respond directly to the newspaper article because they had taken all our words, distorted them, then devoted several pages to the distorted version.

8. **QUESTION:** When your press officer experienced loss of credibility, was there a communication strategy or any kind of a CRP in place?

RESPONSE: We did not have a CRP in place. We figured out our plan as events unfolded. We had never gone out and done interviews, never prepared a formal CRP. I can tell you now that the Navy does not like to be in that kind of a situation. As soon as we realize contamination on a site, we like to get started [with community relations]. The sooner you get started, the better off you are. We learned a valuable lesson in Mechanicsburg, and if nothing else, it was worth that experience.

9. **QUESTION:** Can you describe the situation in Mechanicsburg?

RESPONSE: We had PCBs in the drainage ditch, but that is not what was described in the paper. Mechanicsburg is a supply depot, where the U.S. keeps their strategic supplies on a 700 acre paved site. We keep strategic reserves of lead, chromium, manganese, etc. Mechanicsburg is a ship's parts control center. We have parts of ships in supply there. It's one of those sites that, in time of war, ships parts to whoever needs them. One of the things that was a problem for us when the state discovered the PCBs was that we could not identify their source because we had no record of having stored PCBs on that facility. We finally discovered that we had rebuilt transformers there, and that was the source of PCB contamination. We did an extensive storm sewer evaluation to try to track down where the PCBs were coming from, and we had to replace portions of that storm sewer.

We had talked to the newspaper about other sites, though, including the site where we had buried outdated medical supplies from World War II. That's where the newspaper blew things out of proportion.

10. **QUESTION:** Is this a base where Navy personnel live, and what kind of Community Relations exist with the base people?

RESPONSE: We informed them first, because people on the base don't like hearing about a base problem from a neighbor or friend. They want to know about it first. They were kept informed through briefings.

11. **QUESTION:** On the Formerly Used Defense Sites, does the Corps conduct the community relations plan or is there some leftover military facility that handles it?

RESPONSE: If it's an active installation, the Corps provides technical support; the installation prepares the CRP. For remediation at active installations, there is a book called <u>The Commander's Guide to Installation Restoration</u> -- an Army publication from USATHAMA -- that says the responsibility of the installation commander is to be the paragon of environmental virtue. The cleanup of a site is his responsibility, so even if the Corps may be running everything else at a site, the chairman of the technical review committee is invariably the installation commander.

The CRP is usually prepared by active installations. We do offer to them to do the CRP and allow them to fine tune it, in which case we would turn it over to a contractor. The decision was made a long time ago that, with the number of sites we have in the Kansas City district, we would need an enormous number of people to prepare all the CRPs or even to manage that many contractors.

HEALTH AND SAFETY PANEL SESSION

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1. **QUESTION:** Is a hazardous waste site defined by OSHA? Example: An office trailer in the support zone. Do these workers need training?

RESPONSE: There is an internal inconsistency within the standards. In Section E it is defined that if an employee is on site regularly, and has no exposure or potential for exposure, he still needs 24 hours of training and one day of on-site training. This includes everybody that enters the boundaries of the site.

In Paragraph A of the standard: There must be an exposure from a hazard on-site for 120 to apply. The policy is, if there is a hazard the standard applies, if there is no hazard from the site then the standard will not apply.

COMMENT: Section A states that where exposures are known or potential then the standards apply if in one of 5 categories. The potential for exposure includes accidental exposure.

2. **QUESTION:** Does 1910.120 have a requirement for one Health and Safety Plan, rather than 50, one for each contractor on site. Should there be just one plan for the entire site?

RESPONSE: That is the way the standard is interpreted.

COMMENT: The contractor should approve the plans for the subcontractors.

COMMENT: There is no rule saying there has to be just one health and safety plan (HASP), but any others should be just as strict and specific as the prime contractors, to make life easier. It is the Prime Contractor's responsibility to oversee the subcontractor's HASPs.

COMMENT: The contractors write the HASP and the subcontractors must comply. It is not always the case where it is one site, one HASP, especially for very large sites where there are four or five major contractors. A better way to work it is one project, one HASP.

COMMENT: During contract solicitation, they normally require a HASP. Exceptions are when contractors onsite want a more restrictive plan. They may add to the minimum OSHA and Corps requirements.

3. **QUESTION:** Should contractor's health and safety record be a requirement for bid specs?

RESPONSE: For a request for proposals, the health and safety record is a factor. For an IFB it is not a factor. Contractors at this point should be aware of the requirements. Some major contractors, for example, the government, considered this a prequalification.

4. **QUESTION:** Congress passed a law about agencies assuming responsibility for worker training. Of the 1.8 million workers that qualify for this, 53% are firefighters, who have the highest risk, but are not adequately trained. Thirty-one percent are law enforcement agents, also high risk and one percent are hazardous waste workers who have a lot of

training. Doesn't the firefighter agency have a direct responsibility to provide adequate funding, as Congress had intended the money to be used, as in the case of firefighters with high legitimate claims to be trained rather than for EPA to assume responsibility.

RESPONSE: The request for training is very competitive. Many agencies apply, but only a few get it. This agency has filled their obligation thus far with the money that is available. If there is more money, there will be more training. The Hazardous Materials Transportation Act of 1990 is providing a grant program at the local level through public sector agencies. When this grant goes through, there will be more training from the fire service.

5. **QUESTION:** If the funding is inadequate, why not go back to Congress and say there is not enough money for training, so these people can do their jobs effectively. It seems as though the money is going to the wrong people. Educational Institutions should not be getting the funding because they do not have the authority to help. People who do the work should be getting the money.

RESPONSE: The President's budget cut the programs funding in half. Appropriations are fighting it now.

6. **QUESTION:** What is to be done with utility companies wanting to come on site for routine maintenance, main breaks, etc. Should they have a trained contractor on site with them? Is it okay to just have a site safety person out there to make sure that the utility company complies with the site HASP? How does OSHA feel about this? Is this a violation to have them on site?

RESPONSE: OSHA says there must be site representative who is trained with a trained person monitoring. All utilities should have properly trained people.

COMMENT: We must coordinate very early on. If you know there are gas mains and underground utilities, there is plenty of time before an investigation begins to contact utilities and make them aware of what is to come on this site. Be prepared because there is no excuse to send untrained workers onto the site to be exposed to what is there.

COMMENT: These utility people won't be going onto the sites very often.

RESPONSE: It is not okay to send untrained personnel on site.

COMMENT: There are contractors available to work for utilities that have people that are properly trained. There is no reason for utility companies to put people's lives in jeopardy by sending untrained workers onto a hazardous waste site. If utilities don't have qualified people, there are contractors who do.

7. **QUESTION:** What is going on around the country before we come into town and say we have Superfund site? How are the communities and responders, gas companies, firefighters, etc., handled prior to the listing of Superfund site? As far as training is concerned, focusing only on Superfund is hitting only on a limited portion of the market.

RESPONSE: Superfund is such a small portion of what trainers have to deal with. Many fire chiefs, etc., are stuck to tradition, not training. When dealing with them (firefighters) on Superfund sites, you get the same kneejerk reaction as with various other kinds of exposures. It is very tough to get the cooperation needed that you get from the Corps of Engineers and the EPA.

COMMENT: Concerning the planning step of emergency response, having this carried out at the remedial action phase by the construction contractors will not only entail the fire department but some of the issues on utility services, etc. It is an issue that is difficult with the Corps of Engineers in execution. If it is difficult to affect the execution of the emergency response plan because the service providers are not trained or properly equipped to perform the service. My recommendation for this conference is that the support of a task force that would look at the review process prior to design in terms of the community service based around a selected site and go through a thorough fact finding process to delineate the best course of emergency response that can get plugged into design.

COMMENT: There has to be cooperation from the government to recognize that they must get out more information and get it out in a more timely manner. Also, the need is the same from emergency responders. In the past, when looking at any federal documents with requirements a contractor could assume that these requirements were being met. So in a situation dealing with a large union, such as the fire fighters, you go into a town, coordinating with town officials and a fire chief. If in fact that is not the way this needs to proceed, then that word has got to get out to the contracting and government community because it is a fairly logical assumption to make, that if the fire chief says he can respond there will be a response and there won't be any question as to whether his people are trained. From both sides there has to be a clear view of what all the issues are.

CONCLUSION: We are all now witnessing EPA, Corps of Engineers, and experienced trainers all working together for Health and Safety. One year ago you wouldn't have seen this. Hopefully, there will be more progress in the year ahead, especially with training in emergency response.

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A Comprehensive Groundwater Water Quality Assessment and Corrective Action Plan for a Single Hydrologic Unit with Multiple Contamination Sources

(Author(s) and Addresse(s) at end of paper)

Introduction

This paper illustrates a case where numerous sources of contamination and intermingling plumes exist within a single hydrologic regime. It attempts to demonstrate that a fundamental knowledge of the hydrogeology of the area, comprehensive contaminant tracking, and definition of preferential pathways for contaminant migration can be more useful to environmental restoration efforts than an intensive effort at one facility at a time. It proposes a comprehensive method for groundwater assessment and clean up as an alternative to a site by site approach.

Background

The Savannah River Site (SRS) is a nuclear weapons complex operated by Westinghouse Savannah River Company (WSRC) for the U.S. Department of Energy (DOE). It occupies a three hundred square mile area in South Carolina which bounds the Savannah River (Figure 1).

The General Separations Area (GSA) is a fifteen square mile area which lies near the geographic center of the SRS. To the north and west the GSA is bounded by Upper Three Runs Creek, to the south by Fourmile Creek and to the east by McQueen Branch (Figure 2). The streams each ultimately flow into the Savannah River. These streams are the dominant influence on groundwater flow in the uppermost aquifer below the GSA. The area bounded by these streams exists as part of a single hydrogeologic system.

The chemical separations facilities and many waste management facilities serving the SRS are located in the GSA. More than thirty separate sites in the GSA have been identified for environmental site investigation under either RCRA or CERCLA (Figure 3). These include unlined basins which received waste, shallow land burial sites, coal pile runoff basins, collapsed underground process sewer lines, and leak and spill sites.

A map of tritium concentrations in the water table indicates that some intermingling of plumes has occurred (Figure 4). All of the sites in the GSA exist in the unsaturated zone above the single hydrologic system of the GSA. Once contamination from any site migrates through the unsaturated zone and enters the groundwater it becomes part of that larger system. Most of the sites are characterized by a potential for both hazardous and radioactive components of soil and groundwater contamination.

Discussion

An extensive hydrogeologic characterization has been completed for the F and H Area Seepage Basins (FHSB), which are waste sites in the GSA (Figure 2). An implementable groundwater remediation plan has also been prepared for the FHSB in accordance with RCRA and South Carolina Hazardous Waste Management regulations. Hydrogeologic investigations and preparation of corrective action plans at the other facilities in the GSA are in various later stages of preparation. Schedules for environmental restoration work have been driven largely by regulatory deadlines.

There are two primary findings of the hydrogeologic assessment and modeling studies of corrective action options. First, the plumes at FHSB should not be treated as isolated zones of groundwater. The FHSB plumes exist as part of the larger hydrogeologic regime of the GSA. The migration patterns of contaminants have been linked to features and characteristics of that regional hydrogeologic system. Any groundwater corrective action plan at the FHSB should take into account effects at adjacent facilities and effects on nearby streams and wetlands. Second, the most important corrective action is source control. Preliminary estimates indicate that groundwater remediation schemes will provide only minimal additional benefit to groundwater and stream water quality as compared to the effects of discontinuing discharge of waste to the basins and to basin closure.

These findings imply that a comprehensive approach to groundwater assessment and remediation may be the best way to approach environmental restoration in the GSA. A plan for comprehensive groundwater quality assessment and corrective action for the General Separations Areas of SRS has been developed and proposed as an alternative to groundwater remediation at individual facilities. The plan will allow for interim actions in areas prioritized according to their potential risk to human health and the environment. The plan proposes to treat the entire area as a whole and is based on technical, logistical and cost/benefit considerations. The main obstacle to implementation of this environmental restoration program may be regulatory rigidity.

F and H Area Seepage Basins

The FHSB received radioactive wastewater, primarily evaporator overheads, from the F and H Separations Areas from 1955 to 1988. The basins were designed for slow seepage and migration through the sediments and shallow groundwater to Fourmile Branch to allow for decay of the radionuclides present in the feed streams. During operation they received a combined average of 80 million gallons annually. The components of the waste stream included tritium, cadmium, chromium, barium, silver, phosphate, lead, mercury, nitrate, sodium, Sr-90, Cs-134 and Cs-137.

Past operation of the unlined earthen FHSB for disposal of waste water has resulted in plumes of groundwater contamination. The plumes extend from the basins to the wetlands at Fourmile Branch (Figure 4). The primary contaminants are tritium and nitrate. Concentrations of mercury, lead, cadmium, radium, and gross alpha above the primary drinking water standard are present. The pH of water in the plumes (pH=3.0-4.5) is lower than expected for natural groundwater in the area. Wetlands areas downgradient of the basins and Fourmile Creek have also been impacted by discharging plume water.

The main body of contaminated groundwater flows from under the basins toward Fourmile Branch. Plume water discharges to the creek and wetlands flanking the creek. Areas of dead and stressed vegetation are present in the wetlands. Agents in the wetlands soil which are at levels potentially toxic to trees are pH, nitrate, aluminum, manganese, zinc, cadmium, and sodium. Aluminum and manganese were not present in the waste stream. They are thought to have been leached from subsurface minerals by the low pH plume water. Drought conditions during 1977 and subsequent years are thought to have exacerbated the damaging effects of the contaminated water by concentrating salts and by failing to provide rainwater to dilute the plume water (Greenwood et al, 1990).

Preliminary studies indicate that flushing with clean water reduces leachate to non-toxic levels (Loehle, 1990). It is anticipated that natural rainfall combined with closing the basins should lead to wetlands soil and ecological recovery. Field and laboratory studies involving planting natural wetlands vegetation in stressed soil are planned to test this assertion. Field investigations of the areas suffering vegetation mortality reveal that reforestation is already underway in H-Area.

Secondary succession is occurring in the understory as shrubs and saplings are beginning to re-colonize the areas.

Fourmile Branch has been impacted by groundwater seepage from the plumes of contamination. Stream water samples taken downstream of the basins exhibit higher levels of tritium, nitrate and sodium than samples taken from upstream of the basins. Tritium concentrations in the creek exceed the primary drinking water standard. Concentrations of mobile contaminants in groundwater discharge are diluted by stream flow. Downstream concentrations of nitrate and sodium are elevated relative to upstream samples, but do not exceed primary drinking water standards. No hazardous constituents have been detected in the creek water (Looney et al, 1988).

Environmental Remediation Activities

Two source control measures have been taken at the basins: 1) discontinuing their use and, 2) emplacement of low permeability caps. Use of the basins for waste disposal was discontinued on November 7, 1988. The waste stream which used to be discharged to the basins is treated and the effluent is released to Upper Three Runs under an NPDES permit. Low permeability caps have been emplaced, according to an approved RCRA closure plan, over the basins to minimize infiltration of rainwater through the contaminated sludge and soil beneath the basins.

As required by RCRA, a groundwater remediation plan was developed to address the plumes at FHSB. Preparation of the remediation plan included an extensive hydrogeologic characterization, a review of potential remediation options, and groundwater modeling to assess the effectiveness of the proposed remediation. The results of these efforts are summarized in the following sections.

Geology of the GSA

The uppermost aquifer underlying the GSA is comprised of unconsolidated coastal plain sediments which dip regionally seaward. The sediments are primarily unconsolidated sands and clays. Generally, the sandy units function as aquifers and the clays as aquitards. Thin discontinuous cemented zones are occasionally encountered in core. Carbonate zones ranging from calcareous muds and sands to silicified shell hash have been observed in core from the GSA.

A detailed study of the lithology and hydrology of the Tertiary sediments of the south central portion of the GSA has been conducted as part of the preparation of a groundwater corrective action plan for the FHSB. Geologic correlations of aquifer and aquitard units were made for wells in the area based on core/cutting descriptions and geophysical logs. This information was used to construct lithologic cross sections, structure contour maps, facies maps and isopach maps of the aquifer units and confining beds. Hydraulic head data from the monitoring wells have been compiled and used to construct potentiometric maps of each of the units and to study the vertical head relationships within and between the aquifers. These are combined with groundwater monitoring data to produce a hydrogeologic interpretation which identifies preferential migration pathways.

An example lithologic cross section depicts the aquifer units, and the location of screen zones of the monitoring wells in each unit (Figure 5). The uppermost aquifer is a regulatory term; the uppermost aquifer includes all aquifer units which are hydraulically connected to the water table beneath a site. There are three aquifer units in the uppermost aquifer at the GSA. The aquifer units, their properties and a review of the formation names and hydrostratigraphic nomenclature at SRS have been discussed in detail in publications by SRS workers (Harris et al, 1990; and Aadland, 1990). The three units are commonly known, from shallower to deeper respectively, as the water table, the Barnwell/McBean, and the Congaree.

The aquifer units are separated by two leaky aquitards. The two aquitards are known locally as the Tan Clay and the Green Clay. The Tan Clay supports the water table and overlies the Barnwell/McBean unit. The Green Clay separates the the Barnwell/McBean from the underlying Congaree. Vertical migration through the clays is variable, depending upon the local thickness and competency of the confining units. Local discontinuities in the clays are observed to provide preferential pathways for vertical migration.

The Congaree unit is underlain by the Ellenton Formation which is the principle confining unit for the uppermost aquifer beneath the GSA. The Ellenton is a regionally competent aquitard which hydraulically separates the Tertiary sediments of the uppermost aquifer from the Cretaceous sediments below.

Groundwater Flow in the GSA

Horizontal groundwater flow in the units above the Green clay (the water table and McBean) is dominated by Upper Three Runs and Fourmile Creek. The water table map indicates the presence of a groundwater divide near the geographic center of the GSA (Figure 6 and Figure 7). North of the divide lateral flow is north toward Upper Three Runs Creek. South of the divide, flow is generally southward into Fourmile Creek.

Below the Green Clay, flow in the Congaree is towards Upper Three Runs across the entire GSA (Figure 8). Fourmile creek is not deep enough to incise the Green Clay, and therefore exerts no influence on flow in the Congaree.

Recharge of the uppermost aquifer is from rainfall infiltration through the unsaturated zones and the aquitard units. In the GSA, the water table and Barnwell units discharge into Upper Three Runs and Fourmile Creek. The Congaree discharges into Upper Three Runs.

Preferential Flow Pathways

Preferential contaminant flow pathways have been identified at the F and H area seepage basins. These preferential pathways are often associated with mappable geologic features in the sediments below the basins. Correlations of geophysical logs and core descriptions at monitoring well clusters indicate offset of beds. These displacements are mappable and can be illustrated in cross section (Figure 5). These offsets are interpreted as being the slip surfaces of slumps. A conceptual diagram depicts a slump feature and the mechanism for offset of beds in unconsolidated sediment (Figure 9).

These offsets are observed to displace confining units and provide vertical preferential pathways. The slump feature illustrated hydrostratigraphic cross section lies directly below the F-Area seepage basins (Figure 10). Figure 11 represents the same cross section shown in Figure 5 and depicts contours of concentrations of lead in the groundwater. The tan clay confining unit is offset providing a downward flow path for contaminants beneath the basins. This figure illustrates that the path of contaminant migration is primarily downward in the location of the slump feature.

An example of a slump feature providing a horizontal preferential flow pathway is shown in Figure 12. This figure shows the location of the slump features where they offset the Tan Clay, and the concentrations of tritium in the water table. The offsets coincide with the location of horizontal preferential contaminant pathways. The offset planes apparently provide high permeability zones which allow accelerated flow compared to the adjacent sediments.

It is likely that the individual slump features are associated with regional trends across the GSA. Geologic features tend to occur as part of regional patterns. Regional zones of carbonate have been mapped in areas in the GSA where the most subsurface data exists (Figure 13). The slump features may be associated with the occurrence of carbonate zones (one of several potential mechanisms for slumping is the dissolution of carbonate material and subsequent collapse of overlying sediments). This possibility is under investigation. A petrographic study of the carbonates in thin section is ongoing, and more core and geophysical data from new wells are being used to further map the occurrence of offsets due to slumping.

Not all of the preferential pathways observed at the FHSB have been directly linked to slump features. Other preferential pathways may be related to slump features which have not yet been mapped, or they may be related to textural heterogeneities in the subsurface such as coarse grained sand lenses or high permeability zones in the carbonates. More data is being acquired to investigate the relationship between geologic features and preferential flow. Work done to design a corrective action plan supports the notion that the key to designing an effective groundwater remediation system is to identify and understand the preferential flow pathways.

Corrective Action Plan

The choice of a groundwater remediation plan to treat the hazardous constituents was complicated by the fact that a primary constituent of the plume water is tritium. Tritium is a radioactive isotope of hydrogen (H-3). There is no implementable treatment for tritium removal from water. The half life of tritium is relatively short, approximately twelve years. One reason that the seepage basins were originally used for disposal of this waste stream was to allow for the decay of tritium as the water migrated slowly through the ground towards the creek. This allowed for a smaller amount of tritium to be released to the surface waters which eventually flow offsite than if the waste water was released directly to a stream. In view of the tritium component in the plume water, there was reluctance by project environmental professionals to discharge water extracted from the ground to a surface stream after treatment to remove chemical constituents. One goal of the remediation was to minimize migration of tritium into Fourmile Branch.

The chosen corrective action plan was to extract water before it could flow into Fourmile Branch and the wetlands, neutralize the pH, treat it for chemical constituents, and then inject the treated water back into the ground upgradient of the basins. This cycling of groundwater would restrict tritium from migrating into Fourmile Branch, and allow more time than the natural system for tritium decay. This system seemed the most acceptable solution to the problem of controlling the spread of the plume of hazardous constituents and radionuclides with regard to existing technology and regulatory constraints.

FHSB Plumes are Part of a Larger Hydrologic System

Groundwater modeling studies of the pump/treat/inject system provided unexpected results. Particle tracking analyses were employed to attempt to optimize the design of extraction/injection systems in the water table and Barnwell/McBean units to maintain hydraulic control of the plumes. Results indicate that 100% capture of the targeted plume water in the water table and Barnwell/McBean aquifers is possible, but not if extracted water is injected, back into the aquifers as planned.

Preliminary results indicate that if the targeted plume area is attempted to be controlled and 100% of the extracted water is injected, less than 20% of the plume water can be stopped from entering Fourmile Branch. Correspondingly, there will be an increase in the percentage of plume water that moves down into the Congaree (Geotrans, 1990a; Geotrans, 1990b).

The explanation for the low efficiency of the extraction/injection network is that it was conceptualized as a closed system, but in actuality, there is no mechanism to stop rainwater input into the system. The primary recharge to the shallow aquifers is infiltration of rainwater. By extracting water before it discharges and injecting it upgradient, the mechanism for water to leave the system is removed, but there is no mechanism to stop rainwater from continuing to enter the system. As long as 100% of the water which is extracted is injected, there will be a continual increase in the volume of water in the system. Since this excess water must somehow leave the system, it escapes by flowing around and through the extraction network or by migrating downward.

A system is now being designed to optimize control of the portions of the plume that contain the highest concentrations of contaminants. This type of system will be designed to target the preferential flow pathways. A more narrowly focused remediation, which seeks to optimize control of mass of contaminants, rather than volume of water, is expected to be more efficient.

The necessity of understanding the whole of the regional hydrogeologic setting of the GSA is underscored by the results of both the modeling and the FHSB hydrogeologic characterization. Information on the nature of the relationship between the plumes of contamination and the geology, and how those plumes fit into the larger hydrogeologic system will be needed to properly design a corrective action program at the FHSB.

Source Control the Most Effective Corrective Action

A two dimensional flow and transport model was run to assess the effectiveness of a pump/treat/inject system which successfully prevented 66% of the targeted plume water from entering Fourmile Creek. Modeling of contaminant levels at a hypothetical monitoring well downgradient of the extraction network indicate that the extraction/treatment/injection system would have a negligible effect on the concentrations of nitrate and tritium (Figure 14). Results of the modeling indicate that compared to the closure of the basins, the additional benefit of a post-closure groundwater remediation program will be minimal.

Based on the transport modeling results, it is clear that the most significant corrective action has already been accomplished at the FHSB. The source of contamination has been controlled. Discharge of waste water to the basins was discontinued in November 1988. The basins have been physically and chemically stabilized, backfilled, and RCRA closure caps are being emplaced. Prior to closure of the basins, tritium concentrations in downgradient monitoring wells increased or remained at equilibrium. Since closure, concentrations of tritium in monitoring wells at the basins are declining (Figure 15). The levels of tritium, nitrate, and other contaminants which discharge to the creek and wetlands are anticipated to decline similarly, in response to the termination of discharge and closure of the basins.

Results of the transport modeling indicate that source control (stopping discharge of waste to the basins and covering them with a low permeability cap) is the most important corrective action. On the whole, the studies at FHSB suggest that groundwater corrective action programs will be vastly expensive ($25-30 million) and marginally beneficial. This implies that environmental dollars and efforts in the GSA may be better spent on identifying and eliminating or capping other sources of contamination in the GSA before attempting an extraction and treatment program at any specific facility.

Another argument for comprehensive assessment and corrective action for the entire GSA is that although various corrective action scenarios may be workable, the impact of them on the hydrologic system of the area as a whole has not been fully assessed. Changes to flow patterns at the F and H basins resulting from corrective action could complicate the ongoing groundwater quality assessment and plans for corrective action at adjacent sites.

Comprehensive Approach to Groundwater Clean-Up

A comprehensive assessment of the groundwater contamination in the entire GSA would lead to a more efficient and effective approach to groundwater remediation. There are at least 30 separate potential sources of groundwater contamination in the GSA. These are all in different stages of characterization.

A comprehensive corrective action program for the entire GSA is being developed. One general failing of the plans to remediate the plumes at FHSB, is that the effects of implementing an extraction/injection system on the hydrology of nearby facilities and plumes has not been adequately defined. A comprehensive hydrogeologic characterization of the entire GSA will allow for the most technically sound approach to environmental restoration. It would also provide the most cost effective approach to corrective action facility design. Designing a number of plume specific facilities will likely prove to be the most expensive and inefficient approach in the long term.

One or several large integrated groundwater treatment facilities could be designed to address groundwater contamination problems in the entire GSA. In a comprehensive corrective action plan, extraction and injection well fields could be placed for the best advantage of groundwater clean-up in general. It seems likely that as characterizations proceed in the GSA that modifications will need to be made to the original design at FHSB to adjust for other corrective actions.

Comprehensive Assessment and Corrective Action Plan

The comprehensive assessment of the GSA will be the basis for a conceptual plan for groundwater remediation of the GSA as a whole. The comprehensive assessment will include an interpretation of existing data, a plan for acquisition of additional data, a GSA wide monitoring program, and conceptual design of any appropriate corrective actions. Groundwater modeling will be used to simulate the hydrogeologic system and gauge the effectiveness of proposed corrective action scenarios. Risk assessment will be used to justify a decision not to remediate contamination or to quantify the benefits of a proposed corrective action.

The following sections briefly describe the elements of the comprehensive assessment plan.

Comprehensive Assessment Strategy Document

This document will outline the strategy for the comprehensive groundwater assessment and corrective action for the GSA. A project of this magnitude will require a carefully thought out plan and a great deal of coordination. A detailed schedule and discussion of each of the following sub-tasks and how they are interconnected will be included:

* initial hydrogeologic assessment report
* proposed comprehensive monitoring network
* proposed physical tests required to adequately characterize the multi-aquifer system
* program for unsaturated zone characterization
* stream and wetlands characterization
* preparation of a comprehensive interpretation of the hydrogeology and groundwater quality in the GSA
* modeling of flow and solute transport in both saturated and unsaturated zones
* risk assessment
* feasibility studies and innovative technology assessment
* proposed corrective actions

Once completed this document will serve as a guide for managing the comprehensive assessment of the GSA.

GSA Hydrogeologic Assessment

An initial GSA hydrogeologic assessment report will be completed. This will be accomplished by assembling all existing monitoring well data, geologic data, modeling studies and stream and wetlands data. There are data from approximately 500 monitoring wells in the GSA. This report will attempt to identify all contaminants which may require corrective action. It will also identify areas where no data exists or not enough data exists to make an interpretation.

The report will serve as a guide to planning monitoring well networks and as a data base for groundwater modeling. It will provide plume maps of pertinent pollutants. Hazardous constituents and radionuclides will be considered. Lithologic cross sections and figures showing the extent of contamination in cross section will be provided. An attempt will be made to identify the likely sources of contamination. The report will include plots of time trend data. Interpretations will include whether specific plumes are likely the result of a continuing source or represent a migrating slug such as may be associated with an old spill.

Vertical and horizontal head relationships will be discussed. Estimates of hydraulic conductivity, flow rates and other aquifer properties which can be used in the modeling will be presented and discussed.

The report will include a section which discusses the types of data which should be acquired in order to better characterize the GSA. A discussion of the reliability of the existing data will also be included.

Phase 2 Hydrogeologic Assessment

The initial hydrogeologic assessment will be updated and revised to include geologic and monitoring data acquired during the course of the comprehensive assessment. The new information will be compiled and any changes in interpretation will be documented in a Phase 2 assessment report. The report will include a section which discusses the status of plume delineation and the actions necessary to adequately characterize the system. This includes identification of areas requiring further plume assessment wells and monitoring.

Monitoring and Data Collection Plan

A plan for monitoring and data gathering will be prepared based on the initial hydrogeologic assessment. In conjunction with the comprehensive monitoring well network, aquifer tests and other physical tests which will aid in the interpretation of data and modeling will be proposed. Program plans for various field projects including well installation, coring, slug tests, and aquifer tests will be included. The locations and depths of proposed wells and a cost estimate will be included.

A comprehensive sampling and analysis plan will be developed. Each of the hydrostratigraphic units comprising the uppermost aquifer will be monitored across the area. The monitoring plan will focus on the quality of groundwater in the general area. The global plan will incorporate the regulatory sampling and analysis requirements at specific facilities, and also track contaminant migration beyond adjacent facilities to identify intermingling plumes.

A second phase of well installation and field tests may be required. The In this case, a Phase 2 monitoring and data collection plan will be produced based on the recommendations of the Phase 2 Hydrogeologic Assessment.

Unsaturated Zone Characterization

In conjunction with the installation of a comprehensive monitoring well network, a field study of the unsaturated zone is planned. This will be a program of field permeability measurements and to collect and analyze samples to characterize the unsaturated zone in the GSA. The study will be designed to estimate physical properties of the unsaturated zone. These values will be needed to model the movement of contaminants from a source at land surface (or trench or vault bottom) to the water table for risk assessment. The results of the characterization and the sampling and analysis techniques utilized will be fully documented.

Stream and Wetlands Characterization

Documentation of the impacts of facilities in the GSA on Fourmile Branch, Upper Three Runs Creek and the wetlands surrounding them will be prepared. This program will include wetlands delineation, sampling and analysis of water taken from the wetlands and streams, sampling and analysis of sediments from the wetlands, and studies of the biological community. Results and interpretation of the data collected will be included in a report. All procedures will be fully documented. Sources of variability in the data will be discussed.

Groundwater Flow and Transport Modeling

Groundwater flow and transport models will be used as input to risk assessment and to simulate various corrective action scenarios. These simulations will be used to help select the most appropriate corrective actions for the GSA. The modeling report will include a discussion of the match between monitoring data and model simulations of plume shapes. Estimates of predicted contaminant concentrations through time will be performed. Documentation of the model, parameters, and assumptions used will be included.

Risk Assessment

The site characterization based on information discussed in the hydrogeologic assessment reports and the groundwater modeling will serve as the basis for a risk assessment. The risk assessment will include an identification of populations and a hazard evaluation based on a review of the inherent toxic properties of the primary constituents of interest. Exposure pathways will be identified and documented. Modeling will be employed to calculate doses and quantify risk at the points of exposure. Uncertainties and variabilities in the risk assessment will be fully documented and discussed.

Feasibility Studies and Innovative Technologies

A literature search of potential groundwater treatment technologies and innovative techniques for remediation will be conducted. A discussion of the favorable and unfavorable characteristics of each technology will be presented. This will be the basis of a program of laboratory and field studies to test the most promising technologies. A complete description of each of the test procedures, results and interpretations will be prepared.

Recommendations for Corrective Actions

A document identifying recommendations for future actions based on the findings of the Comprehensive Groundwater Assessment of the GSA will be prepared. This document will identify plumes of contamination which may require corrective action under RCRA or CERCLA. Contaminants of concern will be identified and estimates of the volume of contaminated water to be remediated will be included.

If deemed appropriate, a conceptual plan for remediation of the GSA as a whole will be presented. Various types of corrective action will be considered. These include:

* extraction wells or trenches, treatment and injection
* extraction wells or trenches, treatment and release to streams
* containment, extraction, treatment
* in situ treatments
* immobilization technologies
* some combination of techniques

Executive Summary

The executive summary will briefly describe the major elements of the entire Comprehensive Assessment and Corrective Action Plan for the GSA. The summary will include results of the assessment and modeling. It will reiterate the recommendations for corrective action. The document will address the reliability of the data. The report will caution about potential circumstances or new data which could change interpretations and recommendations presented. It will also include an index to the contents of the other volumes in the Comprehensive Assessment and Corrective Action of the GSA series.

Conclusions

A comprehensive assessment plan has been proposed to provide a framework for investigating and remediating an area with multiple sources of groundwater contamination in the most logical, scientific and cost effective manner. This plan has been devised in response to the results of a series of studies conducted in preparation of a groundwater remediation program for several facilities in the General Separations Areas (GSA), of SRS.

On the whole, the studies imply that environmental dollars and efforts in the GSA will be better spent on identifying and controlling other sources of contamination in the GSA before attempting groundwater remediation at any specific facility. The work done to date suggests that groundwater corrective action programs will be vastly expensive ($25-30 million) and marginally beneficial, as opposed to source control actions. Ongoing work also supports the notion that the key to designing an effective groundwater remediation system is to understand the hydrogeology of the area and its preferential flow pathways.

A comprehensive assessment and corrective action plan for the entire GSA will allow for the assessment of the impact of proposed groundwater remediation activities on the hydrologic system of the GSA as a whole. Changes to flow patterns at any one facility resulting from corrective action which could complicate the ongoing groundwater quality assessment and plans for corrective action at adjacent sites can be considered.

Disclaimer

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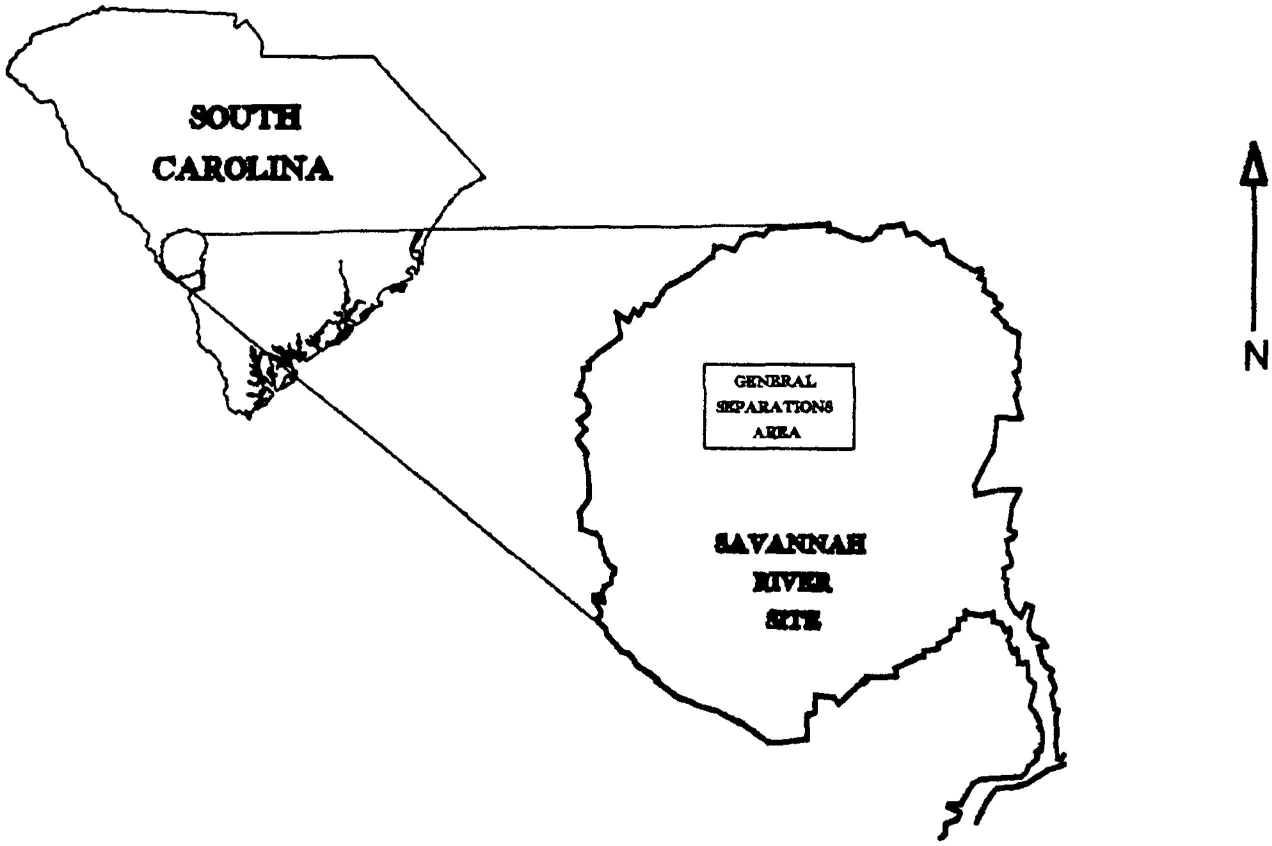

LOCATION OF THE GENERAL SEPARATIONS AREA,
SAVANNAH RIVER SITE

Figure 1. The Savannah River Site (SRS) is a DOE nuclear weapons facility. It is located in South Carolina, encompasses approximately 300 square miles and borders the Savannah River. The General Separations Area is located near the center of SRS.

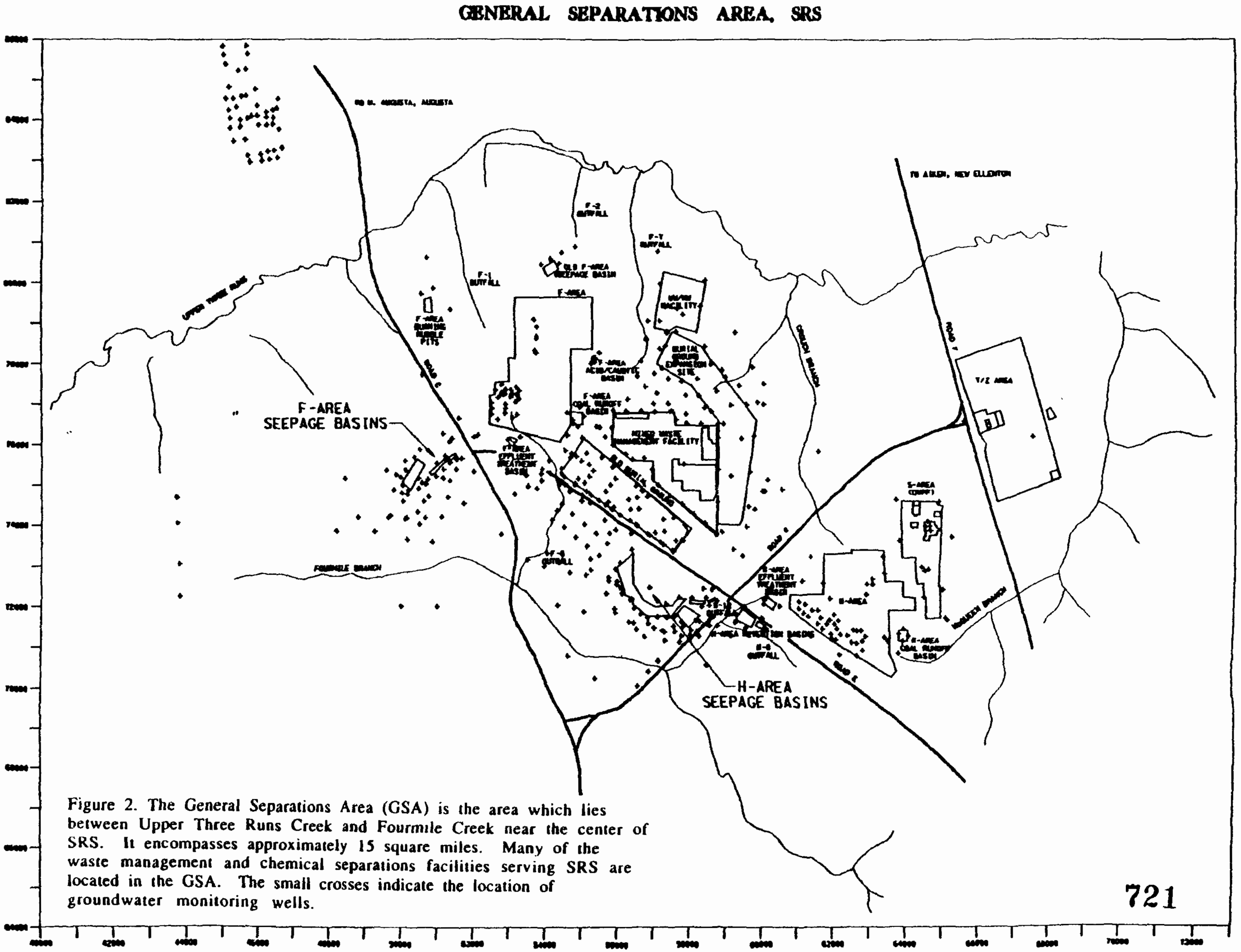

Figure 2. The General Separations Area (GSA) is the area which lies between Upper Three Runs Creek and Fourmile Creek near the center of SRS. It encompasses approximately 15 square miles. Many of the waste management and chemical separations facilities serving SRS are located in the GSA. The small crosses indicate the location of groundwater monitoring wells.

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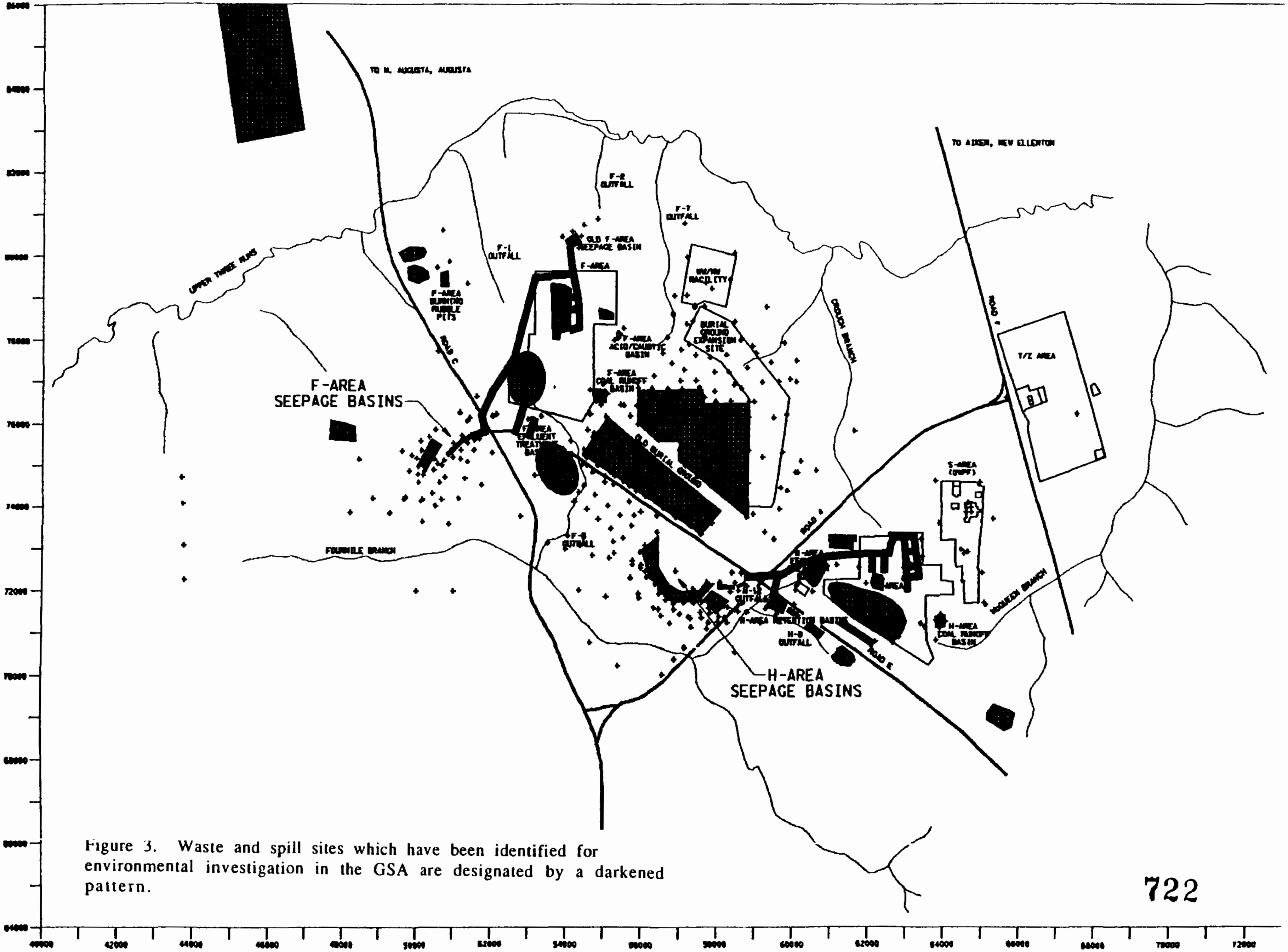

Figure 3. Waste and spill sites which have been identified for environmental investigation in the GSA are designated by a darkened pattern.

TRITIUM PLUMES

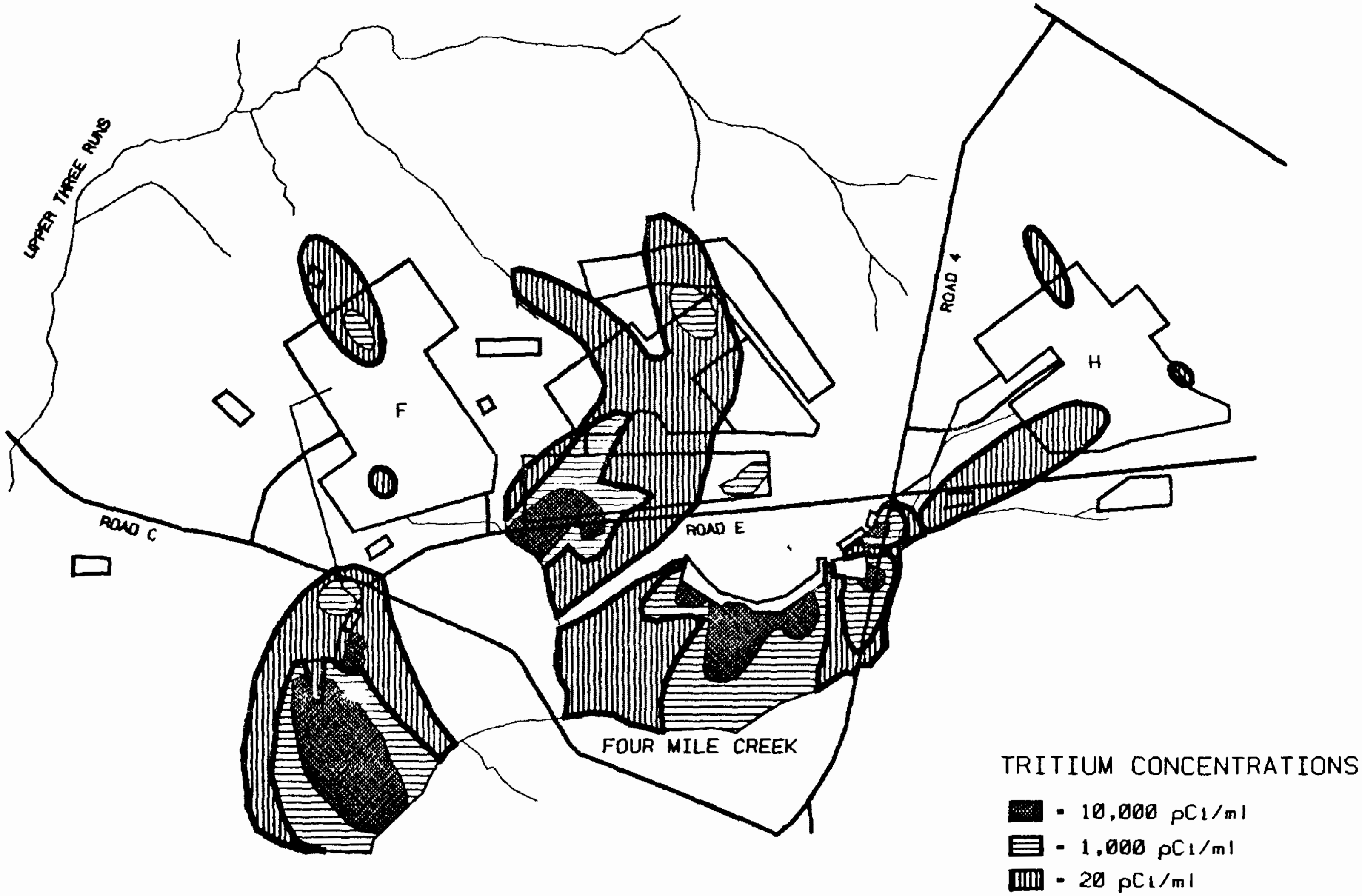

Figure 4. A plume map of tritium concentrations in the water table indicates that plumes emanating from various sites intermingle.

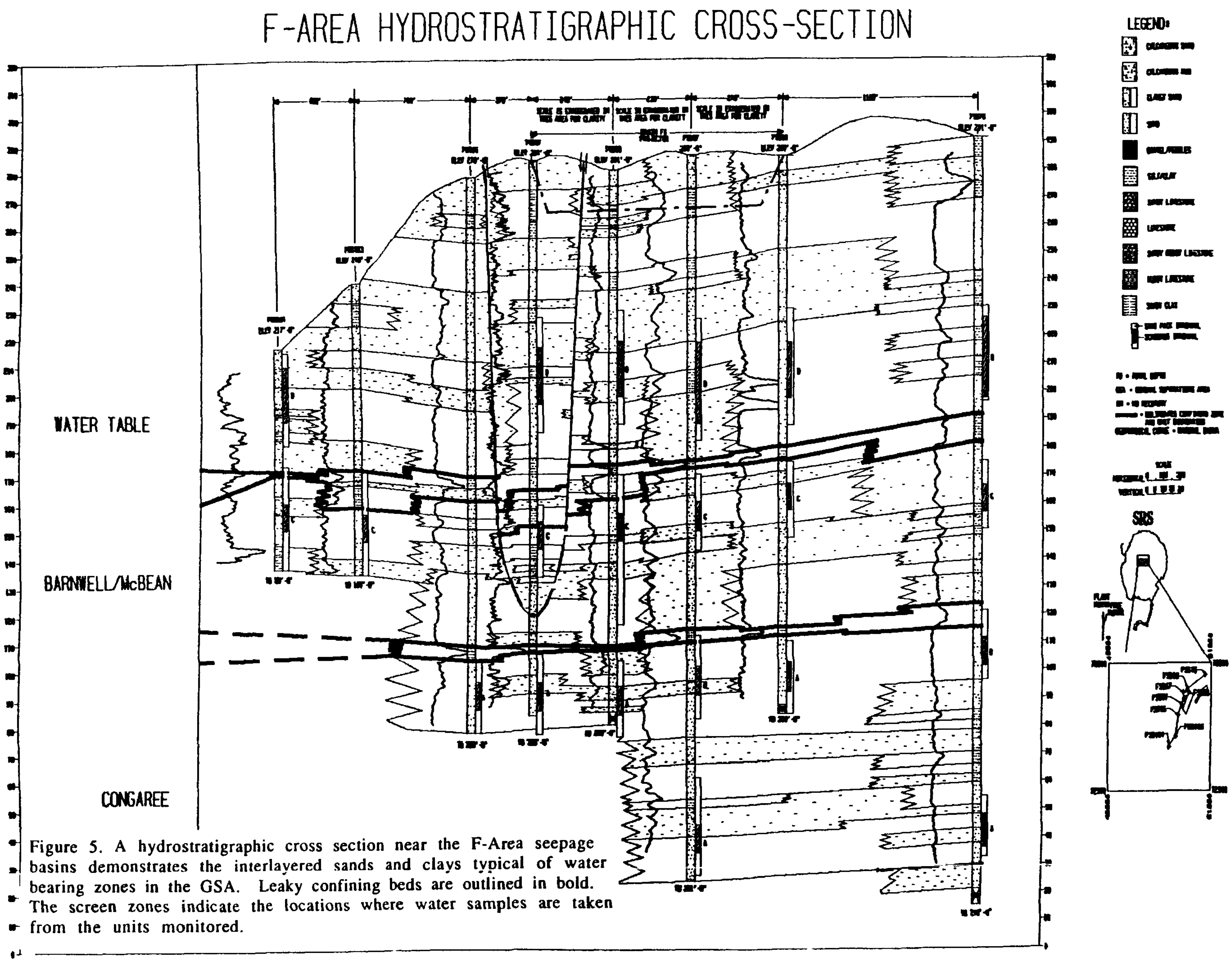

Figure 5. A hydrostratigraphic cross section near the F-Area seepage basins demonstrates the interlayered sands and clays typical of water bearing zones in the GSA. Leaky confining beds are outlined in bold. The screen zones indicate the locations where water samples are taken from the units monitored.

GENERAL SEPARATIONS AREA WATER TABLE

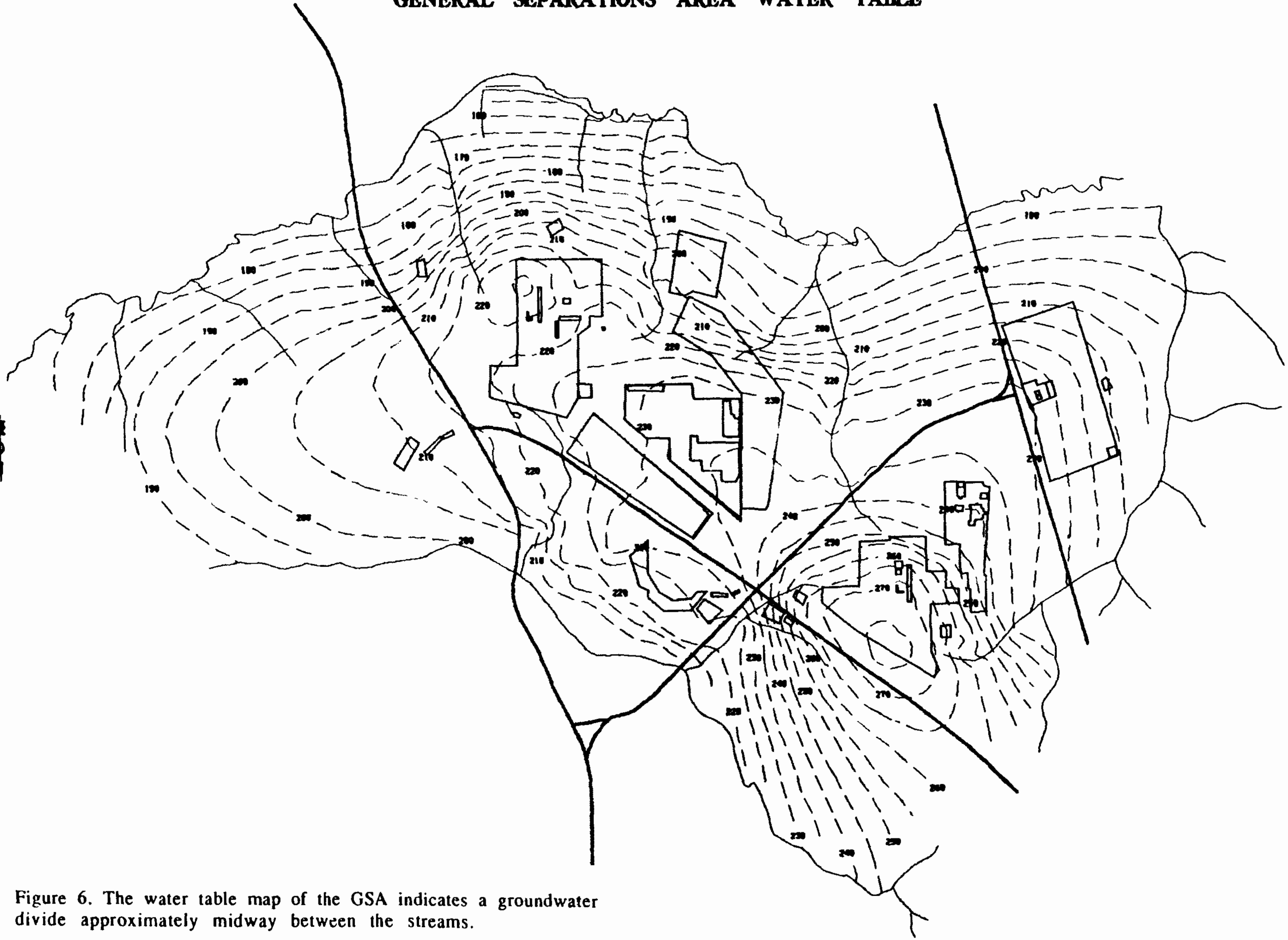

Figure 6. The water table map of the GSA indicates a groundwater divide approximately midway between the streams.

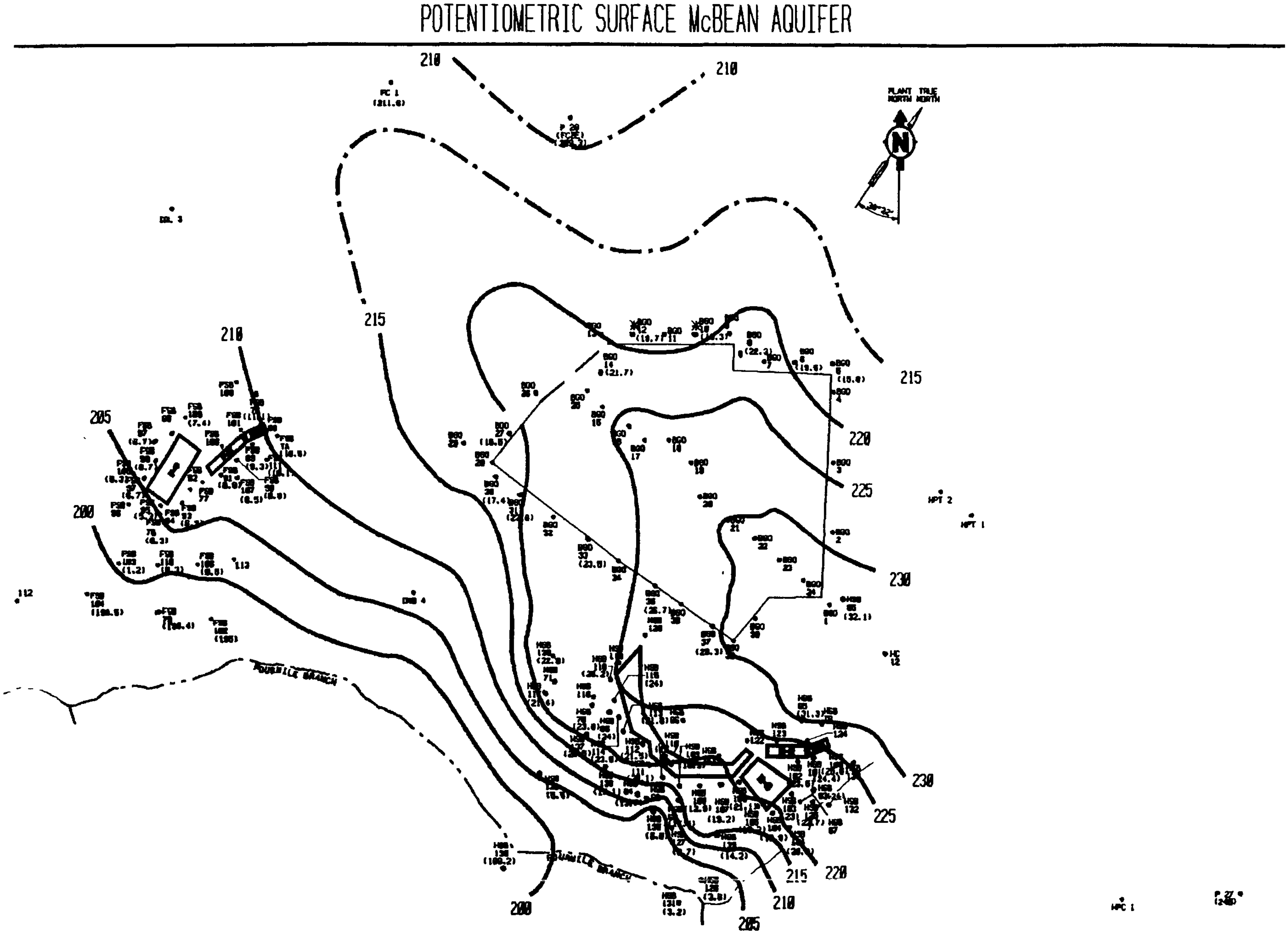

Figure 7. The potentiometric surface map of the Barnwell/McBean unit indicates that flow directions in this unit are similar to those in the water table.

POTENTIOMETRIC SURFACE CONGAREE AQUIFER

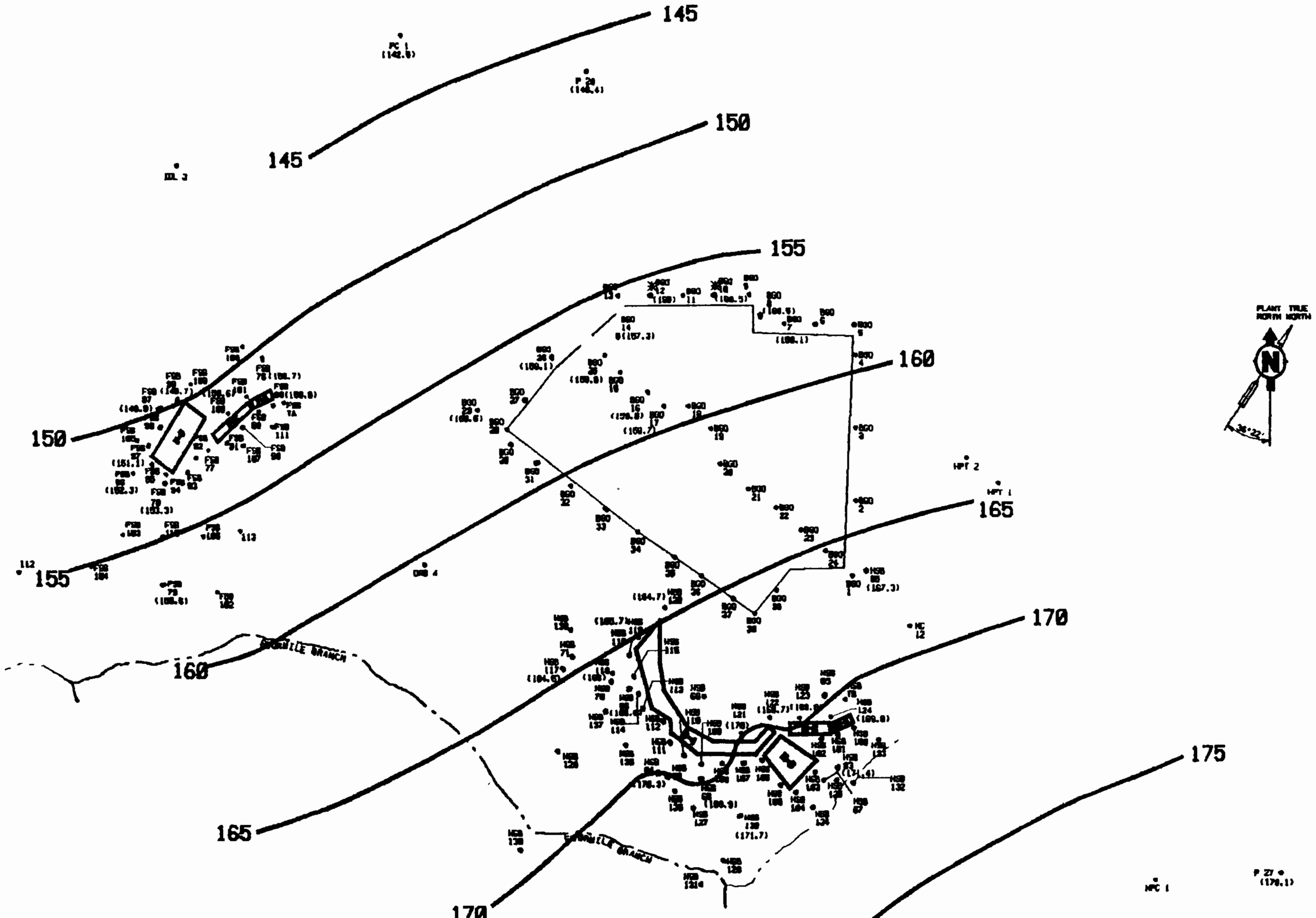

Figure 8. The potentiometric surface map of the Congaree unit indicates that the flow direction in this unit is toward Upper Three Runs Creek. Water is this unit is not discharging to Fourmile Branch.

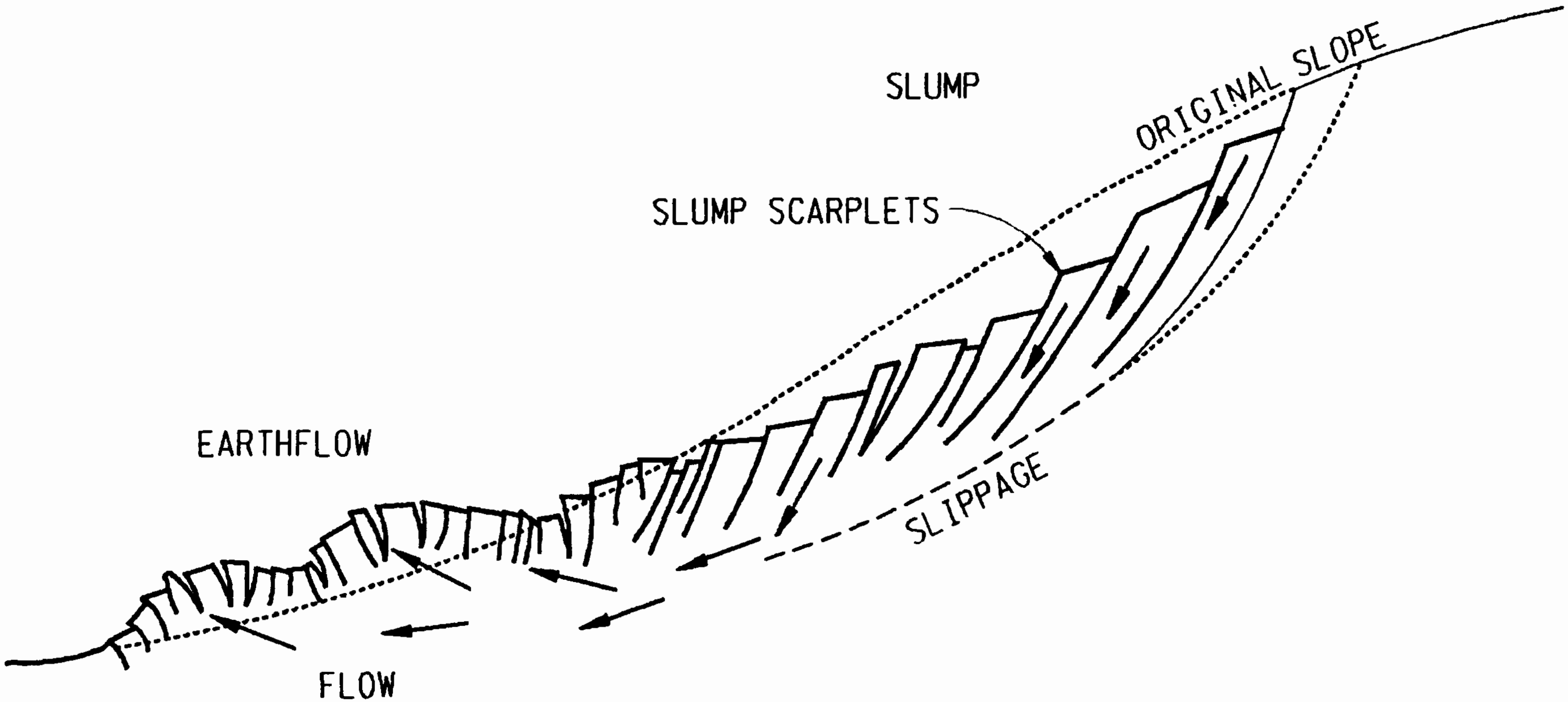

Figure 9. This conceptual diagram of a slump feature illustrates how slump faults may be formed.

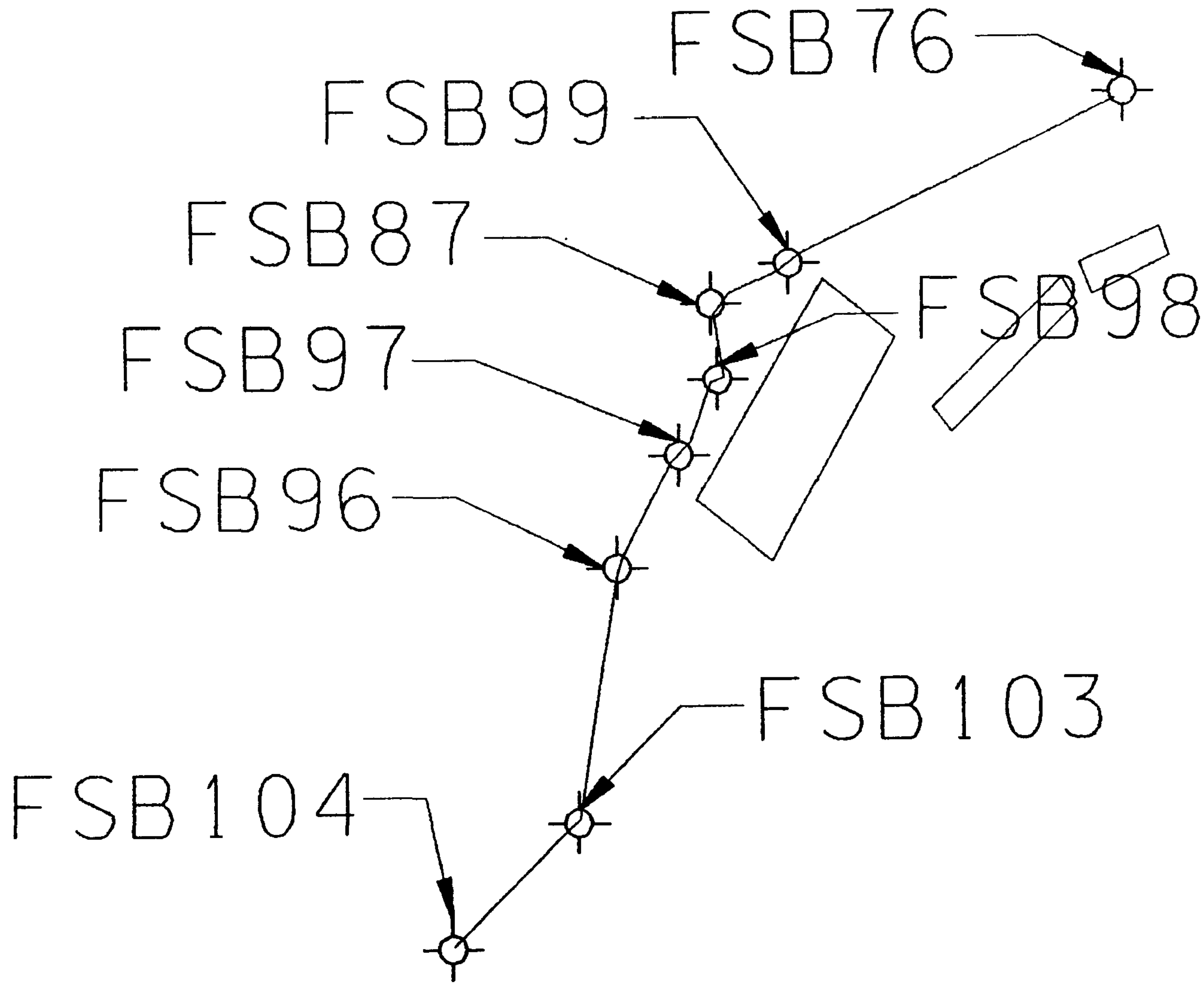

Figure 10. The cross section which illustrates the slump feature is located directly beside the F-Area Seepage Basins.

LEAD CONCENTRATIONS IN F AREA CROSS-SECTION

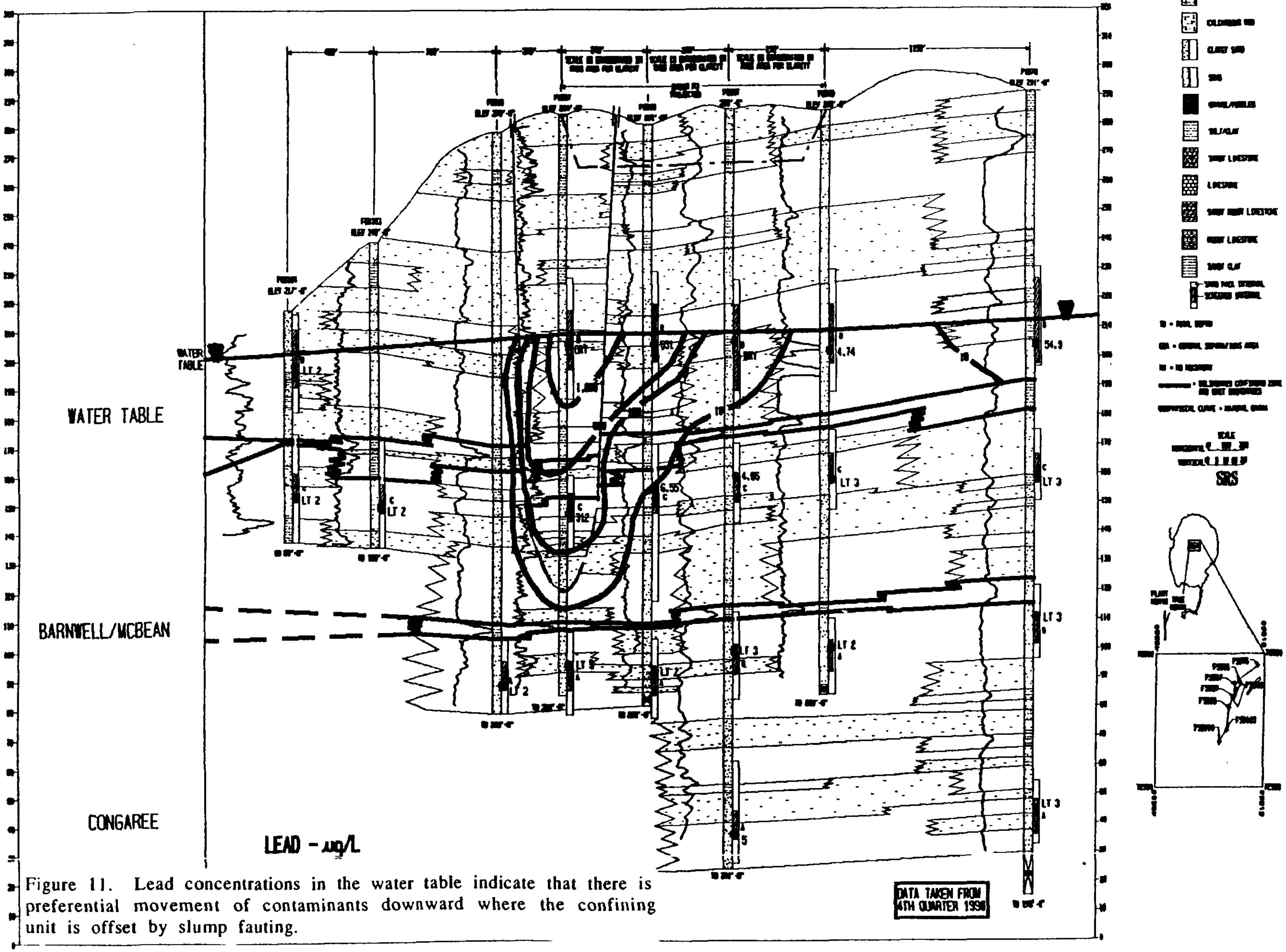

Figure 11. Lead concentrations in the water table indicate that there is preferential movement of contaminants downward where the confining unit is offset by slump fauting.

H-AREA TRITIUM PLUMES

TRITUM (pCi/ml) FOURTH QUARTER 89 WATER TABLE

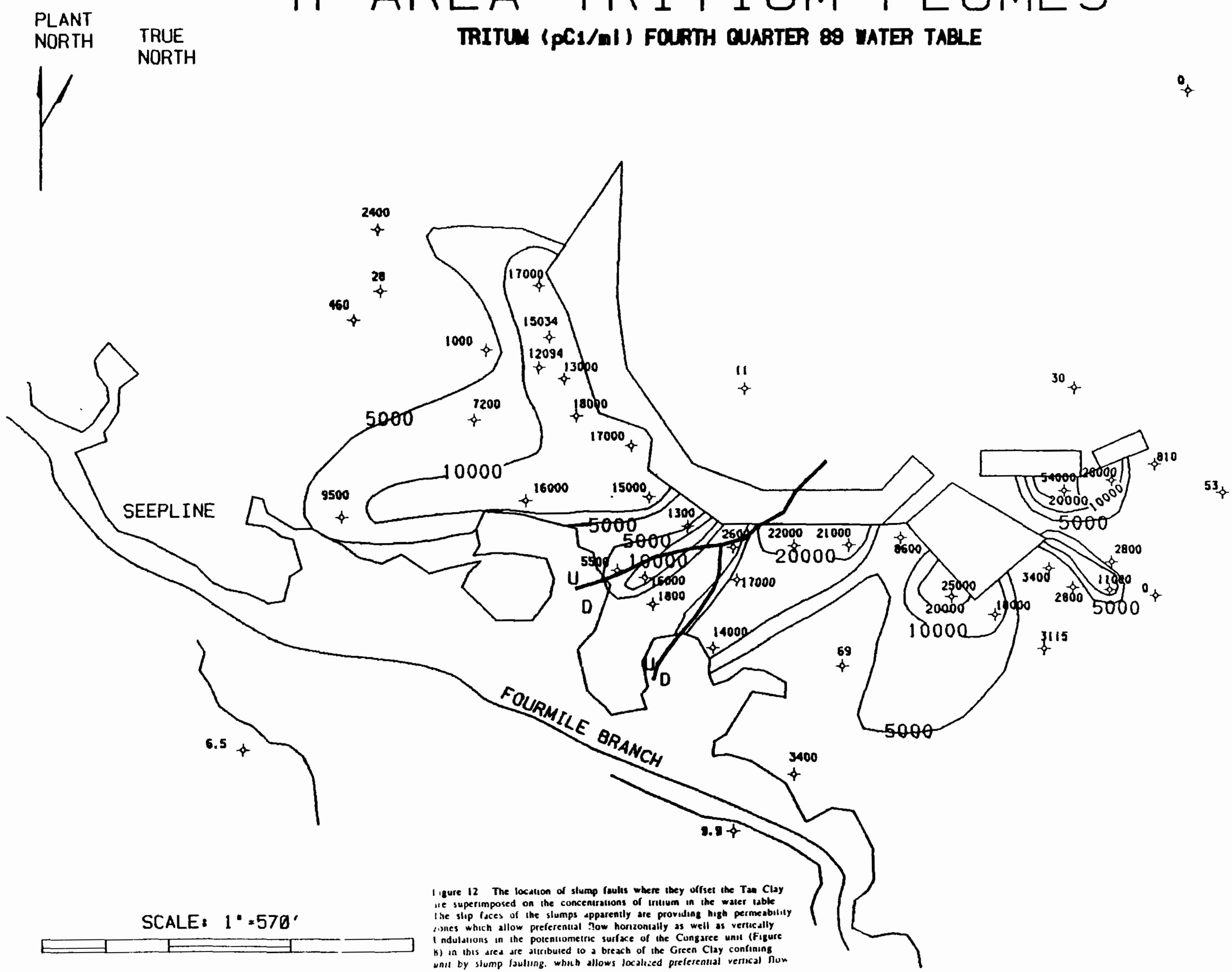

Figure 12 The location of slump faults where they offset the Tan Clay are superimposed on the concentrations of tritium in the water table The slip faces of the slumps apparently are providing high permeability zones which allow preferential flow horizontally as well as vertically Undulations in the potentiometric surface of the Congaree unit (Figure 8) in this area are attributed to a breach of the Green Clay confining unit by slump faulting, which allows localized preferential vertical flow

CARBONATE ZONE ISOPACH MAP

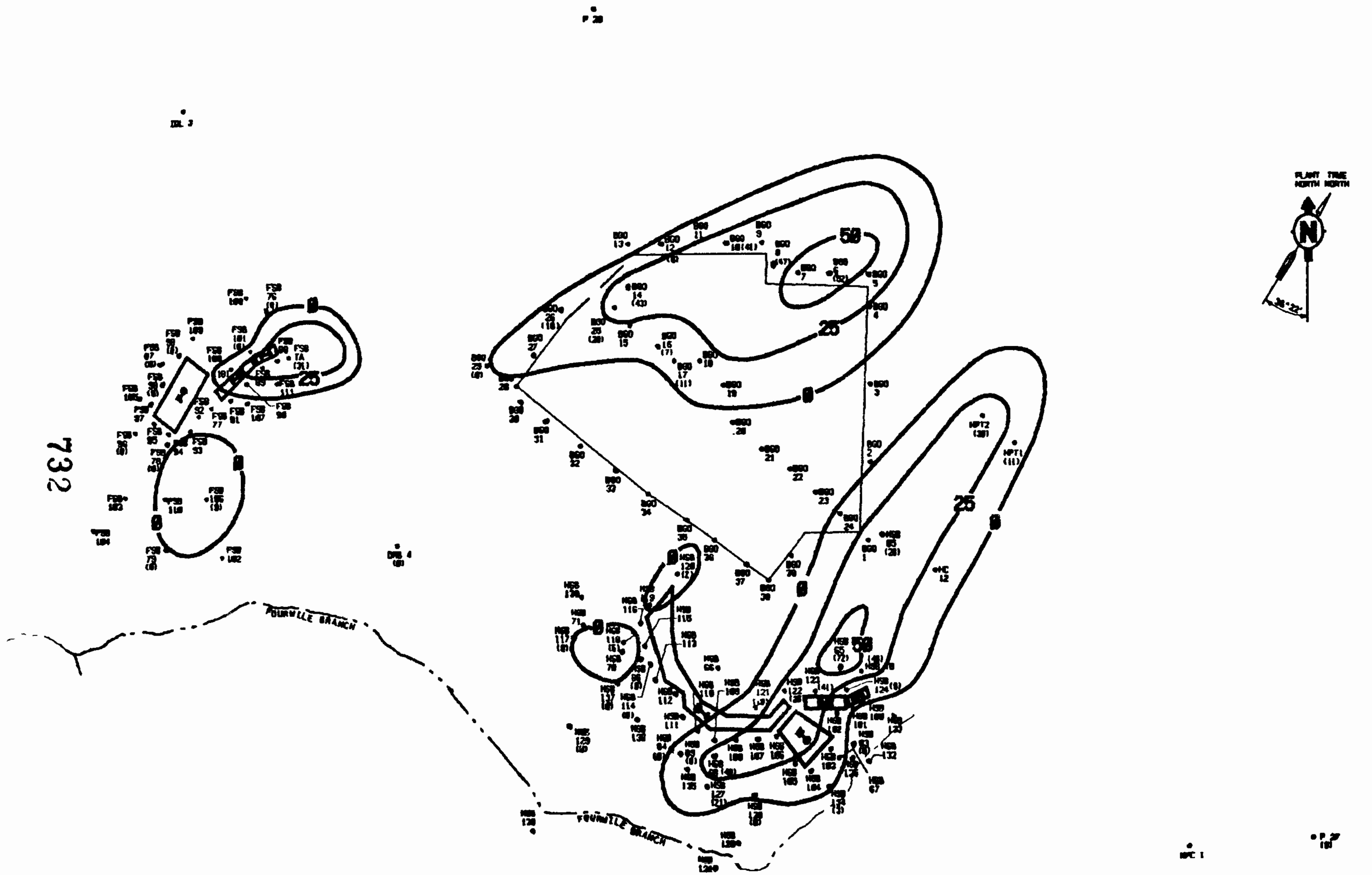

Figure 13. The thickness of carbonate zones in the Barnwell/McBean unit is contoured. There may be a relationship between the occurrence of carbonate and slump faulting, this is being investigated.

PREDICTED CONTAMINANT CONCENTRATIONS

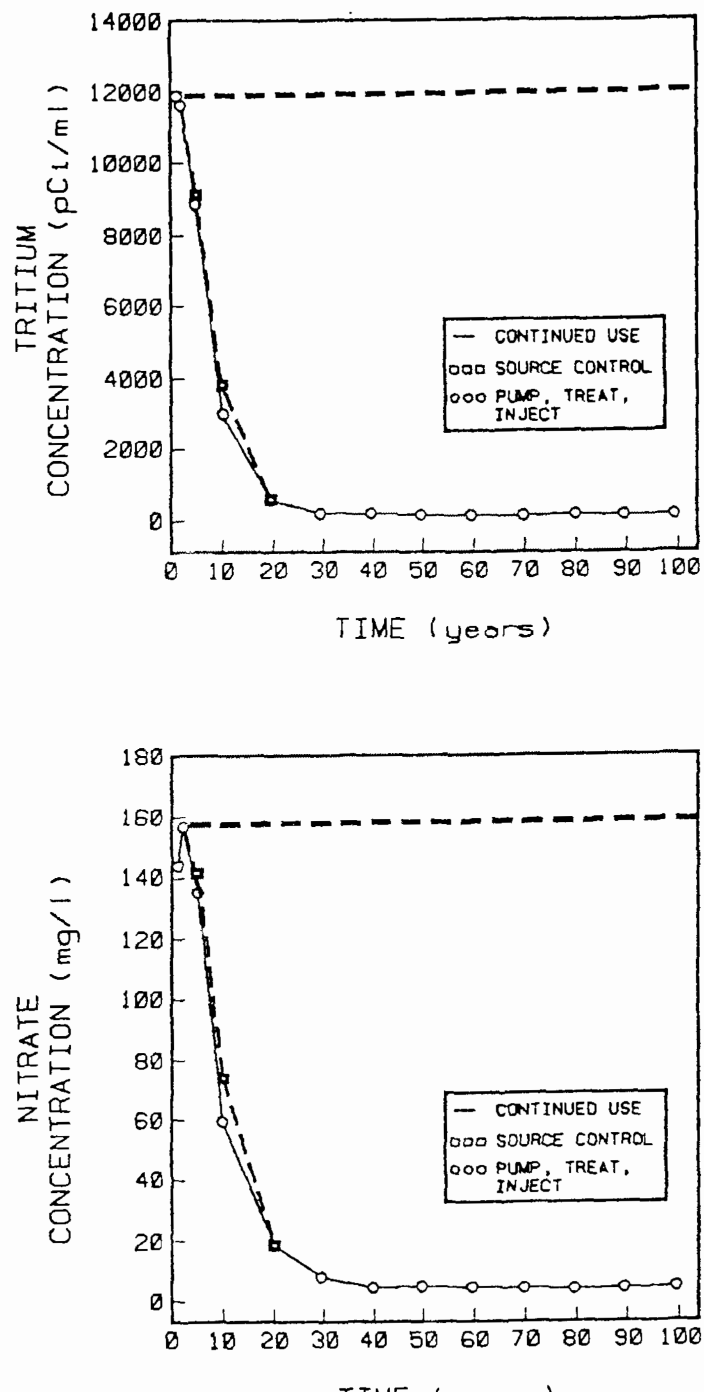

Figure 14. The predicted contaminant concentrations at a hypothetical monitoring well downgradient of the F area seepage basins for three scenarios are compared. The benefit of discontinuing use of the basins and capping is dramatic, but the additional benefit of a pump, treat and inject program is negligible.

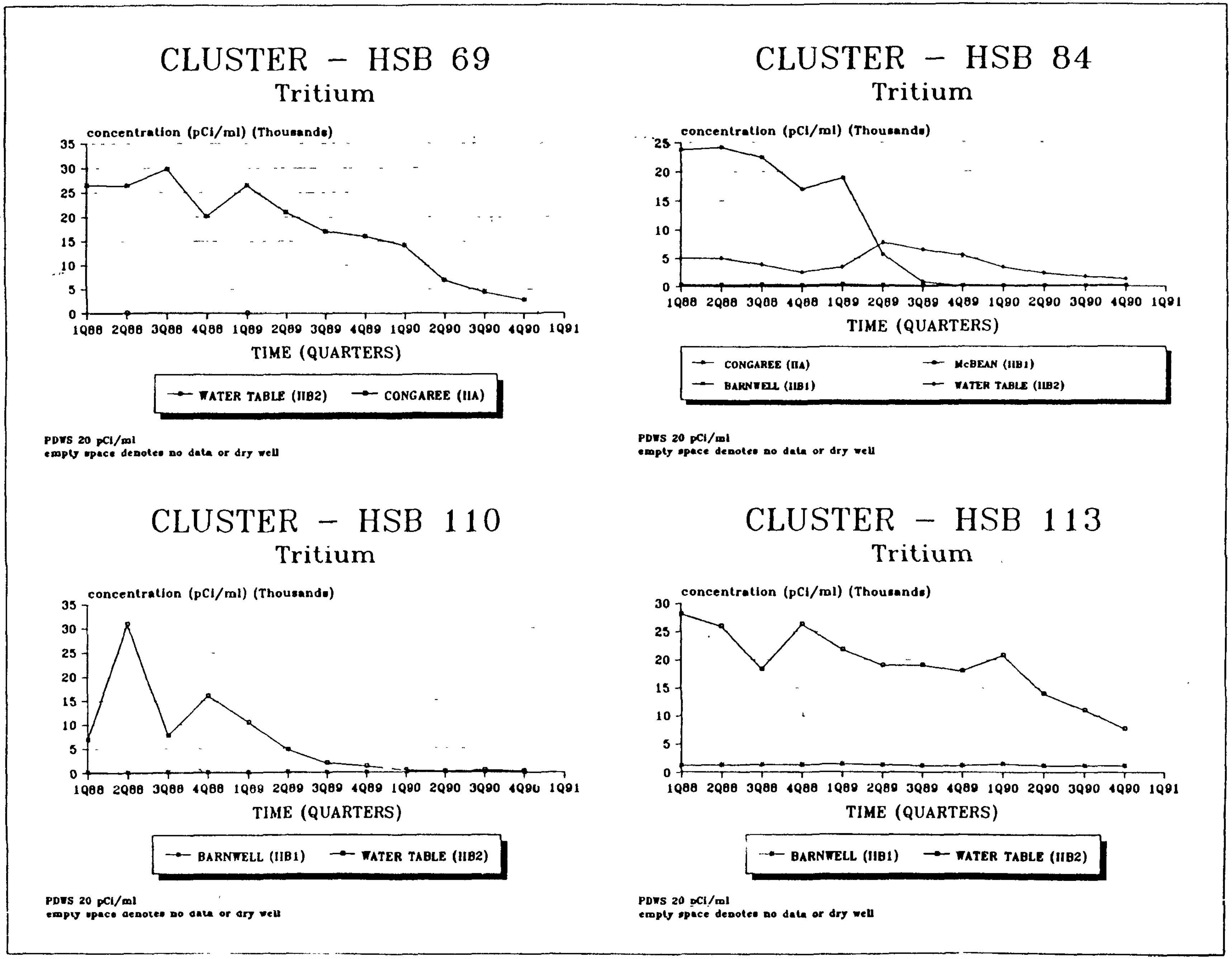

Figure 15. Tritium concentrations at wells monitoring groundwater at the F and H Area Seepage Basins are declining as a result of discontinuing use and closure of the basins.

A Perspective for NAPL Assessment and Remediation

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ABSTRACT

This paper compares contaminant mass release rates to the subsurface at facilities receiving contaminated water and facilities receiving organic fluids (Class One and Class Two sites) with contaminant mass removal rates possible with ground-water (GW) pump and treat. Mass removal rates possible with nonaqueous phase liquid (NAPL) plume investigation and remediation are presented. Containment and cleanup approaches for Class Two sites (NAPL) are discussed. Some reasons for current GW pump and treat failures are also discussed.

OUTLINE

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2.0 Background
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5.0 Summary
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1.0 INTRODUCTION

The issue has been raised regarding the effectiveness of ground-water (GW) pumping and treating for the remediation of abandoned hazardous waste disposal sites. This paper focuses on typical abandoned commercial hazardous waste disposal sites. Many of the simplifying assumptions possible for these Superfund sites are inappropriate for small spill sites.

The purpose of this paper is to present alternative approaches for characterizing and remediating subsurface contamination by nonaqueous phase liquids (NAPLs). The opinions are my own and do not represent the policies of the Agency. For purposes of discussion, it is convenient to group Superfund sites into two categories based on site characteristics. Hypothetical scenarios are presented to illustrate key points and do not represent actual field data from individual Superfund sites. I am soliciting opinions from the technical community on application of these alternative approaches for evaluating remediation of subsurface contamination. This subject is currently under deliberation at EPA and further evaluation of these ideas and of additional field work may result in modifications to Agency policy.

This paper suggests that the problem with GW pump and treat is one of using it on sites with nonaqueous phase liquid (NAPL) plumes. This problem is limited to NAPL sites as GW pump and treat works well for sites without NAPL plumes. A concept of a Superfund site with only a dilute solute plume migrating away is often incorrect; frequently a mobile NAPL plume will be present. If a NAPL plume is present, and not considered, there will be an underestimation of the mass of contaminants released and misunderstanding of the subsurface pathways through which the bulk of the contaminant mass migrates from the site. This paper suggests that sites could be differentiated as to whether they have APL or NAPL plumes.

The first group of topics discusses an identification of the problem. The mass release rates at a hypothetical pair of hazardous waste disposal sites are compared. The practice of looking for a GW concentration of 1, 20, or 33 percent of the equilibrium solubility concentration as an indicator of the presence of a NAPL plume is reviewed. The mass removal rate possible with GW pumping is compared to a treatment train of NAPL pumping, secondary recovery, and GW pumping for currently contaminated waters only. Field data comparing relative proportion of contaminant mass in an aqueous phase liquid (APL) and NAPL plume are compared for a site. The importance of these infrequently investigated NAPL migration pathways is raised. The importance of sampling all major contaminant migration pathways is stated. The differences in sampling depth are compared for APL and three NAPL migration pathways.

The second group of topics evaluates alternative responses to the problem. Proposed remediation and containment responses are discussed. The relative velocity of hydrophobic and hydrophilic contaminants in NAPL and APL plumes are compared. The time required for a mobile NAPL plume to convert into a tail of residual saturation is suggested. Finally, the principal issues are summarized.

2.0 BACKGROUND

The concern about the effectiveness of GW pump and treat operations first surfaced at the EPA Office of Emergency and Remedial Response (OERR) in December of 1987 when GW experts from the EPA lab in Ada, Oklahoma, raised the concern to OERR Headquarter's staff. OERR commissioned a study of 19 sites to investigate the causes for poor response at GW pump and treat sites (EPA 1989). This report found that aquifer cleanup progressed as predicted at some sites, but results at other sites were disappointing.

The study looked at 19 sites where the GW extraction system had been in operation a sufficient length of time for an assessment of whether the contaminant concentrations were declining as predicted. The analysis did not distinguish between different types of sites. The study concluded that there was not a way to anticipate when GW pump and treat would or would not be successful.

Travis and Doty (1990) suggest that the Superfund Program should abandon efforts to remediate GW to health-based levels. Their opinion is that none of the 19 sites showed any conclusive proof of a successful remediation or of satisfactory progress in reducing contaminant concentrations. They suggest Superfund should focus on pumping GW for 3 to 5 years (for mass reduction), and then discontinue GW extraction. GW water pumping is not seen as adequate, and other approaches are not considered. The problems identified in the 19-site study are presented as cause for giving up on efforts to remediate contaminated GW. EPA, on the other hand, prefers to use the problems identified in the remediation of the 19 sites to focus efforts on solutions to the difficulties identified.

3.0 DIFFERENT CONCEPTS OF SUBSURFACE MIGRATION PATHWAYS

This paper suggests that the problem with GW pump and treat is one of a misconception of a hazardous waste disposal facility. The mass of contaminants released is often underestimated and the subsurface pathways moving the bulk of the contaminant mass away from the site are not recognized. Typically, the plume expected is the plume that is sampled (and hence remediated). Typically, the expected plume is a dilute solute (APL) plume. For sites where this concept is correct, GW extraction can remove contaminant mass at an adequate rate. However, for many abandoned hazardous waste disposal facilities, the dilute solute plume (APL) represents a small fraction of the contaminant mass that the facility released to the subsurface. The remaining contaminant mass is in NAPL plumes, both the migrating mass and the stationary tail. Pumping GW before removing the mobile NAPL mass and the NAPL mass in the tail will require inordinate timeframes for the extraction of the contaminant mass.

This paper suggests that site investigators could categorize sites into two classes. Sites in the first class would continue to receive GW pump and treat remediations. Sites in the second class would have their NAPL plumes and tails sampled. GW extraction is important at all sites, but at sites in the second class, it needs to be preceded by extraction of the mobile NAPL (when still present), along with some effort to extract the stationary NAPL tail (residual saturation) using secondary recovery techniques. Extracting GW before removing NAPL will draw uncontaminated water over the NAPL mass and generate more contaminated GW by dissolving the contaminants currently in the NAPL plume into the water. This process can repeat for thousands of years before depletion of the contaminant mass.

This paper suggests that simple extraction of contaminated GW is not adequate to remediate sites in the second class. Approaches proposed in this paper may or may not be sufficient to reach health-based levels in the currently contaminated area. However, demobilization of the mobile NAPL mass may sometimes be a viable approach and will help protect currently uncontaminated areas from exceeding health-based levels in the future. Unfavorable geology can eliminate the possibility of cleaning up an aquifer (e.g., karst terrane can limit the ability to find the plumes). NAPL sites are no different than APL sites in this regard; certain geology will present more challenges than the Superfund Program can address at this point in time. This discussion will focus on sites where the geology allows a successful remediation. This discussion will focus on abandoned commercial hazardous waste disposal facilities. These sites receive many truckloads of waste; a small spill will not present the problem that is discussed in this paper. The smaller contaminant mass may permit successful removal of the mass by GW extraction. This paper will focus on organic chemical contaminants; dissolved metals will not be discussed. Additionally, vapor phase transport pathways exist and can cause contamination of infiltrating rainwater, however, for the sake of focus, vapor phase transport will not be addressed by this paper.

The total mass released to the subsurface should be compared to the amount accounted for in the sampled plumes. Information concerning the exact amount of mass released is typically not available. However, plausible estimates should be made for comparison to the amount found in plumes leaving the site.

The concept of an abandoned hazardous waste disposal site releasing only a dilute solute plume (APL) that transports contaminants from the facility to the sampling well causes problems with the choice of subsurface contaminant migration models. For sites with only an APL plume, the APL models make a realistic attempt to model the situation. For sites where the principal contaminant mass is in a mobile NAPL plume, the use of APL models produces results inconsistent with the actual conditions.

3.1 NEED TO DIFFERENTIATE WASTE DISPOSAL SITES

Superfund sites could be discussed in two groups. The two groups would be differentiated by the scale of the subsurface contaminant mass released and the type of subsurface transport pathway(s). The utility of dividing abandoned hazardous waste disposal sites into two groups is that it allows us to predict whether GW extraction and treatment will work or whether a faster contaminant removal method is required. The correct concept of a site is important for both sampling and remediation. The following paragraphs describe the characteristics of Class One and Class Two sites.

3.1.1 THE NATURE OF WASTES AT HAZARDOUS WASTE SITES

A good concept of a typical abandoned hazardous waste disposal facility begins with the type of waste in the hazardous waste system. The proportion of solid and pourable waste is important to consider in understanding how hazardous waste migrates away from abandoned hazardous waste disposal facilities. Contaminants in solid waste move into the subsurface only after dissolving into the percolating rain water. This pathway is limited by the low hydraulic loading the rain provides. Contaminants in liquid waste move into the subsurface as fluid percolating through the pore spaces in the soil. The hydraulic loading is provided by the waste itself, not the rain.

It is often thought that hazardous wastes are primarily solid materials placed on the land. However, only 10 to 20 percent are solid wastes; the remaining 80 to 90 percent are pourable wastes (Skinner, 1984). Hence, the concept of a solid material leaching into percolating rain water should only be used at those type sites. The most significant contaminant loading comes from liquid hazardous waste.

Hazardous liquid waste can be in two forms: it can be water contaminated with a few ppm of contaminant, or it can be pure organic fluid. Just as the hydraulic loading differed for solids and liquids, the two types of liquid waste pose two different contaminant loading rates. The 1,000,000 ppm contaminant concentration in pure organic fluid provides much more contaminant mass than does water contaminated with a few ppm.

The placement of liquids onto the land was commonly practiced before the promulgation of the Hazardous Waste Regulations in 1980. The Regulations now require treatment to Best Demonstrated Available Technology (BDAT) standards; the only material that can be land disposed is the irreducible treatment residual.

3.1.2 CLASS ONE SITES

If water contaminated with a few ppm of organics is placed into a pit, pond, lagoon, or landfill, then contaminated water will leak out. This, by definition, is called an aqueous phase liquid (APL). The contaminants leaving the site will only form a primary APL plume. This type of site cannot form a NAPL plume. A primary plume is one that carries contaminants from the disposal pit to the sampling point. A secondary plume is one that carries contaminants from a primary plume to the sampling point. A dilute solute model is appropriate for these sites.

3.1.3 CLASS TWO SITES

If organic byproduct fluid is placed into a pit, pond, lagoon, or landfill, then organic fluids will leak out. This nonwater fluid is, by definition, called nonaqueous phase liquid (NAPL). The contaminants leaving the site will form a primary NAPL plume, and a secondary APL plume will form from the NAPL plume. Dilute solute models are not appropriate for these sites since most of the contaminant mass migrates as a highly saturated NAPL plume. The dilute solute contamination that occurs does not start at the site; it starts at the interface between the NAPL plume and the water. Hence, the dilution that occurs between the site and a well, say 200 feet away, is different from the dilution that occurs for contaminants that move 180 feet in the NAPL plume, and then move 20 feet in a dilute solute plume.

3.1.4 HISTORICAL TECHNIQUES FOR IDENTIFICATION OF NAPL

Site investigators have used the occurrence of concentrations of 1, 20, and 33 percent of equilibrium solubility as benchmarks indicating the presence of a NAPL plume (Cherry 1990, Miller 1990). This practice sets the standard too high. Secondary APL plumes will typically show much lower concentrations at the actual well position. Individual molecular identities are typically 0.1 to 2 percent of the NAPL plume. This limits the maximum concentration in GW at the interface between the NAPL plume and the water to approximately 0.1 to 2 percent of the equilibrium solubility. As the hydrophobic contaminant migrates from the interface to a distant point (such as the actual well location and depth), its concentration falls off sharply. Hydrophobic NAPL contaminants exhibit highly retarded transport velocities in dilute solute plumes (APL). Commercial synthetic organic chemical production is only 46 years old. Thus, the more hydrophobic contaminants have limits on the total distance they can travel from the NAPL plume itself. Dispersion of APL transport between primary NAPL plume and sampling point further reduces the concentration.

Sometimes the different plumes move in different directions. If the wells are placed for a different direction of travel, then the distances between the NAPL plume and the well may be too great. Depth of sampling is typically appropriate for dilute solute contaminated GW plumes, and typically a large vertical distance from sinker and floater plumes.

3.2 COMPARISON OF MASS RELEASE RATE AND MASS REMOVAL RATE

A simple mass balance can be used to estimate the timeframe required for remediation. The mass removal rate can be compared to the mass in place to estimate whether the contaminant removal rate is sufficient to clean up the site in a reasonable timeframe. To illustrate the point, the next paragraphs present two hypothetical mass release rates and two hypothetical mass extraction rates. The mass in per year for the example Class One and Class Two sites are compared to the mass extraction rates possible with GW extraction. The mass in per year for Class Two sites is also compared to the mass extraction rates possible using a train of three extraction techniques. The first technique is extraction of highly saturated mobile NAPL mass (where present); the second technique is a secondary recovery technique to remove the residual saturation of the tail and the residual saturation left by pumping the mobile NAPL mass; and the final technique is GW extraction of the mass of contaminant dissolved in GW at the start of remediation (sorbed contaminant mass in equilibrium with the dissolved concentrations is also included). The amount of GW pumping is much smaller in this case because most of the NAPL mass has been extracted by the first two techniques.

3.2.1 MASS IN PER YEAR

3.2.1.1 Class One Sites (APL Lagoon)

The hypothetical Class One site is an unlined lagoon that has water contaminated to 3 ppm placed into the lagoon. For both examples, the hydraulic conductivity is assumed to be 0.001 cm/sec. The area of the Class One lagoon is 10,000 ft^2 based on dimensions of 100 feet by 100 feet. The hypothetical contaminant concentration is 3 ppm.

If this lagoon is kept full; 77,418,000 gallons of water can percolate through the bottom of the unlined lagoon each year. At 3 ppm, this volume of water will contain 232 gallons of organic contaminant. This represents 4.2 barrels per year (55-gallon barrels).

The preceding values are thought to be representative of typical sites. Clearly, all of the values will change from site to site. The reader can vary some of the values and obtain a feel for the range of possible values for the number of barrels of contaminant that can percolate per year. The number will vary, however, all Class One sites will have a small estimate of barrels per year.

3.2.1.2 Class Two Sites (NAPL Lagoon)

Historically, the hypothetical Class Two site is an unlined lagoon that has 55-gallon drums and 5,000-gallon tank truck loads of organic fluids placed in the lagoon. No contaminated water was sent to the lagoon. This site represents the typical abandoned commercial hazardous waste disposal facility that accepted waste from more than one factory; hence, the wastes arrived at the site by either tanker truck or by flatbed truck loaded with up to 80 barrels. For this example, the hydraulic conductivity is also assumed to be 0.001 cm/sec. The area of the Class Two lagoon is smaller, 100 ft^2 based on dimensions of 10 feet by 10 feet. The contaminants are in pure form (neat); that is to say they are approximately 1,000,000 ppm in concentration.

If this lagoon is kept full; 774,180 gallons of organic fluid can potentially percolate through the bottom of the unlined lagoon (this assumes that the ratio of density to viscosity for the organic fluid is the same as water; clearly the ratio can be higher or lower). Since this fluid is pure organic fluid, the amount of organic contaminant is the same as the amount of fluid percolating through the bottom of the lagoon. This 774,180 gallons represents 14,076 barrels per year (55-gallon barrels). This quantity can be expressed as 155 truckloads of waste (3 truckloads per week).

The preceding values are thought to be representative of typical abandoned commercial hazardous waste disposal facilities. Clearly, all of the values will change from site to site. As with the Class One example, the reader can vary some of the values and obtain a feel for the range of possible values for the number of barrels of contaminant that can percolate per year. The number will vary; however, all Class Two sites will have a large estimate of barrels per year.

3.2.2 MASS OUT PER YEAR

3.2.2.1 Ground Water Pump and Treat

The previously stated contaminant loading rates can be compared to hypothetical contaminant mass removal rates possible with extraction of contaminated GW. Clearly, the pumping rate can vary as can the contaminant concentration in the produced waters; however, a representative rate can be suggested. The rate discussed here was based on 10 actual sites where contaminated GW is being extracted (USEPA 1989). The representative GW extraction rate is suggested as 150 million gallons per year. The concentration averaged across all produced waters is 3 ppm (this high concentration is a favorable assumption as a much higher concentration in the lagoon would be necessary to produce waters with a 3 ppm concentration). The reader can vary these parameters and evaluate the possible mass removal rates possible with different pumping rates and different average concentrations.

Removal of 150 million gallons per year at an average concentration of 3 ppm removes 450 gallons of organic fluid per year. This represents 8 barrels of organic fluid per year.

GW extraction and treatment in this hypothetical example can remove 8 barrels per year. For the Class One site that releases 4 barrels per year, this approach can remove the contaminant mass in a similar timeframe to the period that wastes were released to the ground. For Class One sites, GW extraction is a viable tool. For these sites, GW extraction involves removing the contaminants in the same form that they were released.

However, for Class Two sites, the contaminant mass removal rate of 8 barrels per year is so much smaller than the release rate of 14,000 barrels per year that the approach is not viable. For every year of releases, over a thousand years of GW extraction will be needed to remove the contaminant mass by pumping GW with 3 ppm contaminant concentration. This approach does not involve extracting the waste in the form that it was released; it involves extracting a much larger fluid volume with a much lower contaminant concentration.

When the concept of a Class Two site is confused with a site having only a dilute solute plume, the extraction of GW is pursued as a viable approach for containment or restoration. Unfortunately, the concentration reduction over time will be less than anticipated due to the gross understatement of the mass needing removal.

3.2.2.2 NAPL Pump and Burn with Surfactant Wash

A higher mass removal rate is possible by extracting highly saturated volumes of mobile NAPL. This will leave a residual saturation in the area where the NAPL mass was pumped. The tail left by the migrating NAPL plume will also represent a volume of aquifer with residual saturation. Pumping will not remove this residual saturation; a secondary recovery technique is required. (For sites where the mobile NAPL plume has moved so far as to have left its entire mass as a tail of residual saturation, the secondary recovery technique is the first technique to be used, as there is no highly saturated volume that can be pumped.) The secondary recovery techniques will leave a contaminant concentration that is typically higher than health-based levels. GW extraction and treatment is required as a third activity if health-based goals are intended.

Hence, the contaminant mass removal rate suggested is based on a train of three approaches: NAPL pumping, secondary recovery, and conventional GW pumping of a small volume of GW. As with the other hypothetical release and removal rates, the following parameters are felt to be representative; however, they can vary and the reader is encouraged to explore the effect of changing the parameters.

For this hypothetical example, the NAPL extraction rate is set at 5 million gallons per year (20% NAPL and 80% coproduced water). The surfactant wash (secondary recovery technique) is set at a rate of 15 million gallons per year. The final phase, GW extraction, is set at the same rate as the GW extraction alone, 150 million gallons per year. The three phases of extraction are done in sequence rather than simultaneously. This combined treatment train can produce at an average rate of 286,000 gallons of organic fluid per year. This represents 5,200 barrels per year, or 57 truckloads per year.

This extraction train cannot be applied to Class One sites because they do not have a volume of residual saturation of NAPL or a highly saturated volume of NAPL. This train can only be used for

Class Two sites. At Class Two sites where the mobile NAPL plume has dissipated its volume by leaving a tail of residual saturation, only the last two steps of the train can be taken. For Class Two sites with the full train, the extraction rate of 5,200 barrels per year is sufficiently closer to the release rate of 14,000 barrels per year to permit extraction in possible timeframes. The extraction may take longer than the period of releases, but at least it will not be over a thousand times the release period.

This extraction approach involves removing the wastes in the form disposed or as close to it as possible. Removing the wastes in concentrated form increases the removal rate to the point where it is closer to the release rate.

3.3 RELATIVE APL AND NAPL MASS AT A CLASS TWO SITE

This paper suggests that many sites that have had their GW plumes sampled and pumped should have also had their NAPL plume pathways sampled. The hazardous waste practice is not monolithic. Rather, there is a considerable distribution of types of approach. NAPL plume sampling is being done by some site investigators.

The relative importance of the APL versus the NAPL pathways can be seen by considering the rate of waste loading to the facility and the GW's ability to carry the mass away at concentrations typically found in GW. A spill site or underground tank leak of 0.05 gallon per hour may or may not overwhelm the GW's ability to transport the contaminants away. A characteristic of abandoned commercial hazardous waste disposal facilities is that of receiving more barrels of organic fluids than can be transported away dissolved in GW. The ratio of mass in the APL plumes to mass in the NAPL plumes varies; however, a feel for the scale can be obtained by looking at a site where both the APL and NAPL plumes have been investigated.

The Hyde Park landfill/lagoon is a facility that received substituted and unsubstituted organic fluids that were byproducts of a synthetic organic chemical manufacturing facility. Company records show from 66 to 250 million pounds of non-NAPL waste (solid and hydrophilic liquids) were placed in the facility. The records also show 93 to 350 million pounds of hydrophobic organic fluids (7 to 27 million gallons of NAPL) were placed in the lagoon (District Court 1980, Morgan 1979, Versar 1980). The Remedial Investigation has characterized the magnitude of the APL and the NAPL plumes. Three thousand eight hundred gallons of hydrophilic and hydrophobic contaminants were found dissolved in GW. Thirteen million eight hundred thousand gallons of NAPL plume were found migrating down dip of the aquitard (Conestoga-Rovers 1989a and 1989b). Hence, if a site has received more mass than can be explained by the contaminants in solution and the sorbed contaminants that are in equilibrium with those concentrations, it is likely to have had a NAPL plume. The NAPL plume may consist solely of the immobile residual saturation left by a mobile NAPL plume that has depleted its highly saturated volume, or a mobile, highly saturated NAPL volume may also be present. Typical commercial hazardous waste disposal facilities received 2 to 20 truckloads per day. Allowing 1 truck load in solution and 10 to a 100 truckloads for sorption, the rest of the waste must be present as mobile or stationary NAPL mass (volatilization will occur).

3.4 WE NEED TO SAMPLE ALL SUBSURFACE PATHWAYS

We need to sample all subsurface pathways in order to design appropriate remedial/containment measures for Class Two sites. Different pathways flow at different depths, directions, and velocities. Modeling of these parameters can help focus the sampling effort to intersect these pathways. It is important to be aware of five classes of migration pathways:

1 Dilute solute plumes from dry landfills
2 Dilute solute plumes from lagoons

3 Floater plumes - Light Nonaqueous Phase Liquid (LNAPL)
4 Neutrally buoyant plumes - Neutrally buoyant Nonaqueous Phase Liquid (NNAPL)
5 Sinker plumes - Dense Nonaqueous Phase Liquid (DNAPL)

Detailed discussion of modeling the APL and NAPL plumes is beyond the scope of this paper. The reader interested in further discussion is directed to OSWER Directive 9285.5-1 (USEPA, 1988).

4.0 RESPONSE TO PROBLEM OF MASS REMOVAL RATE

4.1 SELECTING APPROPRIATE CLEANUP APPROACH FOR EACH CLASS

This example suggests that it is better to attempt to remove the wastes in the form they were released, or as close to that form as possible. Applying GW extraction to a Class Two site is not limited by the liquid-to-liquid dissolution rate (NAPL to APL); rather, it is limited by the ratio of the total mass in place to the mass removal rate. A triple unit train may or may not be able to reach health-based concentrations in a reasonable timeframe; however, it will make progress much faster than GW extraction alone. At sites where the NAPL mass can be found and extracted, the triple train offers hope of faster, more efficient remediations. Whether the triple train can satisfy all goals or not is an issue; however, the first two unit operations can remove mass faster than GW pumping, and the third unit operation (GW pumping) will be as fast as GW pumping alone. Hence, the triple train will always put you closer to your goals in a given timeframe than GW pumping alone.

4.2 ALTERNATIVES FOR MASS REMOVAL RATE PROBLEM

While GW extraction cannot remove the contaminant mass of a Class Two site in a reasonable timeframe, that is not justification for discontinuing subsurface remedial efforts. The Class One sites can continue to receive GW extraction as the sole subsurface remedial activity. The Class Two sites can have both the APL and NAPL plumes sampled and investigated. The NAPL plumes that can be found can be extracted by pumping of the highly saturated volumes and secondary recovery of much of the residual saturation tail. This may be enough to demobilize the NAPL plume and improve the site sufficiently to be considered remediation of the site. In some cases, it will also be appropriate to follow the first two techniques by conventional GW extraction. For the GW extraction phase to be able to reach health-based levels, the secondary recovery technique must remove most of the mass. The degree to which secondary recovery techniques can remove the mass has yet to be demonstrated. Research is needed on secondary recovery techniques.

If removal of the residual saturated mass is substantially incomplete, further efforts involving extracting contaminated GW may not be worthwhile. It has been suggested that the oil industry can only produce 30 to 50 percent of the oil in the ground, and we should expect the same. For a number of reasons, we may expect better yields.

First, the oil industry deals with very large-scale oil bearing formations; fortunately our plumes are much smaller.

Second, they are producing fuel at an economic cost near 30 dollars a barrel. The additional costs of secondary recovery before the 1972 embargo meant that secondary recovery was not utilized. Early in the oil exploration period, only the easy oil was produced. As oil became more scarce, more costly deposits were exploited. After the cost jump of 1972, it became practical to practice secondary recovery. However, the price of 30 dollars a barrel still limited the degree to which it was practical to produce oil for a profit by secondary recovery techniques.

The Superfund Program is involved with protecting human health from exposure to carcinogenic chemicals. We typically are not limited by a point of diminishing returns dictated by producing oil for less than 30 dollars a barrel. Our reasons for extracting fluids from the ground are profoundly different. The point of diminishing returns is also much different.

Third, the oil industry extracts oil from large deposits that are typically averaging 20 percent oil and 80 percent brine. They try to find domes that trap closer to 100 percent oil to make their efforts more efficient, but typically they must also harvest less concentrated deposits. Hazardous waste NAPL plumes are smaller and the bulk of the migrating mass is saturated. Based on Schwille's (1988) measurements of residual saturation, we may in some cases be able to remove 75 to 85 percent of the highly saturated NAPL volume as free fluid. The remaining 15 to 25 percent is the residual saturation that requires secondary techniques for extraction. The tail of the NAPL plume will be close to residual saturation and cannot be pumped; hence, it also requires secondary recovery techniques.

When initial saturation is only 20 percent and residual saturation is 5 to 15 percent, only 5 to 15 percent of the pore volume can be freely pumped. With 20 percent initial saturation and removing 10 percent, only 50 percent of the oil can be removed by pumping. At hazardous waste mobile NAPL plumes, we may be able to freely pump 75 to 85 percent of the highly saturated NAPL volume and still leave the same residual saturation volume.

The degree to which we can remove the residual saturation by secondary techniques is currently unknown. We are researching this question at the present. However, it is clear that we can spend more than 30 dollars a barrel to push the extent of extraction to higher levels than the oil industry is able to extract economically.

We do feel that there may still be limits to our ability to remove NAPL's from the ground, but it will be a different limit than for the oil industry producing economical fuel for motor cars.

4.3 CONTAINMENT VERSUS REMOVAL

It may be better to immobilize the highly saturated NAPL plumes at multiple sites by NAPL pumping without secondary recovery than to polish a single site to health-based levels. If a mobile DNAPL plume is present, a GW hydraulic gradient control effort will not stop the DNAPL plume. The DNAPL plume will flow under the wells and form a new APL plume on the other side. Effective containment measures at a site require understanding DNAPL pathways.

Hydrophobic contaminants move with a retarded velocity when migrating as a dilute solute (APL), and an unretarded velocity when in a NAPL plume. Hydrophilic contaminants in APL or NAPL plumes flow with a more similar velocity. The actual velocities will depend on the density, viscosity, octanol-water partition coefficient, and aquitard dip to hydraulic gradient comparison. However, the extreme retardation of compounds with log octanol-water partition coefficients over three suggests that the NAPL plume will be faster than the APL plume for these compounds. In these cases, containing the spread of hydrophobics in the fast moving concentrated NAPL plume is more important than containing the retarded flow of hydrophobics in the dilute plume.

This paper suggests that the contaminant mass leaving Class Two sites will be found in two to three forms: highly saturated mobile NAPL plume(s) (if present), tail of plume(s) consisting of residual saturation of NAPL, and a secondary dilute solute plume(s). Historically, during operations of a hazardous waste pit, pond, lagoon, or wet landfill, the waste organic fluids would be saturated in the pit. This will cause highly saturated conditions in the porous media surrounding the pit. The NAPL will displace most, but not all, of the water in the pore spaces. This non-water fluid will move under a pressure gradient (due to negative buoyancy, hydraulic head, or chemical head). As long as the pit is kept full, the plume will not have a tail. The highly saturated conditions will be present from the pit to the front of the NAPL plume. After cessation of waste loading to the pit, a tail of residual saturation will develop between the pit and the mobile NAPL plume. As the mobile NAPL plume migrates, it leaves some of its volume behind in the form of a tail of residual saturation. At some point in time, this will deplete the mass in the mobile NAPL plume. At that point, the NAPL mass will be stationary (further movement of contaminant mass will only occur as a dilute solute plume (APL)). Clearly, some Class Two sites will have three forms present and some sites will have only two forms present; it is a matter of time. If we get to the site after a long time, then the NAPL mass will be a stationary source. If we get to the site shortly after cessation of waste loading, then the mobile, highly saturated NAPL plume will be large.

It has been hypothesized that the time required for the mobile NAPL plume to become a tail of residual saturation is less than a year (Cherry 1991). This would suggest that Superfund sites would generally have a residual saturation volume and a dilute solute plume, but no mobile NAPL plume. This image would support the idea of using gradient control to contain a site that is too difficult to remediate. However, this containment approach would not be valid at sites where there was a mobile DNAPL plume. At these sites, the mobile DNAPL plume will pass under the gradient control well field and form a new dilute solute plume on the other side. This paper suggests that a much longer time is required for the depletion of the highly saturated NAPL mass at commercial abandoned hazardous waste disposal facilities.

4.4 TIME REQUIRED FOR NATURAL DEMOBILIZATION OF NAPL PLUMES

Whether a mobile NAPL plume is present or not is best determined by sampling; however, a theoretical discussion can provide insight for determining when to look for a mobile NAPL plume. For the sake of discussion, DNAPL plumes in simple geology will be discussed. The hypothetical site has one aquifer with one thick impermeable bottom (aquitard) that has a dip, and it is reasonably homogeneous and isotropic. The hypothetical site is an unlined pit that has the same mix of substituted organic fluids poured into it for 10 years at such a rate as to maintain ponded conditions in the pit at all times. This will give a continuous steady release rate. The height of the fluid in the pit will change the mass flux out of the pit, but it will not make a large difference in the velocity of the plume; it will cause a change in the cross sectional area of the plume. The saturated conditions in the pit cause highly saturated conditions in the plume (previously water filled pores prevent full saturation).
The density, viscosity, hydraulic conductivity of aquifer, and dip of the aquitard affect the actual velocity of a DNAPL plume. Clearly, the velocity affects the distance the plume travels each year. We can imagine three segments with different velocities. The velocity of the unsaturated zone segment is the highest; since the pressure gradient is greater than one (say 1.5 for TCE), the direction is downward. The downward migration continues through the saturated zone until reaching the aquitard. This segment is at a slower velocity, because the pressure gradient is now the difference between the DNAPL density and the density of water (say 1.5 - 1 = .5). The third segment is the horizontal migration of the DNAPL plume as it moves down dip. This velocity is the smallest since the gradient is the negative buoyancy multiplied by the slope of the aquitard dip (and some influence due to the natural hydraulic gradient which will be ignored).

The first two segments are relatively fast and the third slow; as an approximation, the first two segments will be considered to require less than 2 months. The 2-month time is small compared to the 10-year life of the pit and will be ignored. Thus, the simplified model has the DNAPL plume migrating down dip of the aquitard. The length traversed each year is X, the actual value of X depends on the parameters discussed above. Using the variable "X" makes the discussion independent of these parameters. At the cessation of waste loading in 10 years, we can expect the DNAPL plume to have moved a distance of 10 X.

Residual saturation can be 5 to 15 percent of the pore volume (Schwille 1988); for this example, the value of 15 percent will be assumed. For this example, an initial high saturation value of 85 percent will be assumed. During the 10 years of waste loading, the plume is highly saturated from the pit to the tip of the DNAPL plume; there is no tail of residual saturation present. After cessation of waste loading, a tail of residual saturation will develop between the pit and the mobile plume. Once the DNAPL plume reaches 5.6 times its highly saturated length, it will consist of a tail of residual saturation that is not moving as a mobile DNAPL plume. The plume will reach a distance of 56 X (lateral spread will reduce total distance).

If it took 10 years to travel a distance of 10 X, then approximately 46 years would be required for the mobile DNAPL plume to dissipate its volume as a tail of residual saturation (total time from start 56 years). Commercial synthetic organic chemical production has been occurring for the last 46 years. Hence, the likelihood of investigating a commercial hazardous waste disposal facility with a mobile DNAPL plume is high. The approach of using gradient control to stop migration on sites where health-based goals are unattainable is unworkable in that the mobile DNAPL plume would not be contained. The mobile DNAPL plume would pass by the containment effort and dissolve into GW on the other side and compromise the effort.

5.0 SUMMARY

In summation, this paper suggests that it is important to sample the proper depths so as to sample all contaminant pathways, especially NAPL migration pathways. The concept of the site must fit the site so that the proper samples are taken, and so that the remedial measures designed for the site actually fit the site. The proper concept of an abandoned commercial hazardous waste disposal facility is necessary for extracting contaminant mass within acceptable timeframes, and for implementation of effective containment approaches.

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OPTIMIZING AND EXECUTING A MULTI-FACETED REMEDIAL ACTION PLAN

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INTRODUCTION

The objective of this paper is to discuss the successful implementation of a multi-faceted, multi-PRP remedial action at the Seymour Site (former Seymour Recycling Corporation) in Seymour, Indiana.

The importance of the this site is the rate of progress made in the implementation of remedial design (RD) and remedial action (RA). The Seymour Site is one of the first NPL sites remediated by the potential responsible party's (PRP's) to reach this point in remediation. The RA is nearly two years ahead of schedule on the 58 month schedule of the Consent Decree.

Although the Consent Order and Remedial Action Plan (RAP) attempted to anticipate every eventuality, the details of program design and implementation required nearly continuous coordination and adjustment. This paper discusses techniques used to accomplish this program in approximately one-fourth of the time initially projected. Particular focus is on the impact on the design and construction processes.

An unusually high level of cooperation was achieved by all parties to the remediation that has enabled the project to reach this level of clean-up in such a short time frame.

BACKGROUND

The general scope of this project is to remediate the site in accordance with the Consent Order, Record of Decision (ROD), and Remedial Action Plan (RAP) through the use of several technologies. Initial remedial action involved the implementation of a Plume Stabilization project in accordance with the Agreed Order to reduce the spread of ground-water contamination prior to finalization of the Consent Decree.

DESCRIPTION OF SITE

The Seymour Site is a 14-acre facility located two miles southwest of the City of Seymour, Indiana, on land owned by the City of Seymour in an industrial park at the local airport, Freeman Field. This facility operated as Seymour Recycling Corporation, a processing center for waste chemicals, until late 1980. When the facility was closed, over 55,000 drums, 100 bulk tanks of various sizes, and tank trucks, most containing waste chemicals, were left on the site. Ten buildings were left standing and an incinerator had been operated at the facility. Hazardous substances had leaked into the ground causing contamination of the soil and the shallow ground water aquifer. Surface water run-off and the incinerator operation had spread contamination along the natural drainage ditch leading from the site, known as Northwest Creek. Vapor emissions, fires, and noxious odors had been common problems prior to site closure.

The Seymour Project begin as a United States Environmental Protection Agency (USEPA) Region V Emergency Response action in 1982. The drums, tanks, and some surface soil were removed from the site and a clay soil layer placed on site. The Remedial Investigation (RI) was completed in 1985. The Feasibility Study (FS) was published in 1986.

PROJECT HISTORY

In response to findings of the investigation, a negotiation among the PRP's, USEPA Region V, and the Indiana Department of Environmental Management (IDEM) ensued. The result of these negotiations was a Consent Decree entered in the Indianapolis Federal District Court in December of 1988, that included 109 PRP's. A Trust Agreement was part of the Consent Decree establishing the Seymour Site Trust (the Trust) with Monsanto Agricultural Chemicals as Trustee.

Geraghty & Miller, Inc. (G&M) became involved during negotiations prior to the Consent Decree. Geraghty & Miller believed that it was important to begin plume capture quickly rather than waiting until negotiations were completed. An Agreed Order between the USEPA and the list of "Generator Defendants" (PRP's) was signed in January, 1987, prior to the conclusion of negotiations with the PRP's to allow the implementation of a Plume Stabilization Project by Geraghty & Miller to reduce the migration of ground-water contaminants. A Discharge Authorization was granted by the City of Seymour (a PRP) in October, 1988, to allow the discharge of pretreated ground water to their public owned treatment works (POTW). After approval of the Consent Decree, the Trust retained Geraghty & Miller as prime contractor to implement the RD/RA and fulfill the objectives of the Consent Decree, the ROD and the RAP.

PROJECT APPROACH

As the Agreed Order dealt only with interim capture and pretreatment of the ground-water plume, it was specific as to the approach to recover ground water, pretreat it, and discharge it to the City of Seymour POTW. This approach was based on a Workplan prepared in December, 1986, by Geraghty & Miller. This interim pretreatment was based on the estimated final pretreatment process so that the preliminary pretreatment plant actually became a pilot plant to test the expected long-term or final treatment method and equipment. A treatability study and test period were required to acclimate the POTW to the pretreated discharge water and ensure that no adverse effects would result from Site discharge.

The Consent Decree and the RAP were specific as to what Remedial Action was to be taken from an overall viewpoint but allowed for the study of various aspects of remediation prior to final selection of method and configuration. For instance, although some type of pump and treat system for ground water treatment was required, the final treatment method was to be determined based upon information obtained during the Treatability Study conducted under the Agreed Order. Final recovery well locations, configurations, and sizing were to be determined after completion of an aquifer step test, additional rounds of monitor well sampling and refinement of the ground-water model. These were some of the numerous aspects to address during the RD/RA implementation that had an impact on the design and implementation process.

Site remediation involved a number of different technologies: ground-water recovery and pretreatment (iron pretreatment, air stripping, filtration, liquid phase adsorption using granular activated carbon (GAC)), discharge to the City POTW, and expansion of the ground water recovery system. Coordination of over twenty employes from eight offices and four different groups internally plus coordination with laboratory personnel, several subcontractors, regulatory personnel, and regulatory consultants made this project and interesting experience. Extensive integration of various tasks performed by or under the direction Geraghty & Miller was required and is ongoing. These tasks are :

- Groundwater Investigation, Sampling, Monitoring
- Plume Stabilization
- Preliminary Pretreatment Plant
- 18 week Treatability Study
- Groundwater Modeling

- Risk Assessment - Water & Air Pathways
- Baseline Air Study
- Past Plant Risk Assessment
- Air Monitoring Programs
- VES Predesign study
- Demolition of On-site Buildings
- Asbestos Removal from Buildings
- Disposal of Hazardous Wastes Stored on Site
- Removal of Contaminated Sediments from Northwest Creek
- Bioremediation
- VES Installation
- Containment and Disposal of all Site Storm Water Run-off
- Cap Construction
- Final Pretreatment Plant Design & Construction
- Sewer Line
- Deep Aquifer Wells
- Long-term Cumulative Risk Assessment

Conventional control and monitoring of project activities plus extensive financial planning and control was and is part of the overall project.

Of significance is the fact that all the remediation work is risk-driven. The objective of the remediation is to reduce risk to a maximum cumulative excess lifetime cancer risk level of 1×10^{-5} at and beyond the site boundaries and of 1×10^{-6} at the site's Nearest Receptor over a 70 year lifetime exposure. Basically, water and air pathways must be considered.

DISCUSSION

The actual RD/RA work can be viewed in two significant, distinct parts, the Plume Stabilization Project and the Remedial Design/Remedial Action. These parts are discussed individually below. Of significance is the number of different tasks that had to be integrated to achieve the objective.

PLUME STABILIZATION PROJECT (AGREED ORDER)

In the first part, Geraghty & Miller, under the Agreed Order, prepared plans and specifications and provided construction management for a ground water pretreatment plant that was a pilot operation to study the proposed treatment methods. At this point in the site investigation, only an approximate value of the volume of ground water to be recovered and treated could be estimated, up to 300 gallons per minute. Consequently, the preliminary pretreatment plant was designed to operate in the range of 100 gpm but with the intent of being expanded up to 300 gpm. The original layout basically consisted of one treatment stream from an air stripper through multi-media filters to a GAC unit. The GAC unit was sized large enough hydraulically to accommodate up to 300 gpm easily and up to 600 gpm if required. Adequate floor space was made available to allow installation of a second air stripper and multi-media filter sized for up to approximately 200 gpm. This plant was completed in the third quarter of 1988 and start-up preparations begin for a late 1988, early 1989 test period.

An aquifer step test was performed and the plant was started up for an 18-week test and phased treatability study. The data obtained from the treatability study and test proved the basic concept of air stripping and GAC adsorption as a viable pretreatment method and indicated specific areas that required further refinement for a final plant configuration. After completion of the study, the plant continued in full operation, for the purpose of plume interception and stabilization, for over fifteen months until being shutdown for modifications. The additional data learned during this fifteen month period was used to further refine the design and long-term operation goals for the final plant.

The aquifer step test indicated that the original ground-water model, developed using data from slug tests performed during the RI, was inadequate. The ground-water model was replaced with a new model of substantially larger scope that was based on data obtained during the aquifer step test and preliminary pretreatment plant operation. This new model revealed that the plume of contaminated ground-water was moving approximately twice as fast as the RI had estimated. The overall impact of this new finding would later have significant impact on the project. If the plume had been moving faster than the original model indicated, then the possibility of a much larger plume existed that may require significantly larger extraction rates for capture and subsequent treatment. As overall treatment strategy and plant design may be impacted by this new development, the importance of obtaining current data for design work was apparent. Consequently, a new ground-water investigation was launched to determine the extent of the plume and to calibrate the model. This data would also be used to develop a solute transport model of the shallow aquifer.

However, RD/RA activity continued, with the understanding that revisions may be necessary in the work based on the new data.

The new study finally determined that the plume was over one mile to the northwest of the site. New pumping strategies were developed and treatment alternatives examined for the farthest area of the plume. It was determined that an additional recovery well pumping at 200 gallons per minute (gpm) would be required at the nose of the plume but the contamination was such that the discharge could go straight to the POTW without pretreatment. After confirmation with POTW officials and concurrence with the agencies on scope, new RD/RA activity for this part of the project was implemented that continues at this time.

REMEDIAL DESIGN / REMEDIAL ACTION

In the second part, the Trust engaged Geraghty & Miller as general or prime contractor to remediate the site. Some of the activities of this part were running in concurrence with the first part. Remedial design activities for the Consent Decree and RAP implementation begin in the second quarter of 1989. Specific objectives of the Trust in addition to satisfying the requirements of the Consent Decree, ROD, and RAP were:

- Solve environmental problems
- Accelerated schedule - early completion
- Avoid stipulated penalties
- Operate & construct without excess exposure of the public to hazardous materials
- No lost workday injuries
- Positive community relations
- Operate within budget

The Trust's strategy to achieve these objectives consisted of the following elements:

- Develop aggressive schedule
- Avoid interruption of engineering
- Develop large bid packages
- Utilize experienced contractors/personnel
- Shorten communication lines
- Team approach between PRP's, contractors, USEPA, IDEM, City of Seymour

- Cost sensitivity
- Community relations
- Flexibility

It was determined very early in the process that time was of the essence in the implementation of the RD/RA. Delays in remediation could potentially increase risk through exposure as contamination could spread. More extensive contamination would only increase costs and time required to complete remediation. In any large project, time to execute the work has a significant bearing on cost, particularly when field activities are underway. Due to the geographical location of the site, project timing and thus completion could also be severely affected by weather, particularly winter and rainy seasons. Another potential source of delay was a lack of current information. Much of the data gathered in the RI/FS phase was several years old when RD/RA activities begin in early 1989.

In order to expedite remediation and to reach the stated objectives in a timely manner, a fast-track approach was used. This approach places tasks and the decision making process in a parallel rather than strictly sequential mode. Multiple activities occur simultaneously with periodic updates and sharing of information to review current status. In short, rather than wait for all data to be collected and analyzed, process design decisions are made based on preliminary information. The design is revised as necessary. Rather than wait for the design to be completely finalized, construction begins with minor changes occurring as part of the construction process. Rather than wait on full regulatory approval, work proceeds with the realization that some changes will probably be required after regulatory agency review and approval.

In order for this fast-track approach to be successful, some specific techniques were adopted. From an overall viewpoint, flexibility and adaptability, the ability to respond quickly to changes, were key traits that were essential for success. First, the project RD/RA was broken into clearly distinct phases that were independent enough so that work could run simultaneously. Second, internal project communications were improved through the use of frequent meetings of all key personnel and routine weekly conference calls among all personnel, including regulatory agencies. The importance of good communication in this approach cannot be overemphasized. Third, informal technical reviews with agency personnel during the engineering process were held to discuss issues and the overall project direction. Fourth, work was allowed to proceed based upon verbal approval from agency personnel rather than waiting for formal, written authorization. It was accepted that this approach was at risk but it allowed engineering design to proceed without significant interruptions.

First Stage - Site Preremedial Investigation

The first stage begin with additional tests and studies being performed on the site in the areas of bioremediation and vapor extraction in preparation for the final remediation. Also, during this period, ground-water sampling continued on the site and a baseline air monitoring study workplan was prepared and submitted for approval.

A preliminary design for the soil vapor extraction system (VES) had been developed during the development of the RAP. The VES predesign study was conducted to quantify and qualify soil contamination and soil gases plus obtain data on the soil permeability over the site so that the design of the VES could be finalized. In the interim, preliminary design drawings were developed and submitted to the agencies for review and approval with the understanding that the design would be modified based on the results of the VES study. The preliminary drawings were used to obtain bid pricing and scheduling so that RD/RA work could go forward.

Second Stage - Initial Remedial Design/Remedial Action

In the second stage, Geraghty & Miller proceeded with design and construction of the RD/RA except for the final pretreatment plant design. By proceeding with the design work, and expecting that changes would be required, it was possible to substantially define the scope of work, prescreen and qualify potential subcontractors, develop a bid package covering the bulk of remedial construction activities, bid the work, award a contract to the selected bidder, and begin field work while final data was still being obtained and evaluated. For bid and design purposes, this stage of the work was broken down to six phases:

I. Site Civil Work

II. Decontamination Facility

III. Demolition

IV. Vapor Extraction System

V. Sediment Removal

VI. Cap Construction

In fact, the bid package was structured in anticipation of the changes by establishing unit prices for work expected to change. Using this approach, valid comparisons between bids could still be obtained thus keeping the bid process competitive and effective. Field mobilization could then occur so that remediation could begin sooner than under a sequential approach. To expedite work, it was decided to prepare an overall Site Health and Safety Plan for all activities and issue addenda for each phase of the work. Likewise, workplans for each phase were individually prepared and submitted for review and approval.

Although the final ground-water pretreatment plant design and construction was not part of this stage of the work, projections and estimations were made as to the configuration and size of the final plant. This information was then used to design the expansion of the existing pretreatment pilot plant building to house the decontamination facilities (increasing square footage from 2640 to 7590) and treatment equipment for use in treatment of site run-off water captured during construction. The treatment equipment for processing site run-off water was selected with the intent of reusing as much equipment as possible in the final design.

The work executed under this phase consisted of preparation of plans (health and safety, and work) and specifications for the expansion of the pretreatment pilot plant building for use in treatment of run-off water and for decontamination of equipment and personnel, demolition of ten buildings on site, nearly all of which contained asbestos, disposal of hazardous wastes stored on site, removal of contaminated sediments from a nearby creek, containment and disposal of all site storm water run-off, installation of the vapor extraction system, application of nutrients to enhance biodegradation, construction of a twelve acre RCRA type cap, and expansion of the ground water recovery system. By the way, this stage of heavy site activity was accomplished with no recordable accidents or injuries after over 300 days in the field.

The soil VES design was modified using the predesign study data and reviewed with the agencies for concurrence before actual construction begin. An interim review meeting was held at the site with all affected parties to discuss the study before the design drawings were revised. After acceptance of the design, the construction drawings were modified and the scope of work changed by contract change order. The unit pricing method of this item netted a cost reduction of over $200,000 because the number of laterals was reduced.

Third Stage - Final Pretreatment Plant Design and Construction

The third stage again used phasing of the work required for remediation. The phases of this work were:

VII. Final Ground-water Treatment Plant

VIII. Lift Station & Sewer Line Installation

IX. Well and Pipeline Installation

In this stage, Geraghty & Miller, using data gathered during the treatability study, finalized design of the final pretreatment plant, modified the existing plant and site run-off water treatment equipment and added new equipment required for the treatment of iron and increased capacity from 100 gpm to 400 gpm. A capacity of only 300 gpm (minimum) was required by the Consent Decree. The final plant capacity was set at the "best guess estimate" based on all known data at the point of design plus projections. This data, from the calibrated model, indicated that the existing two recovery wells would be operated at approximately 140 gpm but that up to an additional 200 gpm may require treatment in the plant if the deep aquifer was contaminated.

This final plant was constructed and placed on-line in the first quarter of 1991. The basic plant configuration consists of large aerator tanks and sodium hypochlorite injection for iron treatment, a continuous backwash sand filter for removal of iron precipitate and sludge, parallel air strippers (existing pilot unit plus a new 300 gpm unit for the expansion) for removal of volatile organics, and a series granular activated carbon (GAC) system with two each 20,000 pound GAC vessels for removal of non-volatile organics and to provide a safe backup for the air strippers. The plant is fully automated utilizing electronic control and instrumentation systems with remote monitoring by use of a computer and modem. A meteorological station installed during early studies was connected into the plant control system for data accumulation.

A new sewer lift station and over 2000 feet of 8" double containment force main is being installed to connect the plant to the municipal sewer system. That work is ongoing. Plans have been made for the installation of four deep aquifer monitor wells that can easily be converted to recovery wells if contamination is found. The pipelines for these recovery wells have also been designed so that installation could be quickly implemented. Capacities for these wells were estimated with a high accuracy based on the extensively developed model.

Plans for the new recovery well discussed as part of the Plume Stabilization Project were also prepared as part of this phase. A new 8000 foot 4" pipeline for that well is currently under design.

Fourth Stage - Long-Term Operation

The fourth stage of the RD/RA involves the shift from construction to operation. The emphasis is on long-term operation, sampling programs, monitoring system performance, and performing risk assessments. This work is phased as follows:

X. Vapor Extraction System Start-up, Operation and Maintenance

XI. Maintenance Plan for Cap and Site and Security Plan

XII. Vapor Extraction System Closure Plan

XIII. Ground Water Monitoring

XIV. Cumulative Risk Assessment

The majority of this work is ongoing or under development at this time. Work continues on these items while completed RD/RA items, such as the final ground-water pretreatment plant, are maintained in operation. Certain closure items, such as Operation and Maintenance Manuals, for the final plant are prepared during this stage. The long-term cumulative risk assessment is also being prepared as part of this stage.

CONCLUSIONS

The successful implementation of the RD/RA at the Seymour Site, using an aggressive, fast-track approach to project execution, has demonstrated the viability of such an approach to the remediation of Superfund sites. The keys to success of this approach are good communication and a cooperative team approach to the project. All parties to the project (regulatory, PRP's, consultants, and contractors) must be part of the team and be willing to operate in a cooperative manner with the common goal of achieving an effective remediation.

V. HEALTH AND SAFETY

EPA/Labor Health and Safety Task Force

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INTRODUCTION

In response to worker protection issues arising from activities at several NPL sites in 1989, Don Clay, Assistant Administrator of the Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency (EPA) established a special EPA/Labor Health and Safety Task Force. The initial goal of the Task Force was to improve adversary relationships that were developing between labor unions, the U.S. Army Corps of Engineers (USACE), and the EPA Regions. The long term goal of the Task Force is to provide a forum for the discussion of health and safety issues at Superfund sites.

The task force, focusing only on worker health and safety issues at hazardous waste sites, is composed of key EPA personnel from the Environmental Response Team and the Hazardous Site Control Division and personnel representing the three principal construction trade unions involved in hazardous waste clean-up. The International Association of Firefighters (IAFF) have recently been included in task force activities. The Occupational Safety and Health Administration (OSHA) and the USACE serve as technical advisors to the task force.

Members include:

1. Joe Cocalis (Co-chair, EPA), EPA Hazardous Site Control Division (HSCD), Design and Construction Management Branch (DCMB).

2. John Moran (Co-chair, Labor), Director Safety and Health, Laborers' National Health and Safety Fund (LNHSF).

2. David M. Traenor, Director of Research and Education, International Union of Operating Engineers (AFLCIO).

3. Donald Elisburg, Executive Director, Occupational Health Foundation. (note: The Occupational Health Foundation is a technical resource center that is sponsored by 25 Unions)

4. Les Murphy, Director, Hazardous Materials training for Emergency Response Personnel, IAFF.

5. Vernon McDougall, Teamsters.

6. Kenneth W. Ayers, Chief, EPA HSCD DCMB.

7. Rod Turpin, Chief, Safety and Air Surveillance Section, EPA Environmental Response Team (ERT).

Note: Technical advisors who have attended meetings include: Thomas Donaldson, Robert Stout, and Reuben Sawdaye (USACE); Maryann Garrahan, Elizabeth Grossman, and Charles Gordon (OSHA); Charles Reese (LNSHF) and Joe Vita (Teamsters); and Sella Burchette and William Zobel (EPA).

The Task Force, which meets bimonthly, has dedicated its recent efforts to reviewing site safety and health issues and all OSWER Superfund safety and health directives and guidelines. The goal of this review is to share with Labor organizations, actions that EPA is undertaking or anticipates to improve worker health and safety at Superfund sites. Specific issues the Task Force has addressed include site characterization (clean versus contaminated areas), training, response to health and safety inquiries, and communications between the various parties involved with Superfund activities.

DISCUSSION

1. Clean versus contaminated areas. One of the issues that the Task Force is investigating is how to designate areas within a Superfund site as "clean"; that is areas where the OSHA worker protection standard does not apply. Of particular concern is for the health and safety of untrained workers performing intrusive operations in designated "clean" areas who uncover unknown pockets of contamination. The Task Force is supporting the development of design guidelines and models which will assist the design engineer in estimating the occupational health risk from existing remedial investigation data. The issue also encompasses the redesignation of established areas.

   a. Design guidelines. Where clean areas are adjacent to exclusion zones, a site assessment should be the basis for the establishment of "clean" areas. Aerial photography, topographic analyses, and site historical data are useful analytical tools, but should be supplemented by sampling and not be the sole criteria used to make decisions.

   A good rule of thumb is to define clean areas as areas with less than three times background concentration. Where background concentrations are exceeded or unknown, a site characterization/risk assessment that is reviewed by a competent person, such as a certified industrial hygienist with site characterization experience, is recommended. (Reference 1, an Environmental Response Team draft fact sheet on establishment of work zones, contains additional information on clean zone designation).

   For intrusive operations in the vicinity of contaminated areas, it is often prudent to require workers to have the 40 hours of training so that they can recognize hazards and take appropriate corrective action.

   b. Modeling. Modeling can be a useful tool for predicting a protective level of occupational exposure from site data. A USACE - EPA team modified existing models to assist in a characterization/assessment of the Baird and

McGuire Superfund site in Holbrook Massachusetts. The models were part of an initial attempt to project borehole concentration to the potential for occupational exposure. The models, which were considered protective, still require refinement and field testing. HSCD, with the cooperative efforts of the Task Force, is pursuing contractor model development and validation.

c. Redesignation of established areas. EPA requires justification for redesignation of clean areas and major changes to this policy are not anticipated at this time. Situations will arise where additional information warrants an investigation into the validity of "clean" zone designations. The proper mechanism to investigate boundaries is through modifications to the Health and Safety Plan (HASP). Boundary modifications should be proposed in writing through the prime contractors' professional staff with review by the industrial hygienist. In situations where the health and safety of workers is in question, a conservative approach is necessary and an interim protective interpretation of boundary lines should be considered.

2. Response to Labor inquiries. The Task Force has strongly endorsed a policy of open communication, in which all health and safety inquiries receive a prompt and professional response. Issues the task force is investigating include: Labor participation in health and safety programs, OSHA inspections, imminent danger, and other unsafe or unhealthful working conditions.

a. Labor participation. The Task Force is encouraging labor participation in the health and safety programs at Superfund sites. A Labor representative should be given the opportunity to accompany the inspector during non-OSHA inspections and evaluations. Situations that exclude Labor participation create an atmosphere of distrust, promote the spread of rumors and are often counterproductive.

b. Health and Safety Enforcement. Inspections for enforcement purposes are the responsibility of OSHA. The remedial action construction manager is responsible for enforcing the terms of the contract for day-to-day worker protection. The construction manager's responsibility include the issuance of stop work orders in situations where violations of the health and safety provisions of a contract are violated.

c. Imminent danger. Whenever and as soon as one is made aware of a danger which could reasonably be expected to cause death or serious physical harm, that person has the responsibility to immediately notify the affected employees, and parties with the responsibility and authority to remove the danger. In situations where an imminent danger exists, both the prime contractor's site coordinator and the construction manager's on-site representative have the responsibility and authority to stop all activities or withdraw employees. If steps are not taken to remove the danger, OSHA should be immediately contacted.

d. Other than imminent danger. For Federal-lead remedial action projects, health and safety inquiries should be channeled through the construction manager, who has the responsibility to notify the prime contractor's site coordinator (or the responsible party) verbally and in writing of the unsafe or unhealthful condition. For other than Federal-lead projects, the prime contractor's site coordinator should be notified verbally and in writing of the unsafe or unhealthful condition.

3. Dissemination of Health and Safety Information. One of the objectives of the Task Force is to identify problem areas and to disseminate information/instruction to remedy the problem. Problem areas previous identified include: confusion about health and safety roles and responsibilities among the numerous parties involved with remedial activities, the establishment of work zones within a site, and compliance with various health and safety instructions and regulations. The establishment of work zones and compliance will be discussed in detail as part of the Environmental Response Team presentations. The roles and responsibilities fact sheet which was drafted by EPA's Hazardous Site Control Division in response to a Task Force request will be discussed in detail here.

a. Roles and Responsibilities Fact Sheet.

(1) Remedial Project Manager (RPM). As the EPA's prime contact or representative for a site, it is important for the RPM to be a strong safety and health advocate. The RPM has the responsibility to coordinate, direct, and review the work of EPA, responsible parties, other agencies, and contractors to assure compliance with the National Contingency Plan. As such, the RPM oversees compliance with health and safety programs. The RPM does not have a direct line of authority to the prime contractor. The RPM should be informed of situations where health and safety issues impact overall project cost, scheduling, technical quality, or public health/environmental protection. However, the RPM's primary responsibility is oversight, not action. Items requiring action should be referred to the appropriate individuals or agencies (i.e. the construction manager, prime contractor, the State, responsible party, or OSHA).

(2) Architect Engineer. The architect engineer (AE) is responsible for the development of specifications for the site health and safety plan and for the description of minimum requirements for health, safety, and emergency response during the remedial design. An estimate of increases hazards over background and the degree of existing hazard should be specified in the remedial design. During the design phase, it is the responsibility of the AE to establish boundaries where 29 CFR 1910.120 applies. The criteria used in such determination should include remedial investigation data and the Agency for Toxic Substances and Disease Registry (ATSDR) Health Assessment.

(3) Construction Manager. The construction manager, usually USACE, BUREC or an ARCS contractor under a contractual or interagency agreement with EPA, or the oversight official for responsible party remediation, oversees the remedial design and remedial action health and safety programs. During design, specification, review and acceptance of the health and safety plan (and program) is a construction manager/oversight official responsibility. During

remedial action, the construction manager/oversight official verifies compliance with the health and safety plan and with the health and safety provisions of site-specific contracts. The construction manager has the authority to suspend unsafe operations and to require modifications to health and safety plans. Results of inspections/oversight are reported to the RPM.

(4) Prime Contractor. Implementation of the Health and Safety Program is the responsibility of the prime contractor for both fund and enforcement lead projects. The prime contractor's HASP is mandated by OSHA and/or the construction contract as the legally enforceable plan on a Superfund site.

(5) Subcontractors. Although subcontractors are responsible for the health and safety of their own employees, they should structure their health and safety plans to smoothly interface with the prime contractors overall site HASP. The prime contractor will review and approve the subcontractor's HASP (note: the subcontractor's HASP will have the prime contractors HASP incorporated into it).

b. ERT Fact Sheets. ERT Fact sheets are discussed in other papers from this session. Areas discussed, in detail include OSHA-EPA relationships, worker training, the site HASP, and the EPA Health and Safety Program.

4. Emergency response. Most sites are too small to warrant fully staffed on-site medical and firefighting facilities. Where services can be provided by surrounding communities, EPA may provide limited training and support to assist the local community in providing OSHA response specific to hazardous waste, on a case-by-case basis. An issue the Task force is investigating is how to obtain agreements early in the remediation process. A fact sheet on this subject will be distributed later this year.

a. Service upgrades for OSHA compliance. To compensate for OSHA requirements specific to hazardous waste training and support, EPA may provide limited training and support to upgrade local service capabilities on a case-by-case basis. The amount of training and support that local firefighting and/or emergency response personnel will require for OSHA compliance (section q of the worker protection standard, if off-site responders) depends on site-specific conditions (i.e. off-site training duration can vary between 24 and 40 hours). Examples of the types of support that may be provided by EPA to local responders on a case-by-case basis include on and off-site training, no-cost personal protective equipment and specialized haz-mat equipment loans, and medical surveillance.

b. Agreements. As a minimum the emergency response plan should be a separate section of the site HASP. Agreements, which must be made prior to site entry are between the party responsible for the HASP and the party providing the response services (i.e. the AE firm for design operations involving site entry and the prime contractor for remedial action). Because failure to secure agreements can result in remedial project delays or work stoppage, it is important for EPA to solicit early involvement of community relations staff and to address emergency response through pre-design work plans, etc. This will entail an evaluation of local fire departments, hospitals, police departments, etc. to provide coordinated services to the RD and RA. Selection of the provider should be based on an evaluation of current capabilities, required support levels, response time, jurisdictional authority, and cost to the Government. This information is often available from information gathered as part of predesign activities.

c. Training. The site industrial hygienist (or equivalent position) should make a copy of the site HASP (to include the emergency response plan) available and provide on-site training for local firefighting and emergency response personnel subject to respond to calls at Superfund sites.

CONCLUSIONS

Because of the complex relationships between the many parties involved in Superfund remedial design and remedial action, health and safety roles and responsibilities are often misdirected, resulting in ineffective or unresponsive programs. The Health and Safety Task Force is an effective forum for resolution of issues and communications between the parties involved with remedial design and remedial action.

DISCLAIMER

This report has undergone a relatively broad initial, but not formal, USEPA peer review. Therefore it does not necessarily reflect the views or policies of the Agency. It does not constitute any rulemaking, policy or guidance by the Agency, and cannot be relied upon to create a substantive or procedural right enforceable by any party. Neither the United States Government nor any of its employees, contractors, subcontractors or their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use or or the results of such use of any information or procedure disclosed in this report, or represents that its use by such third party would not infringe on privately owned rights.

We encourage your comments on the utility of this paper and how it might be improved to better serve the Superfund program's needs. Comments may be forwarded to the attention of Joseph Cocalis, Design and Construction Management Branch, USEPA, Mailcode OS-220W, Washington DC 20460. Mr. Cocalis will relay any comments to the attention of the Task Force, where they will be considered and addressed.

REFERENCES

1. Establishing Work Zones at Uncontrolled Hazardous Waste Sites (in Draft # 9285.2-06fs).

2. Hazardous Waste Operations and Emergency Response: RCRA TSD and Emergency Response Without Regard to Location (#9285.2-07fs).

3. Hazardous Waste Operations and Emergency Response: Uncontrolled Hazardous Waste Sites and RCRA Corrective Action (in Draft #9285.2-08fs).

4. Hazardous Waste Operations and Emergency Response: General Information and Comparison (in Draft, #9285.2-09fs).

5. Hazardous Waste Operations and Emergency Response: Available Guidance (#9285.2-10fs).

Airborne Exposure Control at an Acid Sludge Remedial Site

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1.0 INTRODUCTION

Use of a real time air monitoring program including, mobile work area monitoring, and perimeter monitoring with a centralized alarm function, as a tool to aid in suppression of site emissions is a relatively recent approach to emission control during site remediation. Experience at this site has provided useful information that can be applied to subsequent similar remedial projects. Please note that the opinions in this publication are those of the authors and do not represent any official position of the U.S. Government.

The site consisted of a lagoon which was used for disposal of sulfonated mineral oil production wastes, motor oil reclamation wastes, coal fines, and other sludge residues from approximately 1935 to approximately 1975. In the late 1970s, part of the lagoon wall failed, allowing sludge to enter a nearby creek. This initiated a series of responses culminating in neutralization and stabilization of the site during 1989 and 1990.

During early stages of this effort in 1983, remedial operations were initiated and consequently terminated due to significant release of acidic aerosols and/or vapors into the surrounding environment. In July, 1989, remedial operations were re-initiated and involved primarily excavating the sludge down to bedrock, mixing the sludge with lime (stabilization) to increase the pH, and backfilling to the desired grade.

IT Corporation (IT), serving as an independent consultant to the U.S. Army Corps of Engineers (COE), Omaha District, performed air monitoring consisting of real time air monitoring at the work face, time-weighted average (TWA) sampling at the work face, and datalogging for six existing air monitoring instruments at three perimeter locations. IT also provided related health and safety consulting services. This effort was initiated by the US Environmental Protection Agency (Region III) remedial project manager in order to apply a different technical approach in an attempt to obtain additional information.

This publication specifically addresses the use of real time air monitoring and datalogging instrumentation at this hazardous waste remedial site. Key topics are the airborne concentrations of hazardous chemicals in the active work area, the use of the perimeter monitoring and logging system to track and control airborne exposures at the site periphery.

2.0 BACKGROUND

IT Corporation was contracted during the second year of the remedial action to provide assessments (independent of the remedial contractor) of airborne contaminant concentrations and related on site health and safety practices. IT personnel conducted real time air monitoring for hydrogen chloride (HCl), sulfur dioxide (SO2), and organic vapors at the work face and installed a datalogging system to record and store input from six existing perimeter instruments monitoring hydrogen chloride and sulfur dioxide.

Real Time Air Monitoring

The real time air monitoring for SO2, HCl, organic vapors and a variety of other contaminants was conducted using direct reading instrumentation at four primary locations: near three perimeter monitoring stations and at the downwind edge of the work area. The downwind edge of the work area was assumed to be representative of the worst-case exposure hazard. Monitoring was performed from an all terrain vehicle to enhance mobility and to transport the equipment required for the simultaneous measurement of the three primary analytes. Results were documented on field activities forms and real time air monitoring logs.

The air monitoring for SO2 was conducted using a battery-powered Gastech GX-82 confined space unit, equipped with a sulfur dioxide electrochemical cell. A supplemental SO2 instrument, U.S. Industrial Products, Model SO-261, was used for approximately one month. HCl concentrations were monitored using a battery-powered Sensidyne SS2000 portable toxic monitor equipped with a HCl electrochemical cell and a SO2 scrubber to eliminate interferences due to cross-sensitivity to the two contaminants. Organic vapor concentrations were monitored using a battery-powered Century Systems portable Organic Vapor Analyzer (OVA), model OVA-128. The direct reading instruments were calibrated daily using the manufacturer's recommended procedures. Drager detector tubes were used, when possible, to confirm elevated measurements obtained from direct reading instruments or to investigate other potential contaminants not detectable by the instruments.

Perimeter Air Monitoring

A data acquisition system (logger) was installed to record measurements from existing HCl and SO2 instruments located at the three perimeter air monitoring stations. The system consisted of an 8 channel analog connection board and a Toshiba portable computer, model 3200. The data logger recorded instantaneous readings at 20 second intervals, daily average readings and daily minimum and maximum readings. The system also provided high and low level alarms and constant display of readings. These data were stored on the portable computer hard disc and backed up on 3.5 inch discs.

Data logger channels 1 and 2 recorded measurements for HCl and SO2 instruments, respectively, from air monitoring station 1 located on the northwest perimeter of the exclusion zone; channels 3 and 4 recorded measurements for HCL and SO2 instruments, respectively, from station 2 located on the northern perimeter of the exclusion zone; and channels 5 and 6 recorded measurements for HCL and SO2 instruments, respectively, from station 3 located on the southeast perimeter of the exclusion zone.

3.0 DISCUSSION

Work Face Air Monitoring Results

In general, HCl was not detected. Readings of 2 to 7 ppm were recorded on 2 days. During these measurements the SO2 monitor detected elevated concentrations of SO2. Because the HCl sensor is cross sensitive to SO2, any leak in the scrubber attachment would cause the instrument to read positive in an atmosphere containing SO_2. This was confirmed by using the instrument without the scrubber for one day. During this day, the sensor repeatedly read in excess of 10 ppm. The detector tube tests for HCl were negative, except for one at 0.5 ppm. In summary, these data indicate that HCl, if present, existed at very low concentrations.

Sulfur dioxide was detected regularly throughout the project. Peaks in excess of 100 ppm, the National Institute for Occupational Safety and Health's immediately dangerous to life or health value, were detected in the work area. In addition, airborne concentrations of SO_2 in the work area often appeared to average in excess of the Occupational Safety and Health Administration (OSHA) permissible exposure limit of 2 ppm. Please note that accurately determining a work place average was difficult due to accessibility challenges. Drager tube tests for SO_2 were generally positive, although not in exact agreement with instrument readings.

Elevated SO_2 readings were strongly associated with the disturbance of black sludge material, in excavations and in the mixing pits. Elevated readings occurred throughout the project. However, readings decreased as the sludge excavation and stabilization was completed, and at the project's end, SO_2 was consistently not detectable.

Table 1 presents a summary of SO_2 readings. The "site activity" column addresses remedial activities being performed on-site. The information presented on remedial activities is minimal. If these activities cannot be clearly determined from daily logs, the entry of Unknown appears. The maximum peak reading for each day is also presented. The final column provides a qualitative estimate of exposure. Entries are, Light (average of recorded readings is less than 5 ppm), Moderate (average of recorded readings is 5 ppm to 10 ppm), and Heavy (average of recorded readings is greater than 10 ppm). The assessments in this column are subjective in that they are influenced by a number of factors, such as the time spent on-site, the distance from the source, etc. This column is included only to provide a rough estimate of conditions and is not a quantitative measurement.

In general, organic vapor readings were equal to offsite background during the entire project. Occasional readings of 5 to 10 ppm were obtained. However, these readings were generated from vehicle exhaust, rather than site contaminants. The source was confirmed by conducting repeated tests which tracked readings to vehicle exhaust.

Perimeter Results

The perimeter air monitoring results are summarized in Table 2 and illustrated using sample graphs in Attachment 1. These graphs represent days during which perimeter sensors measured relatively heavy offgassing. Because both HCl and SO_2 perimeter sensors were calibrated to SO_2 and no HCl was detected in the work area, these data are presented as SO_2 concentrations. The data log graphs display readings which represent SO_2 concentrations and time. All daily averages were less than 2 ppm. Maximum (peak) readings ranged from the same as averages to a high of 14 ppm. Any logger measurement greater than 10 ppm is, however, suspect, as the scale of the perimeter monitors was 1-10 ppm. There is no verification that the voltage at the remote connection is linear when the instrument meter exceeds full scale.

The results indicated daily maximum SO_2 concentrations increased for most work shifts during mid-September through October. The frequency of occurrence of peak SO_2 readings also increased during this time period.

A number of factors may have influenced perimeter monitoring instruments and the data logger, such as cross sensitivity of the sensors to the two contaminants, calibration of instruments and weather conditions (temperature, humidity, etc.). The effects of these factors are discussed below:

(1) Perimeter monitoring instruments occasionally failed during active work shifts. When this occurred, no electrical signal would be generated in the corresponding sensor wiring until the sensor was replaced or repaired. In some cases, a failed sensor would be replaced or serviced within minutes. In other cases, the failed instrument might remain on-line due to lack of an immediately available replacement sensor. For the most part, failed sensors were replaced within 30 minutes following failure.

During normal functioning, the perimeter monitors generated 1-5 volts at the remote sensing jack. This voltage corresponded to instrument readings of 0-10 ppm. When an instrument failed or was disconnected, no voltage existed in the sensor leads. The datalogger was set so that zero voltage was interpreted as a negative reading. This setting allowed the low end alarm to trip so that a failed instrument would not go unnoticed. The negative scale limit was approximately minus (-) 2.5 ppm. Thus, during any period in which the sensor was disconnected, the logger recorded a reading of approximately -2.5 ppm. This reading would be included in the daily average, thereby erroneously decreasing it.

(2) It is normal for perimeter sensors of the type used in this project to exhibit drift or change in readings over a period of time. This drift is related to the sensor type and conditions of use. Standard quality control practices generally require calibration adjustments at intervals of appropriate duration to provide the desired accuracy.

The remedial contractor reported that perimeter sensors were calibrated at weekly intervals. Occasionally the calibration of the perimeter sensors was checked, by IT and/or the remedial contractor, with the perimeter sensors at their field locations. This procedure tested the accuracy of the entire remote sensing system. In this procedure, the instruments were exposed to a test gas of 5 ppm while in place at the perimeter stations and connected to the remote sensing system. Ideally, the instrument meters, the datalogger and the strip chart recorders should all have read 5 ppm.

The majority of "field" checks resulted in instrument and logger readings of 4 to 6 ppm, an error range of plus or minus 10 percent of the instrument scale. However, some "field" checks resulted in instrument and logger readings as low as 0 ppm and as high as 10 ppm. These data indicate that a shorter calibration frequency would be more appropriate.

(3) Perimeter sensors often exhibited daily zero drift that appeared to be temperature dependent. This drift took the form of a gradual decrease in the baseline reading, during the morning, with minimum readings occurring in the early afternoon. The baseline readings began a gradual increase from 1500 to 1700 hours and would typically return to approximately the original reading by the end of the day. The typical drift was approximately 0.5 ppm. This drift could not be observed during days in which significant off-gassing was detected, since the peaks masked any drift.

(4) Transmission from nearby (1-3 feet) hand held radios was observed to cause false readings on the datalogger. Hand held radios were frequently used near the datalogger to communicate with field crews during off-gassing and subsequent suppression activities. The magnitude and direction of radio-induced deflection varied with the type and individual radio units. Radios at 456.800 MHz caused a negative deflection of 0.3 ppm, radios at 136.4125 MHz with a private line tone (sub-audible) of 4 Z (136.5 Hz) caused a positive deflection of 0.18 ppm.

Each transmission lasted approximately 5-20 seconds. The number of individual transmissions during an off-gassing event was varied and is estimated to have been 5-20 transmissions over a 5 minute time period. Due to the magnitude of the deflections in logger readings, the effect of radio transmissions was probably minimal.

4.0 CONCLUSIONS

Use of a real time air monitoring program including, mobile work area monitoring, and perimeter monitoring with a centralized alarm function, as a tool to aid in suppression of site emissions is a relatively recent approach to emission control during site remediation. Experience at this site has provided useful information that can be applied to subsequent similar remedial projects.

4.1 Supplied air (Level B) personal protective equipment for on-site workers was appropriate in light of the work area SO2 readings.

4.2 Real time monitoring at the work face can be used as a first indicator of unacceptable off-gassing if it is possible for the operator to maintain an appropriate location relative to the emission source. Specific recommendations for this activity include:

- Radio communication with the control center,
- An all terrain vehicle,
- Outer instrument cases which can be kept closed during instrument operation,
- Instruments with adjustable, audible and visual alarms, and
- Rugged instruments which will operate accurately under adverse conditions.

4.3 Real time perimeter monitoring with an alarm system can be an effective tool in the control of airborne emissions that pose a potential risk to off-site receptors. Appropriate installation offers the following:

- Instant, unattended alarm function when preset concentrations are exceeded,
- Instant, high resolution measurement of elevated readings,
- Instant alarm notification of major sensor failure or disconnection,
- Instant notification of the effect of emission suppression activities, and
- Verification of on-site sensor calibration.

Please note that this type of air monitoring application is limited to contaminants that can be measured on a real time basis. Unfortunately, there are numerous contaminants that cannot be measured using this method.

4.4 Of the monitored airborne chemicals, SO2 was the only agent detected in the work area at a concentration approaching or exceeding the PEL or TLV.

4.5 A number of recommendations can be made for future similar projects based on lessons learned at this project. The perimeter air monitoring program should include the following:

- A computerized, centralized system with continuous display and adjustable high and low alarms for each channel,
- High alarms set at suppression concentrations, low alarms at readings that will indicate sensor disconnection or failure,
- Perimeter sensors calibrated in place (at the point of use) on a daily basis or on a cycle proven to minimize inter-calibration drift, and
- Monitoring stations sheltered from direct sunlight and environmental extremes where possible.

5.0 ACKNOWLEDGEMENTS

The authors would like to thank the following U.S. Corps of Engineers personnel:

Larry Janis
Sandra Cotter
Gregory McCleaf
Nancy Flaherty
James Thornton

The authors would also like to thank Melissa Smith for her invaluable technical support and James Bolden, Mark Brown, Phillip Mitchell and Lawrence Webster for the field work which made this publication possible.

Table 1: Real Time Monitoring for Sulfur Dioxide At The Work Face

Date	Site Activity	Maximum Peak	Average
7/26	Stabilization & bedrock neutr.	4 ppm	Light[1]
27	Unknown	17 ppm	Moderate[2]
30	IT worked on datalogger system	No monitoring	-
31	IT worked on datalogger system	No monitoring	-
8/1	IT worked on datalogger system	No monitoring	-
2	IT worked on perimeter system	No monitoring	-
3	IT worked on perimeter system & health and safety issues	No monitoring	-
6	Stabilization	>100 ppm	Heavy[3]
7	Stabilization	>100 ppm	Heavy
8	Stabilization	>100 ppm	Moderate
9	Stabilization	38 ppm	Moderate
10	Moving stabilized material	0 ppm	Light
13	Moving stabilized material	No monitoring	-
14	Stabilization	0 ppm	Light
15	Stabilization	8 ppm	Light
16	Stabilization	18 ppm	Light
17	No stabilization	1 ppm	Light
20	No stabilization	0 ppm	Light
21	No stabilization	0 ppm	Light
22	IT worked on datalogger system	No monitoring	-
23	No stabilization	0 ppm	Light
24	No stabilization	0 ppm	Light
27	Stabilization	0 ppm	Light
28	Unknown	14 ppm	Light
29	No stabilization	0 ppm	Light
30	Unknown	>100 ppm	Heavy
31	IT participated in meetings	No monitoring	-
9/1	Unknown	0 ppm	Light
4	Unknown	0 ppm	Light
5	Unknown	0 ppm	Light
6	Stabilization & spreading	39 ppm	Moderate
7	Maintenance	No monitoring	-
10	Stabilization	30 ppm	Light
11	Stabilization	10 ppm	Light
12	Stabilization	>100 ppm	Heavy
13	Stabilization	30 ppm	Light
14	Unknown	1 ppm	Light
15	Unknown	Eqpt. failure	-
17	No stabilization	No monitoring	-
18	Stabilization	10 ppm	Light
19	Unknown	11 ppm	Light
20	No stabilization	2 ppm	Light
21	Stabilization	24 ppm	Light
22	Stabilization	43 ppm	Heavy
24	Stabilization	>100 ppm	Moderate
25	Unknown	38 ppm	Moderate
26	Unknown	1 ppm	Light
27	Unknown	>100 ppm	Heavy

28	Unknown	1 ppm	Light
29	No intrusive work	2 ppm	Light
10/1	IT instrument failure	No monitoring	-
2	Unknown	10 ppm	Light
3	Stabilization	18 ppm	Light
4	No stabilization	No monitoring	-
5	Stabilization	25 ppm	Moderate
6	Unknown	>200 ppm	Heavy
7	Unknown, IT in meetings	No monitoring	-
8	Unknown, IT in meetings	8 ppm	Light
9	Stabilization	>200 ppm	Heavy
10	Stabilization	45 ppm	Heavy
11	No stabilization, ATV broken	No monitoring	-
12	No stabilization, ATV broken	No monitoring	-
15	Stabilization	105 ppm	Heavy
16	Breaking sludge	70 ppm	Heavy
17	Stabilization	45 ppm	Moderate
18	Intrusive work stopped 1030	No monitoring	-
19	Stabilization	30 ppm	Heavy
20	Stabilization	57 ppm	Moderate
21	Stabilization	64 ppm	Moderate
22	Stabilization	34 ppm	Light
23	Unknown	3 ppm	Light
24	Unknown	37 ppm	Light
25	Stabilization	5 ppm	Light
26	Unknown	0.5 ppm	Light
29	Unknown	12 ppm	Moderate
30	Stabilization	4 ppm	Light
31	Moving stabilized material	0 ppm	Light
11/1	Moving stabilized material	0 ppm	Light
2	Moving stabilized material	0 ppm	Light
3	Moving stabilized material	3 ppm	Light

[1] Light = average of recorded readings is less than 5 ppm
[2] Moderate = average of recorded readings is 5 ppm to 10 ppm
[3] Heavy = average of recorded readings is greater than 10 ppm

Table 2: Perimeter Air Monitoring Results in Parts Per Million

Date		Station One HCl	Station One SO2	Station Two HCl	Station Two SO2	Station Three HCl	Station Three SO2
07-31-90	Avg	0.218666	0.475263	-0.02653	0.612320	1.208898	1.061149
	Max	0.228545	0.617653	0.007459	0.632181	4.14935	13.4155
08-01-90	Avg	0.451147	0.428022	0.181675	0.007628	0.911855	1.084212
	Max	23.2559	6.79416	4.84107	10.3078	5.26882	11.1299
08-02-90	Avg	-0.11792	-0.21958	-0.21878	-0.37336	-0.12829	-0.34056
	Max	0.028976	0.001274	0.020885	0.019380	5.15901	7.43604
08-03-90	Avg	0.443268	0.337027	0.168542	0.181443	0.052394	0.194220
	Max	0.639779	0.695016	10.4676	5.27453	0.26115	0.709795
08-06-90	Avg	0.484450	0.418807	-2.11133	0.241870	0.126346	0.377092
	Max	0.64539	0.808455	0.574055	0.759921	1.067	2.35527
08-07-90	Avg	0.544382	0.475654	1.292675	0.293881	0.248152	0.638332
	Max	1.05736	1.17624	1.46763	0.376954	8.22274	9.42208
08-08-90	Avg	0.533688	0.445015	0.464795	0.242475	0.125985	0.390085
	Max	5.61039	5.64917	5.39973	4.01638	5.66539	7.34186
08-10-90	Avg	0.538808	0.436993	0.312858	0.151392	-0.16118	0.434448
	Max	0.635496	0.55897	0.625608	0.327764	0.116236	0.873183
08-13-90	Avg	0.540385	0.507235	0.423118	0.220187	-0.03552	0.565080
	Max	0.566658	0.542068	0.499985	0.260167	0.003776	0.655714
08-14-90	Avg	0.548493	-0.27696	0.525347	0.426712	-0.00555	0.606832
	Max	0.573434	0.493171	0.546927	0.451359	0.454662	1.68909
08-15-90	Avg	0.453457	0.207691	0.458411	0.385293	0.593955	0.454818
	Max	4.94167	5.41362	3.88458	2.33972	3.78823	4.26275
08-16-90	Avg	0.467520	0.451739	0.373333	0.341133	0.572897	0.344434
	Max	0.576578	0.998285	0.629004	0.530362	0.762311	0.748656
08-17-90	Avg	0.498662	0.450805	0.284010	-0.20471	0.570381	0.370274
	Max	0.58538	0.561429	0.524528	0.468853	0.66691	0.680923
08-20-90	Avg	0.568870	0.560707	0.630285	0.505975	0.653720	0.670684
	Max	0.581381	0.573418	0.694142	0.560074	0.6629	0.722861
08-21-90	Avg	0.491828	0.550301	0.675476	0.610965	0.594187	0.699200
	Max	0.558821	0.576066	0.691499	0.626207	0.600454	0.741739

Table 2: Perimeter Air Monitoring Results in Parts Per Million (Continued)

Date		Station One		Station Two		Station Three	
		HCl	SO2	HCl	SO2	HCl	SO2
08-23-90	Avg	0.167908	0.715023	0.694002	0.613176	0.587820	0.663353
	Max	0.433813	0.734829	0.702448	0.633248	0.602651	0.684825
08-24-90	Avg	0.369186	0.487178	0.649511	0.359173	0.560531	0.546370
	Max	0.436606	0.526338	0.689921	0.637136	0.584771	0.625827
08-27-90	Avg	0.361122	0.429385	0.378752	0.180582	0.538100	0.496318
	Max	0.462934	0.547596	0.675072	0.865464	0.939162	1.59305
08-28-90	Avg	-0.07811	0.229015	0.678973	-0.22509	0.093500	0.601037
	Max	0.708685	1.24318	11.3162	11.2104	1.66008	1.55757
08-29-90	Avg	0.582038	0.374222	0.591518	0.335953	0.569180	0.561076
	Max	5.83666	5.17254	5.82542	4.77801	1.03548	1.6067
08-30-90	Avg	0.503138	0.341401	0.583764	0.327647	0.909965	0.894283
	Max	0.814141	0.817908	0.856212	0.582444	11.0752	11.0788
08-31-90	Avg	0.533452	0.266057	0.270274	0.188341	0.407468	0.513857
	Max	0.571578	0.324318	0.562824	0.255483	0.537233	1.17897
09-01-90	Avg	0.377099	0.327884	0.272388	0.252883	0.458980	0.548537
	Max	0.492256	0.477168	0.572793	0.523614	0.546564	0.794785
09-04-90	Avg	0.613669	0.565861	0.724469	0.664847	0.486005	0.706176
	Max	1.25812	0.965062	8.91864	11.7645	1.2595	1.67074
09-05-90	Avg	0.626169	0.609145	0.433282	0.238900	0.562125	0.742994
	Max	0.630534	0.612388	0.477095	0.239699	0.593961	0.765523
09-06-90	Avg	0.599665	0.536501	0.311532	0.165086	0.946363	0.905739
	Max	1.21665	1.27323	4.29643	3.44505	1.98293	1.6339
09-10-90	Avg	0.496377	0.581192	0.616805	0.429819	0.153495	0.157642
	Max	0.689274	0.671465	1.18834	1.25237	0.543277	0.297858
09-11-90	Avg	0.596304	0.570512	0.242190	0.270041	0.366015	0.318243
	Max	1.01667	1.0408	2.2842	7.21022	2.96037	2.4897
09-12-90	Avg	0.629796	0.593574	0.387854	0.248828	0.441124	0.299024
	Max	1.63974	2.20533	2.98588	1.31325	3.20235	2.14476
09-13-90	Avg	0.211830	0.587735	0.622905	0.315686	0.447746	0.056875
	Max	1.63061	2.69881	7.14937	4.93893	4.92422	4.98306

Table 2: Perimeter Air Monitoring Results in Parts Per Million (Continued)

Date		Station One		Station Two		Station Three	
		HCl	SO2	HCl	SO2	HCl	SO2
09-14-90	Avg	0.632037	0.601776	1.011046	0.565748	0.465359	0.410863
	Max	1.3665	0.665422	10.2855	10.3379	0.758623	0.474119
09-15-90	Avg	0.678694	0.660285	0.475876	0.238004	1.134496	1.166132
	Max	0.689358	0.679499	0.517087	0.254694	2.79069	2.97085
09-17-90	Avg	0.658989	0.691291	0.457825	0.876272	0.457238	0.444048
	Max	4.17587	3.92223	3.02186	5.31377	3.71701	1.16935
09-18-90	Avg	0.567901	0.564394	0.620693	0.310657	0.612096	0.701284
	Max	0.979477	0.768038	2.50606	1.06799	8.59351	8.03739
09-19-90	Avg	0.445739	0.592316	0.851918	0.501377	0.801310	0.917769
	Max	0.679667	0.889377	8.01287	9.12265	11.1004	10.8246
09-20-90	Avg	0.319884	0.529228	0.637655	0.381250	0.540646	0.698602
	Max	0.625353	0.577498	0.670237	0.421774	0.599124	0.806667
09-21-90	Avg	0.502197	0.523810	0.643043	0.428452	0.692534	0.715351
	Max	0.592521	0.627136	1.98722	1.00473	4.23503	4.67376
09-22-90	Avg	0.392080	0.529538	0.643417	0.376264	1.225300	1.289720
	Max	0.970332	1.20346	1.78366	1.62171	10.0934	11.642
09-27-90	Avg	0.322738	0.305549	0.613436	0.599032	0.540003	0.571834
	Max	8.22386	6.63425	10.9986	12.6445	4.74135	4.61632
09-28-90	Avg	0.160800	0.227759	0.636793	0.439748	0.748594	0.783730
	Max	0.466969	0.570098	10.7084	11.5001	8.792481	10.8006
09-29-90	Avg	0.509437	0.725175	0.571423	0.490644	0.438842	0.711938
	Max	0.934412	0.835951	0.701654	0.693644	0.669437	1.08464
10-01-90	Avg	-0.03679	0.764152	1.338748	1.231777	0.455651	0.791022
	Max	0.086942	0.926013	11.5491	11.6919	8.96364	10.5988
10-02-90	Avg	0.451966	0.779963	0.450112	0.112906	0.662610	0.896587
	Max	0.82033	0.834333	1.98199	0.852321	4.10752	4.3711
10-03-90	Avg	0.329090	0.720115	1.272049	1.202671	0.015805	0.055366
	Max	1.23255	0.878661	10.9073	11.3207	2.37276	1.96524
10-04-90	Avg	0.433147	0.684140	0.844350	-1.02877	0.556522	0.644311
	Max	0.538248	0.765003	11.2116	3.67831	0.679064	0.901597

Table 2: Perimeter Air Monitoring Results in Parts Per Million (Continued)

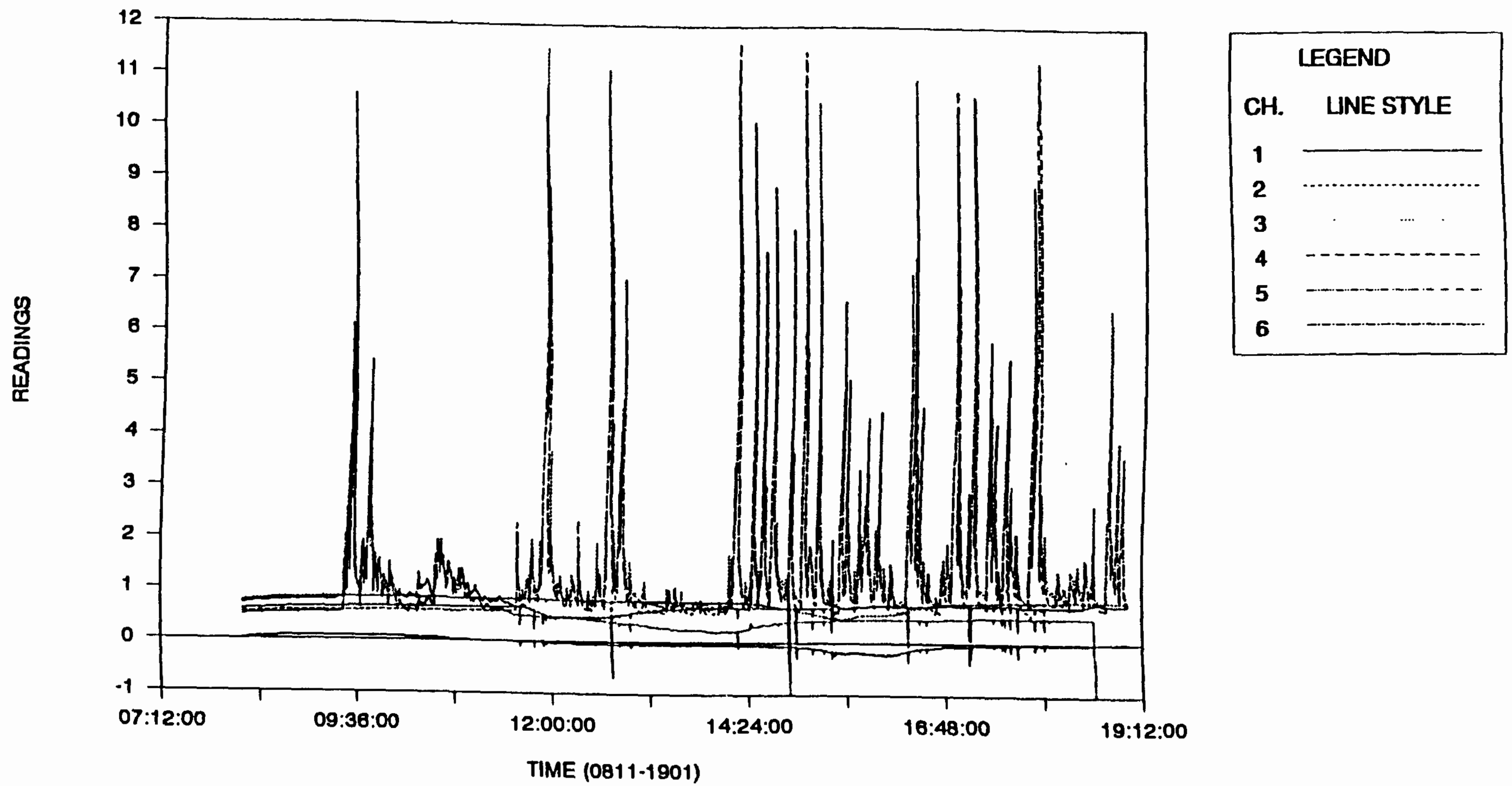
Date		Station One		Station Two		Station Three	
		HCl	SO2	HCl	SO2	HCl	SO2
10-05-90	Avg	0.337549	0.592207	0.533152	0.273072	0.482702	0.547457
	Max	2.58424	2.43555	5.95856	3.33339	1.93792	2.05161
10-06-90	Avg	0.144389	0.552109	0.854951	0.539427	0.461862	0.536748
	Max	6.04446	9.89101	11.4171	12.23	0.598889	0.710884
10-07-90	Avg	0.203678	0.667160	0.307422	0.848566	0.469162	0.447423
	Max	4.24588	0.76933	0.459641	0.9053	0.56014	0.639269
10-08-90	Avg	0.216242	0.548916	0.584957	0.417435	0.246155	0.662276
	Max	4.95017	6.19211	6.3775	5.19925	5.35341	7.59283
10-09-90	Avg	0.369269	0.389111	0.651374	0.824325	0.163596	0.193971
	Max	0.490225	0.708028	10.7252	11.044	0.241926	0.325377
10-10-90	Avg	0.409392	0.638191	1.263770	0.820481	0.291845	0.304925
	Max	0.603731	0.813129	10.6528	10.1462	0.510044	0.811593
10-11-90	Avg	0.642055	0.735746	0.525351	-1.29730	0.983460	1.143544
	Max	0.692225	0.849916	1.19827	1.17865	4.98269	6.3925
10-12-90	Avg	0.574869	0.709460	0.297965	1.177523	0.648506	0.875071
	Max	0.597795	0.718229	0.317629	1.18569	1.54515	1.81553
10-15-90	Avg	0.356748	0.724645	0.271591	0.630567	1.315751	0.868958
	Max	0.571927	0.844392	1.36599	1.35353	4.16883	7.18853
10-16-90	Avg	0.493103	0.766151	0.563084	0.615993	0.786316	0.581671
	Max	1.0705	1.77038	5.3952	2.23998	3.23031	3.77464
10-17-90	Avg	0.441467	0.647236	1.178451	0.359008	0.286432	0.511471
	Max	5.0764	4.94936	13.0279	11.3586	6.79763	6.97684
10-18-90	Avg	0.509233	0.711977	0.935273	0.515698	0.084801	0.208100
	Max	0.613982	1.03719	13.6996	1.52486	0.196473	0.370799
10-19-90	Avg	0.590917	0.782786	-0.30333	0.654874	0.288101	0.488409
	Max	0.772166	1.03627	0.619428	0.870908	2.29855	6.61175
10-20-90	Avg	0.485579	0.522958	1.318833	1.701023	0.387232	0.745319
	Max	1.15056	0.792444	10.8837	12.0178	1.66324	3.3339
10-21-90	Avg	0.069186	0.847718	0.458957	0.962250	0.566888	0.394888
	Max	8.18505	5.9021	12.5905	13.8455	8.07674	3.03305

Table 2: Perimeter Air Monitoring Results in Parts Per Million (Continued)

Date		Station One HCl	Station One SO2	Station Two HCl	Station Two SO2	Station Three HCl	Station Three SO2
10-22-90	Avg	0.396159	0.717306	1.041768	0.361557	0.445705	0.554291
	Max	4.45959	6.21439	11.0256	11.0157	4.8817	4.9769
10-23-90	Avg	0.525435	0.760732	0.437081	-0.68047	1.038122	1.391161
	Max	0.632874	0.969035	0.663212	0.33695	11.8846	13.4662
10-24-90	Avg	0.250841	0.508911	0.782840	1.022063	0.488120	0.775249
	Max	1.53931	0.719265	14.4231	14.2214	5.31435	12.5049
10-25-90	Avg	0.300442	0.541110	0.709762	-0.32901	0.689267	1.067826
	Max	0.719591	1.08792	1.23537	1.6382	5.40751	8.46791
10-30-90	Avg	0.206132	0.484855	0.357939	0.626638	0.232645	0.257112
	Max	0.792664	0.625406	1.31845	2.00388	0.579698	1.23587
10-31-90	Avg	0.166417	0.475593	0.395247	0.471956	0.376058	0.211860
	Max	0.302162	0.521282	3.87723	2.17151	0.634779	0.619953
11-01-90	Avg	-0.64198	0.023151	0.088870	0.439167	0.010480	0.146103
	Max	4.70063	4.82902	5.06107	5.08053	4.76726	7.97325
11-02-90	Avg	-0.56463	0.084276	0.062430	0.473396	0.083017	0.184529
	Max	-0.28445	0.254457	0.282891	0.563062	0.404541	0.425997
11-03-90	Avg	-0.59535	0.019943	0.052388	0.443151	-0.06792	0 159726
	Max	-0.34578	0.24595	0.250881	0.554115	0.341658	0.409535

7779

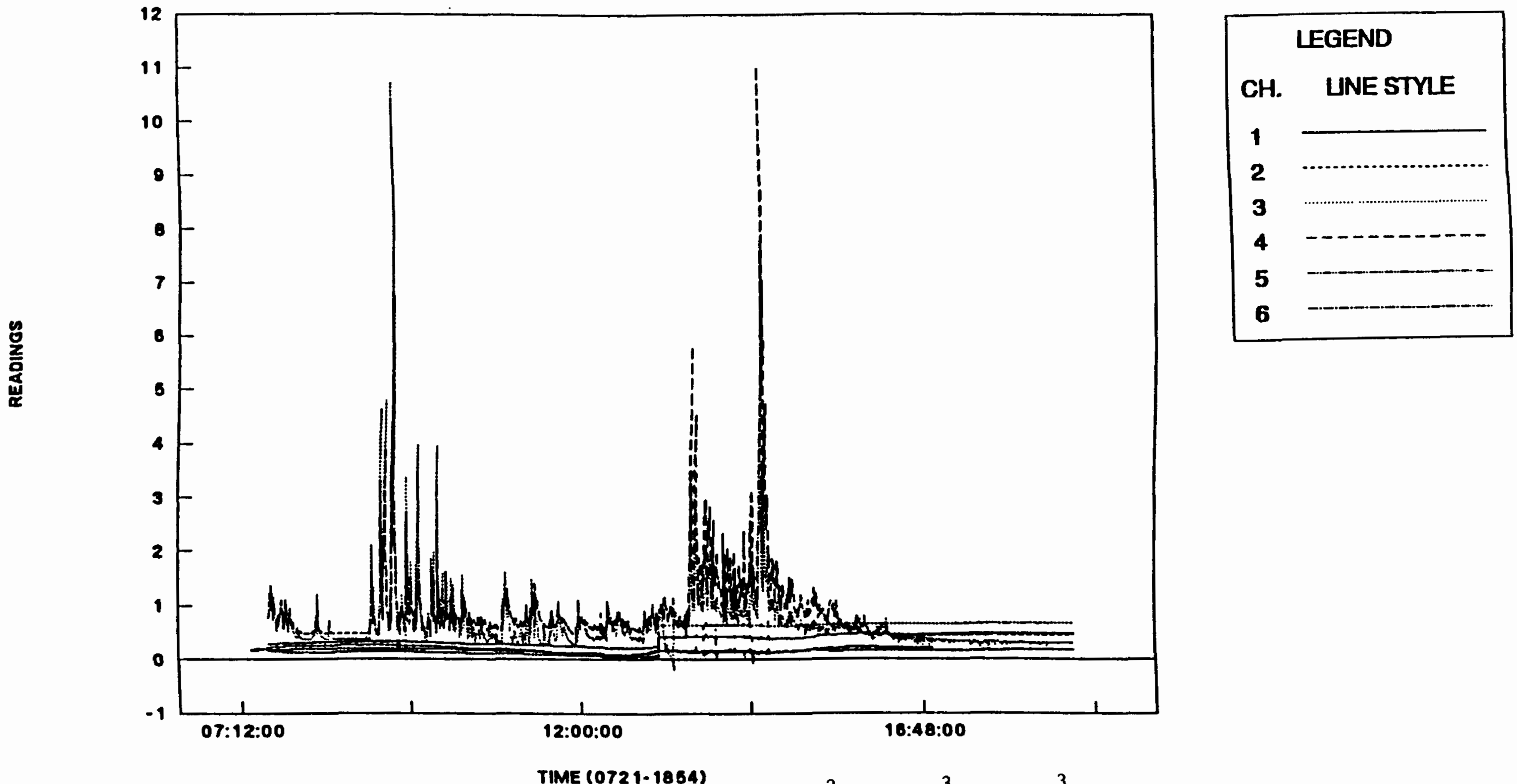
10-01-90



Station	1	1	2	2	3	3
Analyte	HCl	SO_2	HCl	SO_2	HCl	SO_2
Start pt	0.015770	0.75043	0.582637	0.51805	0.467794	0.705448
Avg	-0.03679	0.764152	1.338748	1.231777	0.455651	0.791022
Min	-0.70322	0.149153	0.582297	-0.19799	-2.46169	-0.77556
Max	0.086942	0.926013	11.5491	11.6919	8.96364	10.5988

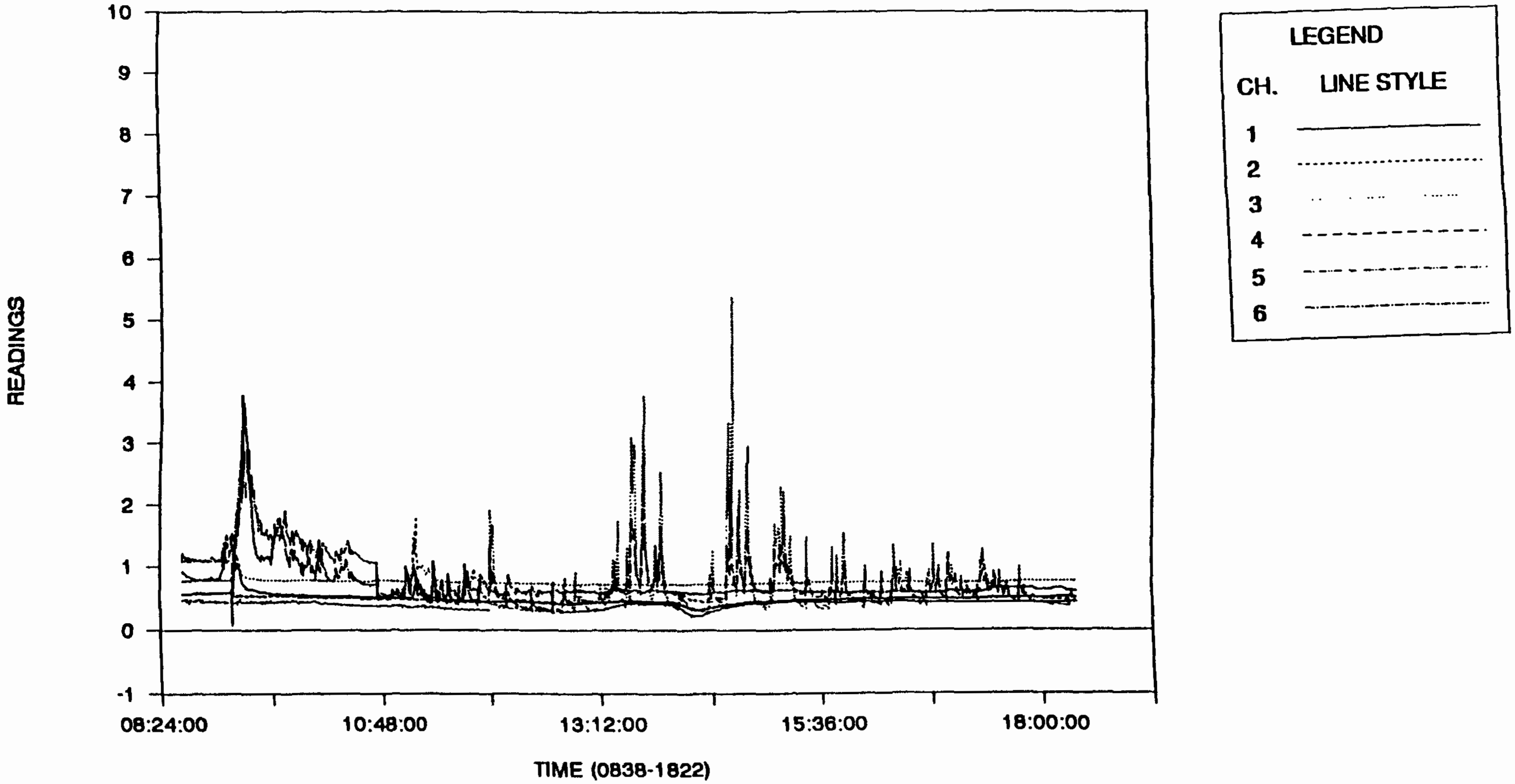
780

10-09-90



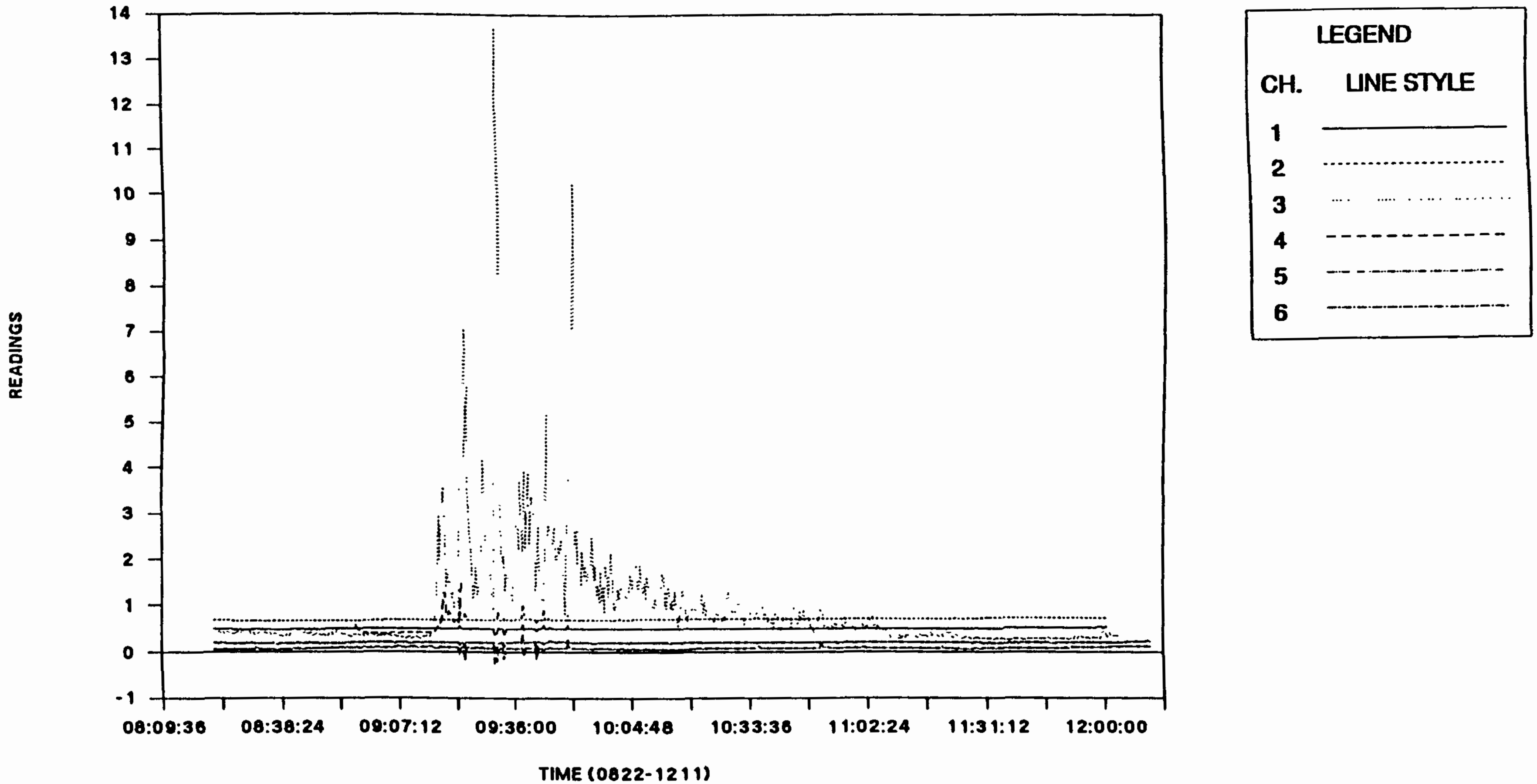
Station	1	1	2	2	3	3
Analyte	HCl	SO_2	HCl	SO_2	HCl	SO_2
Start pt	0.290938	0.158835	0.84765	0.781805	0.155473	0.178048
Avg	0.369269	0.389111	0.651374	0.824325	0.163596	0.193971
Min	0.210622	0.007481	-0.18590	0.390039	-0.06407	0.028662
Max	0.490225	0.708028	10.7252	11.044	0.241926	0.325377

10-16-90



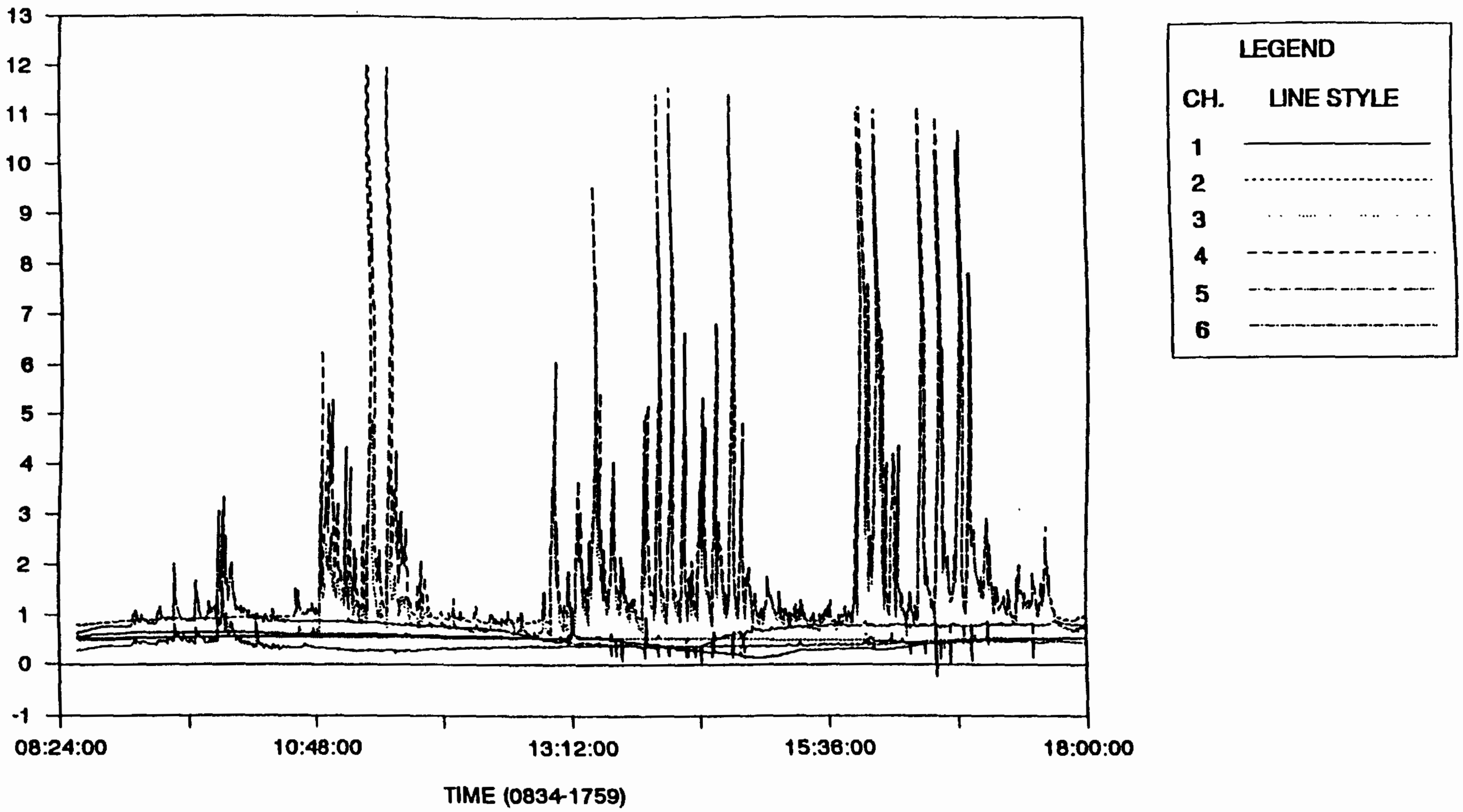
Station	1	1	2	2	3	3
Analyte	HCl	SO_2	HCl	SO_2	HCl	SO_2
Start pt	0.574353	0.776523	0.467085	1.0855	1.11965	0.922852
Avg	0.493103	0.766151	0.563084	0.615993	0.786316	0.581671
Min	0.325611	0.712316	0.271601	0.080240	0.424303	0.211295
Max	1.0705	1.77038	5.3952	2.23998	3.23031	3.77464

10-18-90



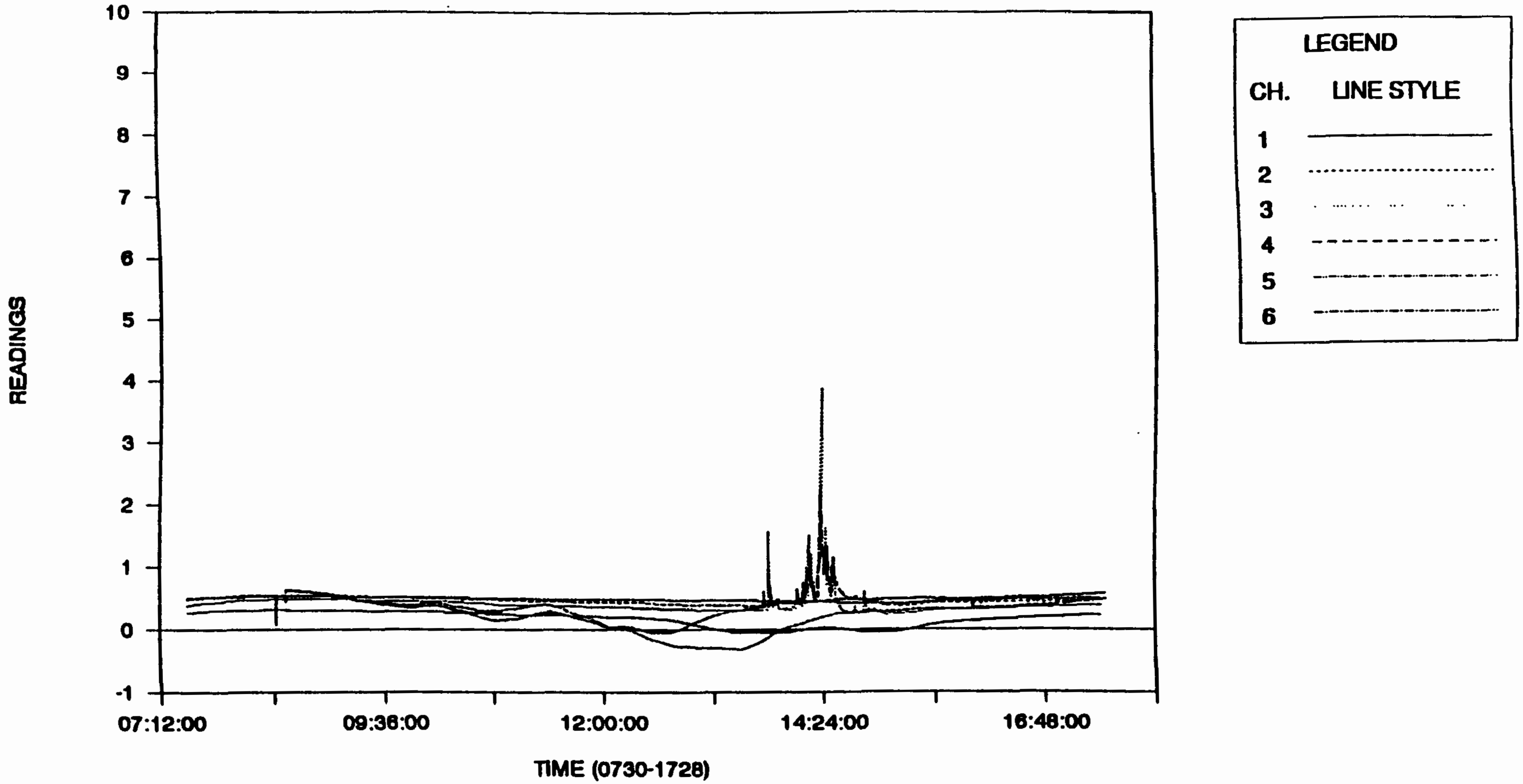
Station	1	1	2	2	3	3
Analyte	HCl	SO_2	HCl	SO_2	HCl	SO_2
Start pt	0.49895	0.701635	0.41941	0.591409	0.069038	0.208253
Avg	0.509233	0.711977	0.935273	0.515698	0.084801	0.208100
Min	0.371238	0.608064	0.268825	0.398294	-0.25770	-0.02024
Max	0.613982	1.03719	13.6996	1.52486	0.196473	0.370799

10-20-90



Station	1	1	2	2	3	3
Analyte	HCl	SO_2	HCl	SO_2	HCl	SO_2
Start pt	0.558845	0.518263	0.502079	0.791116	0.274582	0.628264
Avg	0.485579	0.522958	1.318833	1.701023	0.387232	0.745319
Min	-0.24384	-0.21191	0.453572	0.784361	-0.26382	0.079391
Max	1.15056	0.792444	10.8837	12.0178	1.66324	3.3339

10-31-90



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Station	1	1	2	2	3	3
Analyte	HCl	SO_2	HCl	SO_2	HCl	SO_2
Start pt	0.256236	0.490557	0.372369	0.48342	0.42992	0.615005
Avg	0.166417	0.475593	0.395247	0.471956	0.376058	0.211860
Min	-0.05898	0.396807	0.108864	0.076504	-0.05580	-0.32251
Max	0.302162	0.521282	3.87723	2.17151	0.634779	0.619953

An Overview of the
NIEHS Superfund Worker Education and Training Grant Program

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INTRODUCTION

The Superfund Amendments and Reauthorization Act of 1986 (SARA) authorized an assistance program for training and education of workers engaged in activities related to hazardous waste removal, containment and emergency response. Grant recipients must be non-profit organizations with demonstrated access to appropriate worker populations and experienced in implementing and operating worker health and safety education training programs. The National Institute of Environmental Health Sciences (NIEHS) was given responsibility for establishing and managing this program.

The scope of training in this area is great since the United States is a major producer of hazardous materials and waste. The Environmental Protection Agency (EPA) estimates that 57 million metric tons of hazardous wastes are produced each year. In addition, the Occupational Safety and Health Administration (OSHA) estimates that 13,600 spills of hazardous materials occur annually outside fixed facilities and 11,000 spills occur annually within fixed facilities. An estimated 1.2 million workers are involved with such uncontrolled hazardous material clean-up and emergency response.

During the first three years of the NIEHS Superfund Worker Training Program, the eleven initial grantees developed curriculum and started training programs throughout the country to help employers meet OSHA training requirements under 29 CFR 1910.121, Hazardous Waste Operations & Emergency Response. Over 6,340 safety and health training courses have been delivered to the target populations identified by Congress reaching approximately 154,241 workers involved in hazardous waste operations and emergency response. This resulted in almost 3 million contact hours of classroom presentations and hands-on field exercises.

During 1990, Congress significantly expanded the NIEHS worker training program by allocating an additional $10 million to support worker training activities. After soliciting new applications through a December 1989 Federal Register announcement, the NIEHS received 41 new applications with combined budget requests totalling over $44 million. After a lengthy review by committees of outside experts and other federal agencies, the NIEHS announced ten new awards in September 1990, including 5 existing grantees and 5 newly-supported organizations. There are now over 60 individual institutions in this program. This new support expands the scope of NIEHS-supported training to include workers involved in generating and transporting hazardous materials and wastes, oil spill cleanup workers and workers involved in the cleanup of nuclear weapons facilities.

BACKGROUND

Hazardous waste workers include workers at active and inactive treatment, storage and disposal sites, hazardous waste clean-up sites, and emergency response personnel. In addition to actual site workers and managers, Federal, state and local personnel may be involved with site investigation and remedial action.

Of the various sites, those involved with hazardous waste clean-up and remedial action pose the most severe health and safety concerns. These sites are characterized by the large variety and number of substances present, unknown substances and general uncontrolled condition of the site. Among the many potential hazards at these sites are:

1) Chemical and radiation exposures
2) Biological hazards
3) Fire and explosion hazards
4) Safety and electrical hazards
5) Heat stress and cold exposure
6) Oxygen deficiency and confined spaces

An important component of health and safety programs for hazardous waste workers is appropriate health and safety education and training. The Superfund Amendments and Reauthorization of 1986 contains important occupational health and safety provisions which address these needs. Section 126 required the Occupational Safety and Health Administration to promulgate interim (in 60 days) and final (within 1 year) standards for the health and safety protection of employees engaged in hazardous waste operations. These standards must address the following worker protection provisions:

1) Site Analysis
2) Training
3) Medical Surveillance
4) Protective Equipment
5) Engineering Controls
6) Maximum Exposure Limits
7) Information Programs
8) Handling
9) New Technology Program
10) Decontamination Procedures
11) Emergency Response

A minimum level of training for hazardous waste workers and supervisors is specified in Section 126(d). General site workers are required to receive a minimum of 40 hours of initial instruction off-site and a minimum of three days of actual field experience under the direction of a trained, experienced supervisor at the time of assignment. Supervisors are required to receive the same training as general workers and a minimum of eight hours of specialized training on managing hazardous waste operations.

The Superfund Amendments and Reauthorization Act of 1986 established a program of grants for training and education of workers who are or may be engaged in activities related to hazardous waste removal, containment or emergency response. Recipients of these grants were to be nonprofit organizations with demonstrated ability to reach target worker populations and with demonstrated experience with implementing and operating worker health and safety training and education programs. Responsibility for administering this grant program was given to the National Institute of Environmental Health Sciences (NIEHS).

The National Institute of Environmental Health Sciences is part of the National Institutes of Health (NIH) in the Department of Health & Human Services (HHS); its mission is to support research and training efforts which increase understanding of the relationship between environmental exposures and human health effects and disease.

Congress authorized funds for this program for a five-year period beginning in October, 1986. Up to $10 million may be used for this program in each fiscal year. In the 1989 appropriation the Congress increased the program to $20 million per year for Fiscal Year 1990 and 1991.

DISCUSSION

Program Description

The NIEHS hazardous waste worker protection program sought grant applications from qualified nonprofit organizations to develop and administer health and safety education programs for hazardous waste workers. Target populations for this training are:

(1) Workers at active and inactive hazardous waste treatment, storage and disposal facilities.
(2) Workers engaged in clean-up or remedial action at waste sites.
(3) Emergency response personnel.
(4) State and local personnel engaged in hazardous waste site investigation, remedial action or clean-up.

Training programs were to satisfy minimum requirements for hazardous waste workers as specified in Occupational Safety and Health Administration (OSHA) regulations which are or may be promulgated. Grants were made for curriculum and training materials development and support, direct student training and support,and training program evaluation. It was intended that the grants address all of the above elements in order to achieve a fully integrated and effective program. Training and education programs had to address each of the following elements, at a minimum, for all workers:

(1) Biology, chemistry, physics and nature of hazardous materials
(2) Industrial toxicology
(3) Safe work practices and general site safety
(4) Engineering controls and hazardous waste operations
(5) Site safety plans, standard operating procedures
(6) Decontamination practices and procedures
(7) Emergency procedures and self rescue
(8) Safe use of field equipment
(9) Handling, storage, and transportation of hazardous wastes
(10) Use, care and limitations of personnel protective clothing and equipment
(11) Safe sampling techniques
(12) Rights and responsibilities of workers under OSHA

In addition to the above education and training, some foremen, supervisors and other general site workers with additional technical responsibilities were required to provide additional specific training to include topics such as:

(1) Site surveillance
(2) Site safety plan development
(3) Use of special instrumentation for site assessment
(4) Safe use of specialized equipment
(5) Use and decontamination of special personnel protective equipment
(6) Other topics which may be specific for a particular work site

Applicants were to have demonstrated experience with implementing and operating worker health and safety training programs and to have the ability to reach target populations who are or will be engaged in hazardous waste removal, containment or emergency response. A major goal of this grant program is to assist organizations with development of institutional competency to provide appropriate training and education to hazardous waste workers. Consortia consisting of two or more nonprofit organizations were encouraged to apply and share grant resources in order to maximize worker group coverage and to bring together appropriate disciplines and talents. To the maximum extent, training programs were designed to include a mix of classroom instruction and hands-on demonstration and instruction which simulates site activities and conditions. It was intended that offsite instruction be supplemented with onsite training under the direct supervision of trained, experienced personnel.

Full program grants were awarded to organizations with demonstrated past worker health and safety training and education capability and ability to reach and involve target populations. Grants were for hazardous waste curriculum development, direct worker training, program evaluation activities, and related support activities. Grants were made for a five year period with annual renewal based on availability of funds, determination that grants are achieving training objectives and recipient submission to NIEHS of copies of all training and educational materials developed under the grant.

Characteristics of Hazardous Waste Worker Training Programs

Hazardous waste worker training programs funded by NIEHS grants have the following characteristics:

(1) Demonstrated ability to reach and involve target worker populations engaged in hazardous waste clean-up, containment or emergency response.
(2) Demonstrated past worker safety and health training and education capability.
(3) A Program Director with demonstrated capacity for providing leadership and assuring productivity of labor education programs. The Program Director shall have responsibility for general operation of the training program including quality assurance and program evaluation.
(4) Sufficient program staff with demonstrated training experience to assure curriculum development, training and quality assurance. Availability of appropriate technical expertise including but not limited to toxicologist and industrial hygienists must be demonstrated.
(5) Availability of appropriate facilities to support described education and training activities.
(6) A specific plan for preparing course curricula, distributing course materials, conducting direct worker training and conducting program evaluations. The plans include involvement of appropriate health and safety disciplines.
(7) A Board of Advisors or consultants representing user populations, industry, governmental agencies, academic institutions or professional associations with interest and expertise in worker training and hazardous waste operations. The Board is to meet regularly to evaluate training activities and will provide advise to the Program Director.
(8) Consortia must have specific plans and mechanisms to implement the cooperative arrangements necessary for program integration and to insure effectiveness. Specific expertise, facilities or services to be provided by each consortium member must be identified.

The Current NIEHS Program

In May 1987, the NIEHS awarded eleven multi-year grants to non-profit organizations for curriculum development and initial worker training. The NIEHS grantees, which include 5 consortia of universities and public health organizations, 5 international unions and one municipal fire department, are charged with adapting existing health and safety information to fit the needs of a wide variety of exposed hazardous waste workers and emergency responders across the country.

During the first three years of the NIEHS Worker Training Program (FY 1987-89), the NIEHS has successfully supported eleven primary grantees that represent over sixty different institutions who have trained over 154,000 workers across the country and presented 6,340 classroom and hands-on training courses, which have accounted for almost 3 million contact hours of actual training. Approximately 60% of the NIEHS-supported training was focused on reaching public sector emergency responders, such as police and firefighters, who constitute the bulk of the target population identified by Congress in Section 126 of SARA.

In response to an additional Congressional appropriation of $10 million for support of worker training activities related to hazardous waste operations and emergency response, the National Institute of Environmental Health Sciences (NIEHS) published a Federal Register notice on December 28, 1989 soliciting applications to support direct training activities by non-profit organizations targeted to employees handling hazardous waste or responding to hazardous materials releases.

With the recent awarding of supplemental funding to five additional non-profit organizations, the NIEHS is now supporting sixteen separate institutions and consortiums, which involve 58 organizations that are currently conducting training activities throughout the nation. NIEHS grantees have developed curriculum which is tailored to the educational needs of each of the target populations identified by Congress. See Appendix A for a annotated list of the current programs.

Quality Assurance

NIEHS has established stringent requirements for the development of quality, state-of-the-art training programs by the grantees. In addition, NIEHS has pursued a rigorous quality control audit program.

Under the OSHA standards only general criteria are provided for training and trainers. OSHA has proposed a Training Program Accreditation Standard which will be under 29 CFR 1910.121. A final 29 CFR 1910.121 standard is at very best over a year away and probably much more than that. In the interim there are no criteria which permit the employer of trained personnel or government agencies to evaluate or judge the acceptability, appropriateness, or quality of training programs, much less the competence of those so trained. Further, annual refresher training has begun. The quality of such training faces the very real potential of erosion to the least level of competence of refresher trainees, a problem exacerbated by the wide range of differences in training programs being provided to meet the initial training requirements as well as a lack of verification of basic training adequacy.

At a meeting of the NIEHS Worker Training grantees in June 1989, it was recognized that while each grantee had developed and was delivering quality training programs, a comprehensive "Criteria for Training Providers" was not only appropriate for these grantees but had merit in providing guidance to other Federal agencies, State agencies, and private organizations engaged in hazardous waste operations. As a result, an ad-hoc committee was established to consider the merits of the concept and to develop a draft document of key issues for consideration.

The ad-hoc committee concurred with the merit of concept, developed a draft document, and met in early January, 1990 to refine the draft. The ad-hoc committee draft was then circulated to NIEHS, all grantees, and a broad range of external experts for review and comment. A meeting was then held in Washington, D.C. in March, 1990 of the grantees, the external experts, and several Federal agency representatives. This NIEHS Worker Training Grant Technical Workshop resulted in a document for use by the worker health and safety training community.

There was general agreement among the participants on a number of issues. Participants reached agreement that: 1) the time specified for coverage of the topics required under 29 CFR 1910.120 was inadequate to present a quality training program; 2) Emergency Response personnel should be covered by the OSHA accreditation regulations; 3) the final OSHA regulations establishing a new occasional worker category which would require only 24 hours of training for General Hazardous Waste Site Operations could not be sufficiently detailed to develop a recommended guideline; 4) that refresher training where mandated by 29 CFR 1910.120 should be covered by the accreditation procedures and should only be delivered by training providers whose relevant core program is already accredited; 5) and that hands-on training should be an essential element of the generic training programs and should encompass at least 1/3 (one-third) of the training program hours.

Two major issues emerged during the workshop conference. The OSHA regulations under 1910.120 essentially focus upon these major hazardous materials operations categories: General Hazardous Waste Operations, RCRA-TSD Operations, and Emergency Response. Each deals with and is faced with potential exposures to hazardous materials. Yet the setting for each is dramatically and materially different. Hazardous waste operations, for example, are covered not only by 1910.120 but generally by the OSHA Construction Standards under 29 CFR 1926. RCRA sites are covered by the OSHA General Industry Standards under 29 CFR 1910. The work environments, employment practices, and potential exposures vary dramatically in these different settings. As such, these basic issues need to be considered when addressing training programs to meet the needs of workers and employers in these diverse settings.

The second issue relates to emergency response. While there was broad agreement that the Emergency Response category should be covered by the OSHA proposed Training Accreditation Rules under 29 CFR 1910.121, there was substantial concern about the content and criteria for such training programs.

National Clearinghouse on Occupational and Environmental Health (NCOEH)

In order to assist with the broad dissemination of curricula for hazardous waste worker training, NIEHS supported the creation of the National Clearinghouse on Occupational and Environmental Health. The Clearinghouse was established through a supplement to the Laborers-Associated General Contractors grant who sub-contracted with the Workplace Health Fund in Washington, D.C. The Clearinghouse has created a curriculum guide of training materials and a resource library of health and environmental information regarding hazardous waste, toxic releases and emergency responses. The Clearinghouse also publishes a regular newsbrief and serves as a networker between NIEHS grantees and other organizations concerned with quality worker safety and health training.

(1) Goals of the National Clearinghouse

Specifically the National Clearinghouse is:

a) to assist with organization of technical workshops to facilitate updating and clarifying the complex and continually evolving knowledge in the field;

b) to produce a monthly newsletter for similar purposes and to facilitate information sharing between grantees;

c) to develop a brochure, portable exhibit and training catalog about the training for outreach purposes;

d) to collect, archive, and report upon new information;

e) to serve as a central repository for curricula and other information related to hazardous waste training; and

f) to work with NIEHS grantees to develop protocols and quality controls over the dissemination of this curricula.

The National Clearinghouse's first major task was to establish protocols and quality control over dissemination of curricula. The Clearinghouse was assigned the task of collection and distribution of grant-developed curricula to second round applicants for the next round of training grants, and for the general public. A major component of this task was to produce a catalog of the curricula. Based on the interest in the catalog and curricula we have learned that there is a considerable demand for high quality training and training materials that will address the 1910.120 requirements, and that are likely to satisfy the criteria for accreditation. NCOEH has answered hundreds of phone calls and written requests about these materials.

Two other items have greatly contributed to the demands for National Clearinghouse services. The first is a document developed by NIEHS and its grantees in collaboration with other agencies and concerned parties titled, **Worker Criteria for Worker Health and Safety Training for Hazardous Waste Operations and Emergency Response.** In the absence of an accreditation standard, it has been this document, even in its preliminary draft form, that many people have turned to--including OSHA--for guidance as to what constitutes appropriate, quality training of workers in the field of hazardous waste.

The second has been demand for the **Hazardous Materials Training for First Responders** curricula developed and produced by the International Association of Fire Fighters. Inquiries and orders have been received from a wide range of entities, from heavy industry to municipal fire departments and LECPs, who find this first responder or awareness level training applicable to their needs.

National Clearinghouse: Communications & Networking

While the distribution of curricula and the "Criteria" publication have been major activities other activities have also been on-going. These include drafting copy and designs for a program brochure, developing a training catalog and assembling an exhibit. These are being developed for outreach purposes. An internal newsletter is published monthly for circulation among grantees.

Additional technical workshops have been held including one clarifying the nature of emergency response training and a second on development of health effects modules. This latter workshop was cosponsored with the Association of Occupational and Environmental Health Clinics with whom NIEHS and the grantees are working to obtain case-based training materials to help teaching about health effects. A technical workshop on quality training for prevention of work-related injury and illness associated with hazardous chemical transportation has been suggested.

A computerized data base has been established for collecting, archiving, and circulating abstracts of relevant pertinent books and documents. The National Clearinghouse has been aided in this regard by the input of a number of people involved with building labor and health and safety resource centers including Helen Beal at OSHA, Ruby Tyson, librarian for the AFL-CIO, librarians for AFSCME, OCAW and NIEHS, and in particular the Labor Occupational Health Program at UC-

Berkeley whose guidance documents on organizing a labor health library have proven to be an invaluable resource.

In this second year of its operation, the National Clearinghouse hopes to better respond to the needs of grantees and put their claims to our attention at least on par with those of the general public. This will be aided by a streamlined and clarified decision-making process with grantees to have a more formal and continuous mechanism for input in the form of an Executive Committee to the Advisory Board.

This structure reflects a sense of ownership and investment in the National Clearinghouse operation on the part of grantees, which should help to "institutionalize" the project and nurture both a clear and official role for these "worker educators." The role of an Advisory Committee has been spelled out and executive officers proposed for election annually. This clear mechanism of involvement and decision-making should foster among the labor and university colleagues an on-going mechanism for cooperation and collaboration -- essential elements in maintaining high quality training.

The National Clearinghouse can carry out outreach on the program's behalf in consultation with NIEHS and the grantee executive committee. Plans are being made to exhibit, distribute copies of the program brochure, training catalogs, and other documents produced in conjunction with NIEHS and its grantees at approved exhibits and meetings. The National Clearinghouse is willing to accept relevant notices, documents, news or other items for inclusion in the newsletter and looks forward sometime in the future to producing a quarterly or bimonthly newsletter for a wider audience. The National Clearinghouse is developing and maintaining mailing lists in order to notify those interested when new or updated documents, such as the training catalogs and curricula listing, are available.

The National Clearinghouse Tomorrow -- Potential

In the future, the National Clearinghouse will move toward improving and expanding efforts in each of the above areas. The Workplace Health Fund publications program is growing rapidly, so the Fund and National Clearinghouse together are increasingly becoming a focal point for distribution of occupational health and safety literature. The infrastructure built for this purpose can then in turn support further literature distribution.

The library and information infrastructure being built can eventually serve as an increasingly more effective vehicle for workers, their leadership and communities to access the information they need to empower their own efforts to improve both occupational and environmental health and safety. Because of the centralized Washington, D.C. location the National Clearinghouse can be an efficient resource center for supporting improved research and research as well as training.

Because of the heavy demand for information and materials experienced and the appreciation expressed upon finding items in a readily accessible, centralized source, a strong long-range potential in this project is to foster ongoing collaborative efforts between labor, the academic community, and government.

CONCLUSION

When Congress passed the Superfund Amendments and Reauthorization Act of 1986 (SARA), it gave NIEHS two major tasks: to develop programs to support basic health research on risks posed to human health by hazardous waste sites and to support curriculum development and pilot worker training efforts targeted to employees who are involved in cleaning up hazardous waste sites, handling toxic materials or responding to hazardous environmental releases.

Populations of hazardous waste workers continue to increase including hazardous waste generators, employees involved in cleanups at Department of Energy (DOE) nuclear facilities, hazardous materials transportation workers and volunteer firefighters who respond to hazardous releases.

Currently, the NIEHS Worker Training Program is concerned with promoting the development of quality training curricula, adequately qualified training staff, effective methods for assuring the competence of trainees in a core of required skills and knowledge, and functional evaluation procedures for worker training programs.

The NIEHS Superfund Worker Training Program is committed to assuring that the Congressional mandate for worker protection under SARA (Section 126) is carried out by creating field-tested models of effective training techniques and skills-based curriculum across the country that are accessible to a broad cross-section of the hazardous waste workforce.

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Appendix A.

SUMMARY OF NIEHS FUNDED SUPERFUND WORKER TRAINING GRANTS

The following is a general summary of the sixteen Superfund worker training grants supported by NIEHS. Individuals are encouraged to contact grantees directly for more specific information about a particular program.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Marianne Brown
University of California
California Consortium
UCLA Center for Labor Research and Education
1001 Gayley Avenue, Second Floor
Los Angeles, CA 90024

Telephone: 213-825-3877
Fax: 213-825-3731

Other Participating Organizations:

University of California at Berkeley
Labor Occupational Health Program
University of California at Los Angeles
University Extension Program
University of California at Davis
University Extension
University of California at Irvine
Extension Program
University of Southern California
Continuing Education Program
Los Angeles Committee on Occupational
Safety and Health

Target Training Populations:

Superfund site workers; state/county emergency response personnel; waste transportation personnel; and waste site assessment workers

Program:

Curricula have been developed for all target populations involved in handling hazardous waste and emergency response. New courses have been pilot tested. Courses are delivered throughout the state of California, with recent expansion into Nevada, Arizona and Federal Region Nine.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

David McCormack
International Association of Fire Fighters
1750 New York Avenue, NW
Washington, DC 20006

Telephone: 202-737-8484
Fax: 202-737-8418

Other Participating Organizations:

None

Target Training Populations:

Emergency response personnel and first responders nationwide

Program:

Curricula and training materials are being developed to training fire fighters nationwide. These could eventually affect the nation's entire fire service i.e., approximately one million professional and volunteer fire fighters. The program places emphasis on improved training to assure that personal protection is adequate for use by fire fighters in responding to hazardous substance emergencies. The materials have been pilot tested in the fire service. The end products will be disseminated among the fire service nationwide.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Audrey Gotsch, Ph.D.
University of Medicine
& Dentistry of New Jersey (UDMNJ)
New Jersey/New York Consortium
675 Hoes Lane
Piscataway, NJ 08854-5635

Telephone: 201-463-4500
Fax: 201-463-5231

Other Participating Organizations:

New Jersey Department of Labor
Hunter College, School of Health Sciences
Empire State College
State University of New York
New York Committee for Occupational Safety and Health
Oil, Chemical, and Atomic Workers Union, Local 8-149

Target Training Populations:

Waste clean-up site workers and supervisors, site assessment personnel, waste treatment, storage and disposal facility works and waste transporters. Target personnel for emergency response personnel that are first responders include 100,000 police, fire fighters, and emergency medical technicians in New Jersey.

Program:

Curricula are being developed for all areas of hazardous waste and emergency response as required by OSHA including that for first responders. New courses are pilot tested for both 40 hour clean-up work and first responder courses including: six hours for first responder awareness; eight hours for first responder operations; and twenty four hours for hazmat technicians. In addition, courses of eight hours for HazMat Emergency Medical Technicians have been prepared and offered.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

David M. Treanor
International Union of Operating Engineers
1125 Seventeenth Street, NW
Washington, DC 20036

Telephone: 202-429-9100
Fax: 202-429-0316

Other Participating Organizations:

None

Target Training Populations:

Operating Engineers engaged in hazardous waste operations.

Program:

Curricula are being developed and used in training programs targeted at on-site worker populations of equipment operators. Emergency response training is included as part of the curriculum. Trainers from the union locals are trained in an eighty hour "train-the-trainer's" course. The trainers return to their local and train workers in forty hour sessions.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Sylvia Krekel
Oil, Chemical & Atomic Workers
255 Union Boulevard
Lakewood, CO 80228

Telephone: 303-987-2229
Fax: 303-987-1967

Other Participating Organizations:

None

Target Training Populations:

Hazardous waste treatment, storage, and disposal facility workers

Program:

A curricula are being developed and used in training programs targeted at on-site worker populations of oil, chemical, and atomic workers. Training emphasis is placed on treatment, storage, and disposal sites. Emergency response training is included as part of the curriculum. Rank and file trainers from OCAW local unions are trained in a "train-the-trainer's" course then go on to train workers in eight hour (refresher) and twenty-four hour (basic training) sessions.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Charles (Chuck) Levenstein, Ph.D.
University of Lowell
Research Foundation
Northeast Consortium
One University Avenue
Lowell, MA 01854

Telephone: 508-934-4000
Fax: 508-452-5711

Other Participating Organizations:

- Boston University School of Public Health
- Harvard Educational Resource Center
- Tufts University, Center for Environmental Management
- Yale University, Occupational Medicine Program
- Massachusetts Coalition for Occupational Safety and Health
- Maine Labor Group for Health
- Connecticut Committee for Occupational Safety and Health
- Rhode Island Committee for Occupational Safety and Health

Target Training Populations:

Waste site clean-up workers; emergency response personnel, treatment, and disposal facility workers; and waste transporters

Program:

Curricula are being developed for all areas of hazardous waste and emergency response, including first responders. New courses were pilot tested. Courses are delivered in six New England states.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Frank Martino
International Chemical Workers Union
1655 West Market Street
Akron, OH 44313

Telephone: 216-867-2444
Fax: 216-867-0544

Other Participating Organizations:

United Steel Workers of America
University of Cincinnati
Greater Cincinnati Occupational Health Center

Target Training Populations:

Industrial fire brigades and hazardous waste treatment, storage, and disposal facility workers

Program:

Curricula are being developed and used in training programs targeted at on-site worker populations of member of the International Chemical Workers Union and the United Steel Workers of America. Training emphasis is placed on hazardous waste treatment, storage, and disposal site workers and those workers serving on emergency response teams or fire brigade teams in plants. Emergency response training is included as part of both curricula and both are given in thirty-two hour courses - eight hours more than the minimum required. A course for workers at nuclear facilities has also been developed.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Chief Roger Ramsey
Seattle Fire Department
301 Second Avenue South
Seattle, WA 98104

Telephone: 206-386-1481
Fax: 206-386-1669

Other Participating Organizations:

Washington State Fire Training Service

Target Training Populations:

Emergency response personnel and first responders

Program:

Curricula are being developed for emergency response for first responders. New courses have been pilot tested. Courses are delivered to Seattle Fire Department Personnel. The Washington State Fire Training Service delivers the basic course on recognition and identification of hazardous materials to fire fighters in other fire departments in Washington State.

NIEHS Superfund Worker Education and Training Grant Program

<u>Principal Investigator/Institution</u>:

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College of Medicine
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<u>Telephone</u>: 513-558-1751
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<u>Other Participating Organizations</u>:

Southeast Michigan Coalition on Occupational Safety and Health
Greater Cincinnati Occupational Health Center
University of Illinois
University of Kentucky
University of Michigan
University of Wisconsin
Murray State University
Michigan State University
Purdue University

<u>Target Training Populations</u>:

Waste site workers and supervisors; treatment, storage, and disposal site workers; emergency response personnel; and waste transporters

<u>Program</u>:

Curricula are being jointly developed for all areas of hazardous waste and emergency response personnel. New courses have been pilot tested and are now delivered in six mid-western states.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Higdon Roberts, Ph.D.
University of Alabama Birmingham
Center for Labor Education and Research
University Station
1044 South Eleventh Street
Birmingham, AL 35294

Telephone: 205-934-2101
Fax: 205-975-6247

Other Participating Organizations:

Deep South Educational Resource Center

Target Training Populations:

Heavy equipment operators, laborers, waste transportation workers, and governmental personnel involved with hazardous waste sites

Program:

Curriculum have been developed and being used in training programs targeted at on-site worker populations including technical personnel, general laborers and equipment operators and transporters. Emergency response training is included for general hazardous substance site workers. Curriculum for RCRA site workers is under development. Courses are given at locations through-out the southeast.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

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Laborers-AGC Education
and Training Fund
Route 97 and Murdock Road
PO Box 37
Pomfret Center, CT 06259

Telephone: 203-974-0800
Fax: 203-974-1459

Other Participating Organizations:

None

Target Training Populations:

Skilled construction laborers engaged in hazardous waste clean-up

Program:

Curricula are being developed for use in training programs targeted at on-site worker populations of laborers. Emergency response training is included. Trainers from the union locals are trained in a 120 hour "train-the-trainer's" course. The trainers return to local training centers and train workers in 80 hour sessions. Supervisory courses are given.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Brian Christopher
Alice Hamilton Occupational Health Center
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Washington, DC 20003-2756

Telephone: 202-543-0005
Fax: 202-546-2331

Other Participating Organizations:

Illinois Institute of Technology Research Institute
University of Maryland
Alaska Health Project
North Carolina COSH
AFSCME

Target Training Populations:

The Hamilton Center has targeted state/county/local governmental workers for awareness training, with most being identified through AFSCME. Two regional training centers in the Mid-Atlantic and the Pacific Northwest will conduct training for all populations covered by OSHA 1910.120.

Program:

Curricula are being adapted to cover all the proposed target populations, with the addition of courses for oil spill cleanup workers, which will be developed by the Alaska Health Project. Most of the training will take place in Maryland, North Carolina, Illinois & Alaska.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

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International Brotherhood of Teamsters,
Chauffeurs, Warehousemen and Helpers
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25 Louisiana Avenue, NW
Washington, DC 20001

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Fax: 202-624-6918

Other Participating Organizations:

None

Target Training Populations:

The Teamsters union proposes to initiate a training program which focuses on two important worker populations: 1) truck drivers involved in hazardous waste site cleanup; and 2) drivers and handlers who are involved in transporting hazardous materials.

Program:

For cleanup workers, the Teamsters will be adapting the Laborers/AGC curriculum to be delivered at seven existing regional training centers-- three on the West Coast, two in the East and two in the Midwest. For transporters of hazardous materials, a 3 and a half hour awareness course will be established based on new DOT regulations and delivered to transportation workers in regional sessions across the country.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

Jeffrey A. MacDonald
George Meany Center for Labor Studies
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Silver Spring, Maryland 20903

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Fax: 301-434-0371

Other Participating Organizations:

University/College Labor Education Centers
International Chemical Workers Union
Railway Labor Executives Association
AFL-CIO Department of Occupational Safety & Health

Target Training Populations:

The Meany Center is developing a national training program for railroad workers who are involved in transporting hazardous materials and hazardous waste. Tiered training will be targeted to railroad workers who are involved in both awareness level of spill reporting, as well as actual response action and cleanup of hazardous materials.

Program:

Regional hazardous materials awareness training will be conducted by various adjunct university faculty in labor education programs for railroad workers who may be involved in emergency responses to hazardous spills and releases. A longer course for maintenance of way workers and signalmen who are involved in actual spills cleanups will be developed and conducted in conjunction with the International Chemical Workers Union (ICWU).

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

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Service Employees International
Union, AFL-CIO
1313 L Street, NW
Washington, DC 20005

Telephone: 202-898-3200
Fax: 202-898-3491

Other Participating Organizations:

None

Target Training Populations:

A nationwide program is being developed to train highway workers, sewage and water plant operators and gas utility workers in first responder awareness and hazardous materials technician level competency.

Program:

SEIU will be developing regional level hazardous materials training courses in conjunction with existing NIEHS grantees on the West Coast, the Midwest and the East Coast. SEIU proposes to train public sector first responders with an adapted 8 hour awareness course.

NIEHS Superfund Worker Education and Training Grant Program

Principal Investigator/Institution:

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International Union, UAW
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Detroit, Michigan 48214

Telephone: 313-926-5566
Fax: 313-824-5700

Other Participating Organizations:

University of Michigan

Target Training Populations:

Workers in the transportation and metalworking industries who are engaged in hazardous waste generation operations will be targeted for both awareness and technician-level training. Both general generator site workers and industrial emergency responders will be targeted in the Midwest.

Program:

UAW will develop its program based on the work of its existing joint labor-management hazard communications program, which supports the development of trained local union safety and health leaders. Extensive job site exposure and task analysis for workers involved in hazardous waste generator operations will be conducted as part of developing site-specific curricula on hazardous waste handling and industrial emergency response.

NIEHS Superfund Worker Education and Training Grant Program

Notice: While the majority of this report has undergone extensive agency review for other purposes and is consistent with regard to NIEHS policies, the combined report to EPA's 1991 Conference on Design and Construction Issues at Hazardous Waste Sites has not received formal peer review. It is published here as an timely interim report of information should be available for immediate use. Please contact Denny Dobbin for further information.

Hazardous Waste Sites:
Worker Protection Perspectives

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I. INTRODUCTION

The Laborers Health and Safety Fund, a jointly trusted labor-management group, has been intimately involved in hazardous waste activities at the local site level to the Federal level with specific regard to worker safety and health issues for over two and a half years. This involvement has been on a national scale involving NPL sites and state designated uncontrolled hazardous waste sites and through participation as members of the EPA-Labor Task Force on Superfund Safety and Health. Extensive interactions have occurred with local, state, federal agencies including EPA, OSHA, and the U.S. Army Corps of Engineers, owners; contractors; construction management firms; LEPC's; Emergency Responders; and several construction labor unions.

What has emerged in the analysis of several case histories is a rather comprehensive view of the complexities in the implementation of the regulations mandated by the Superfund Amendment and Reauthorization Act in a confusing arena involving several regulatory agencies and the contractors, training providers, LEPC's, community representatives, construction managers, emergency responders, and workers who are directly involved in remediation activities. The central role of worker protection in these complex undertakings will be addressed.

II. BACKGROUND

The Superfund Amendment and Reauthorization Act (SARA) passed by the Congress in 1986 established two essential components relevant to worker protection at hazardous waste sites. Title I Section 126 essentially established the worker protection and "right to know" initiative and required OSHA [126(a)] and EPA [126(f)] to promulgate specific regulations to protect workers involved in hazardous waste operations and emergency response. Likewise, OSHA was mandated to promulgated regulations to accredit training programs pertinent to the training requirements established by the Congress within SARA and promulgated by OSHA pursuant to the Title I. OSHA promulgated the worker protection regulations embodied within 29 CFR 1910.120 as interim final regulations on December 19, 1986 and subsequently issued final regulations which became effective on March 6, 1990. A correction notice was published on April 13, 1990 and on April 18, 1991. OSHA has only issued a notice of proposed rulemaking regarding the accreditation of training programs. OSHA has issued various directives concerning 1910.120 but has not issued a comprehensive compliance guideline to it's enforcement staff to aid in a uniform hazardous waste site inspection policy.

EPA was likewise mandated by Congress under SARA to establish several elements related to Community Right-to-know, known as Title III. This was addressed in several sections to Title III and includes establishment of LEPC's (Local Emergency Planning Committees) in many communities throughout the country. EPA retained of course, the responsibility for directing the nations efforts to clean-up uncontrolled hazardous waste sites through a process of identification, evaluation, ranking, listing, and either directly funding removal or remediation efforts or causing such to occur by PRP's (principal responsible parties). EPA was also required to promulgate worker protection standards for those places of employment not covered by the OSHA regulations (codified at 40 CFR Part 311).

The Department of Defense (DOD) and Department of Energy (DOE) also have uncontrolled hazardous waste sites on the federal facilities for which they are responsible. Such facilities are exempt, however, from SARA Title III requirements but federal employees are covered by the OSHA regulations by Executive Order 12196, including those engaged in hazardous waste operations and emergency response. Non-federal workers are covered by the respective OSHA or EPA regulations.

ATSDR (Agency for Toxic Substances and Disease Registry) was created by SARA and mandated among other things, to conduct and report Health Hazard Assessments at each uncontrolled hazardous waste site which EPA listed on the NPL (National Priority List). ATSDR has no such authority for federal facilities, although MOU's (Memorandums of Understanding) are intended with DOD and DOE to fill that gap.

Various other federal agencies have defined roles with regard to hazardous materials if one considers the broad range of uncontrolled hazardous waste sites, transport of hazardous materials, hazardous materials spills on land and water, hazardous waste disposal, and the like. Agencies potentially involved in some required manner with uncontrolled hazardous waste sites are:

EPA -	Superfund Program Lead Agency.
OSHA -	Worker Protection standards and enforcement thereof.
NIOSH -	Research in support of OSHA proposed standards, Health Hazard Evaluation (HHE's), and certification of respiratory protective devices.
USCG -	Spills of hazardous materials in waterways.
DOD -	Facility sites
DOE -	Facility sites
ATSDR -	Health Assessment Reports, Public Health Advisories
NIEHS -	Worker Training Grant program as established by SARA.
DOT -	Transport of hazardous materials.
States -	Title III programs, 23 State OSHA's, State "EPA" programs, State Health Departments (some with ATSDR contracts to develop health assessments).
BLM -	(Bureau of Land Management) Federal lands with waste sites.
USACE -	U.S. Army Corps of Engineers serves essentially as hazardous waste site remediation project managers for the EPA at sites for which EPA is directing the remediation rather than a PRP.
DOJ -	Consent degrees with PRP's.

A "typical" Superfund Site remediation project will involve the following agencies directly:

USEPA - (regional office primarily)
USACE - (district office primarily)
STATE - (several agencies possible)
Local Community - (LEPC or committee)
ATSDR - (directly or contractor)

OSHA - (directly, only if requested acting on a complaint or under a directed investigation)

A "typical" uncontrolled hazardous waste site also involves the following usually private entities:

site characterization contractor
design contractor(s)
RI/FS contractor(s)
ROD contractor(s)
Prime contractor on the site
Sub-contractors on the site
Workers (organized and unorganized)
Local community emergency responders
Local emergency medical personnel
PRP's
Hazardous waste transporters, if a removal project.
Hazardous waste receivers, if a removal project.

From initial listing for evaluation and ranking to the first "shovel full of dirt" in a remediation action typically requires 6-8 years.

Each phase requiring activity on the site requires compliance with worker protection regulations.

SARA uniquely establishes the requirement that all workers whether employed by private employers; local; state, or federal governments; and even volunteer emergency responders be protected in accordance with established regulations when engaged in hazardous waste operations and emergency response. While all workers so engaged must be protected, the responsibilities for ensuring such protection has been nested within a large number of governmental agencies with inherently different missions and jurisdictions. In waste site activities, these differing jurisdictions result in discrete boundaries being drawn with OSHA being responsible for site worker protection and EPA responsible for site activities and public protection. In actual practice, such clear distinctions do not occur as site worker protection issues are directly linked to public protection issues, for example.

III. CASE HISTORIES

Quincy Naval Yard; Quincy MA.

As one element of the massive multi-billion dollar Boston Harbor clean-up project, the ex-Quincy Naval Yard was selected as the site for a sewage sludge treatment facility. The site had been previously declared an "uncontrolled hazardous waste site" by the State of Massachusetts thus requiring compliance with 29 CFR 1910.120. Extensive clean-up and removal had occurred on the site before the Boston Harbor project element work began. The construction of the treatment facility required substantial ground work, pipe laying, pile driving, and foundation laying. This work was defined in the specifications as NOT COVERED by 29 CFR 1910.120 despite the fact that it was still carried as an uncontrolled hazardous waste site by the State. One excavation event lead to worker exposures resulting in acute exposure health effects. Despite the insistence of the construction management firm that no special precautions were necessary and that the contractor would not be reimbursed for additional worker protection measure instituted, the owner, the Massachusetts Water Resources Authority, over-ruled the management firm and 1910.120 based worker protection practices and procedures were utilized in all of the excavation activities in area's previously identified as contaminated (prior to earlier clean-up) and in such activities where very deep excavations were required. This specific site was the basis for OSHA's first policy statement indicating that a designated uncontrolled hazardous waste site could have "clean zones" not requiring compliance with 1910.120 (P.K. Clark, OSHA letter to J. Moran dated July 30, 1990).

Bunker Hill; Kellogg, Idaho

One of our nation's largest NPL sites, it evidenced total disregard of the EPA and OSHA requirements when visited in 1989-1990. Severely contaminated equipment was sold to private parties from the site, the site was not secured and children played in the areas severely contaminated with lead and arsenic. Many other serious problems were evident. ATSDR, for example, issued a Public Health Advisory in 1990. The yards surrounding homes in nearly communities had several inches of the top soil removed and replaced with clean soil to reduce the potential for further childhood lead poisoning. Even this work was performed in violation of 1910.120 and indeed, the OSHA Area Director permitted, once the issue was raised, that such workers could be trained at the OSHA created 24 hour category months before that final 1910.120 was in place and law.

EPA subsequently issued an order requiring several site activities to remedy the earlier abuses occurring at the site particularly with regard to the smelter complex including security fencing, cessation of sales of scrap materials and equipment, and abatement of deteriorated asbestos insulation.

Further, much work on the site was being done under emergency action provisions under EPA contract thus avoiding compliance with the Congressionally mandated Davis-Bacon Act wage provisions. A subsequent ruling, specifying compliance requirements by the Department of Labor was applied nationally.

Newport, Rhode Island

Excavation work in preparation for the construction of a multiple story building in a major urban area uncovered a partially collapsed large fuel storage tank. Soil samples evidenced 7-9 ppm lead in the EPTox test (it is, then, a hazardous waste) and 3,000-7,000ppm total lead (to which workers were exposed as dust and orally due to transfer of dirt from hands and clothing). This contaminated soil was to be removed. Is this a work area which requires compliance with 1910.120? NO according to OSHA at that time. The "hazardous waste" debris from the excavation was transported over community streets to a community owned lot where it was stored.

This example is one of many related to an emerging national problem where "hazardous waste" is encountered in "normal" construction activities. It is not uncommon and has not been addressed, as yet, by the regulatory agencies at the federal level.

Arkansas

A PRP incinerator operation worked their laborers 12 hour shifts, sometimes back-to-back, while wearing Level C and Level B equipment. A site review suggested that a large number of the 1910.120 requirements were not being complied with. Working with the contractor, the key site management was replaced and compliance with 1910.120 pursued as a top priority. Workers called the area OSHA office, which was unable to respond except through the Dallas Regional office. They were advised that response from Dallas would take some time. Months later, OSHA still had not responded, although activities at the site have improved significantly.

Charles George Landfill; Tyngsboro, Massachusetts

OSHA responded to this NPL site based upon written complaint filed by an employee representative, after all other avenue's to address worker protection concerns were rebuffed by the prime contractor and the federal agencies involved. Response required more than 4 weeks from the time the complaint was filed. OSHA found heat stress and confined spaces program inadequate (technically) but stated that they could not cite the contractor because 1910.120 only requires that there be such elements in the Site Safety and Health Plan. The report of the investigation took weeks. The closing Conference with workers and worker representatives was narrowly structured to cover only the organized sub-contractors not the prime or the whole site despite the 1910.120 requirement that the prime is responsible for safety and health on the whole site. Nearly all sub-contractors, the prime and the Corps of Engineers were eventually cited by OSHA. The prime contractor contested the citations and some were dismissed by the U.S. Department of Labor solicitor in Region I as "unenforceably vague".

Work has essentially concluded but a special study indicated subsidence was more severe that anticipated and liner life may be as little as four years. Latest concerns from the community involve excessive methane levels in the collection system, manholes, and from the capped area vents. The town is now concerned about fire and explosion potential.

During early work, run-off to a stream next to the site occurred as evidenced by a dark colored sediment. Analysis by EPA indicated, as reported at a community meeting, that the stream was "relatively safe". No analytical data was provided nor numbers given despite requests. This heightened worker and community concerns because of the appearance that the Federal agencies were not being completely open with the community and the workers, many of whom attended the community meetings.

Nyanza; Ashland, Massachusetts

Requests for information by workers and their representatives was essentially ignored by the prime contractor, the Corps of Engineers, and EPA. Worker representatives were initially not allowed on the site even in the support zone. Based upon limited information in the Local Repository, a report identifying areas of concern was prepared by worker representatives. A worker filed a formal compliant with OSHA, which responded some four weeks later.

The EPA Regional office instituted procedures requiring that all contact with the EPA regarding this site be in writing. OSHA's attempt to conduct an inspection was rebuffed by the contractor with the Corps of Engineers initially supporting the contractors position. OSHA had to obtain a federal court order to enter the site. The contractor then denied right of worker representatives to accompany the OSHA inspection team. OSHA sought another court order although uncertain as to how to proceed in the matter. Extensive discussions resulted in an arrangement between OSHA and the Corps of Engineers with the Corps directing the prime contractor to allow the inspection to occur with employee representatives accompanying the inspection team.

Issues of worker acute illness when a large number of partially filled drums were uncovered in a "clean" zone, compliance with many requirements of 1910.120, excessive levels of and the inability to adequately monitor mercury and dimethyl mercury, results of analysis of samples taken near but outside the site showing high levels of mercury, and failure to develop a coordinated emergency response plan with the local community resulted in nearly all sub-contractors, the prime, the Corps, and EPA being cited by OSHA and closure of the site for over 6 months. The time period encompassed by this case was over a year in duration.

Baird-McGuire; Holbrook, Massachusetts

This site employees both a ground water treatment and incineration approach to remediation. The area upon which the treatment plant was to be constructed is immediately contiguous to the contaminated zone and decon pad but was, none the less, termed clean in the specifications thus not coming under the provisions of 1910.120. Once completed, however, the Plant must be operated under 1910.120 provisions. Workers and their representatives asked the basis for the "clean" designation. Nine months later, after that work area was sampled and analyzed for the first time and the whole site characterization was re-examined and other "clean" areas on the site were declared contaminated, an answer to this simple question was provided. In the meanwhile, hot zone activity could not begin because the local emergency responders were not prepared, lacking training and equipment. During that time the ATSDR Health Assessment Report was released and the incinerator approach discussed with the local community. Both were received with alarm and concern.

Central to resolution of the zone designation and thus 1910.120 compliance issues at this site was a definition of what constitutes "reasonable possibility of exposure" to workers. Such is a requirement under 1910.120(a). An initial meeting with OSHA by worker representatives, workers, the contractor, and the Corps of Engineers resulted in OSHA's being unable to provide any guidance on this issue as compliance policy had not been established by OSHA headquarters. Over four months later, OSHA provided written guidance (P.K. Clark, OSHA letter to J. Moran dated October 3, 1990). In the site characterization re-evaluation a dispersion model was developed to serve as one tool to address this issue.

IV. WORKER PROTECTION ISSUES

The few cases briefly highlighted in the previous section serve as the basis for the focus on worker protection issues specific to activities pertinent to the scope of the OSHA and EPA hazardous waste operations and emergency response standards. The issues of concern which have arisen in our analysis and which are discussed below are not one's uniquely occurring at only an individual site rather they represent issues relevant to all. More importantly perhaps, our initial focus on worker protection issues has clearly demonstrated that these issues are related and central to nearly all hazardous waste site activities including the local community.

Responses to information requests:

One of the most serious problems we have observed was the response to requests for information from workers, worker representatives, and even contractors. Despite the requirements of 1910.120(i) and 1910.120(b)(1)(v) and the broader requirements under the hazard communication regulations (1910.1200 and 1926.59), there is a great reluctance particularly on the part of Federal agencies to respond to requests for information. The simplest question, such as the site characterization data supporting zone designations, has required several months for a response. In other cases, information requests were simply denied and workers, their representatives, and/or contractors had to seek information at the local information repository.

The failure to promptly and professionally respond to even the simplest of information requests or questions was a common failing at each of the hazardous waste sites we have evaluated. The consequences have been deepening of communication problems between site owners/managers and contractors, sub-contractors, and workers; development of a higher level of mistrust; greater costs; and increased concerns from the local communities. It is clear to us that the rights of workers and their representatives to information pertinent to the potential risks workers face on hazardous waste sites is poorly understood by most Federal agencies involved and by most contractors as well.

Many have been surprised at the impact of these failures to communicate when worker protection concerns were voiced and further that the impact has spread beyond the workers on the site to the local community. Projects have been stopped or delayed, costs have unnecessarily increased, public and worker confidence has been eroded, contractors have been unnecessarily impacted, and concerns have been raised at headquarters level of agencies involved thus creating substantial additional effort and frustration at the agencies field and regional levels.

Fundamental to the reasons for the reaction to these issues is the increased awareness principally though the required 1910.120 training requirements and OSHA's hazard communication standards by workers and worker representatives of the potential hazards associated with uncontrolled hazardous waste site work. Safety hazards have long been recognized in the construction industry with little recognition of the health hazards associated with such work. This has begun to change with the implementation of the worker right-to-know requirements under the OSHA Hazard Communication regulations. A similar increased awareness is developing at the public level as well, as a consequence of the community right-to-know SARA Title III requirements and the Community Relations Plan required by EPA for NPL site remediation and longer term removal projects.

While hazardous waste site risk assessment has become a sophisticated science and risk management has reasonably well understood dimensions as embodied within 1910.120, our abilities at effective risk communications with workers, contractors, emergency responders, and local communities is terribly inadequate. Where a minor risk communication problem can begin and spread to large dimensions is when worker protection concerns are not adequately addressed when first raised.

Worker representatives:

While responses to requests for information or to questions from worker has been a significant problem, the problem for representatives of such workers has been even more difficult. Worker representatives have been denied access to hazardous waste sites on which the workers they represent work. Access denial has been to the support zone area containing site offices, not just the operating areas on the site despite the fact that such representatives have the proper training although such is not required to enter the support zone. Representatives have likewise, been denied access to information such as Site Safety and Health Plans, Site Characterization Reports, participation in OSHA walk-around inspections, and the like.

Much of the basis for this problem arises from the apparent fact that most Federal agencies and many contractors are simply unaware of the rights worker representatives have under the OSHAct to act in behalf of the workers they represent. Further, when a worker raises a safety and health concern to his or her representative, that representative not only has a moral and ethical burden to address the concern, but a legal one as well. Denial of worker representative participation in safety and health issues is not only a violation of OSHA regulations but such serves to escalate concerns among the workers.

Training

The interim 29 CFR 1910.120 required a minimum of 40 hours of training off-site and 24 hours site-specific for uncontrolled hazardous waste site workers. The final 1910.120 regulations added a 24 hour off-site 8 hour on-site worker training category, although such was not specified in SARA as was the 40 hour requirement. While the on-site distinction between the two categories is blurred at best in actual reality this is compounded by OSHA's failure to provide compliance guidelines. Unfortunately, the general trend is toward employment of only 24 hour trained workers despite the inherent danger in assuming the site to be within OSHA's limits for such workers.

In addition to the dimension of the training issue noted above; owners, site-managers, and contractors have the added problem that no criteria exists, with regard to training program content, curriculum, trainer provider requirements, testing, and the like. Those issuing specifications, therefore, have little to require except minimum training hours and the broad list of issues to be addressed as contained in 1910.120.

The consequences of these issues are that a broad range of worker and supervisor competency and proficiency exists on hazardous waste sites. In cases where well trained and poorly trained workers have been employed at the same site, a large disparity exits related to emergency response actions, personal protective practices, worker practices and procedures, etc. This has resulted in well trained workers in Level C equipment working alongside poorly trained workers in Level D gear who were suffering acute irritation responses and poorly trained workers using inappropriate respiratory protection when faced with an acute exposure situation.

1910.120 Regulations:

The 1910.120 regulations were mandated by Congress in SARA. Initially issued as interim regulations on Dec. 19, 1986, the final regulations became effective March 6, 1990. Despite the fact that 1910.120 represents a reasonably broad based regulation unlike most other OSHA regulations and that it establishes regulatory compliance requirements in a unique construction setting, no compliance guideline or directive yet exists.

This is a particularly relevant issue as much of the 1910.120 standard is in performance language. Absent specific compliance guidelines or directives enforcement is extremely difficult. For example, 1910.120 requires that a confined space program be part of the site safety and health plan. In an actual case OSHA was unwilling to cite a contractor for not having a confined space program because the contractor stated that no worker would enter a confined space thus on such procedure was required in the Plan. 1910.120 does not offer this option, however. In another instance, the confined space program was incorrect and indeed a threat to worker safety. Again OSHA refused to cite on the basis of the fact that, in accordance with 1910.120, the contractor did indeed have a written confined space program even though it was incorrect. The problem is that while 1910.120 requires several procedural plans such as for Confined Spaces, the only criteria as to the content of such is contained in references to the standard which are not enforceable per se.

Similar problems have occurred with the required heat stress program. In that instance a contractors heat stress program involved workers weighing "in" in the morning when they started work and weighing "out" at the end of the day. Clearly the purpose of a heat stress management program is to prevent acute heat illness especially heat stroke which can occur quickly and be life threatening. The program noted above completely failed to provide adequate protection for the workers but OSHA did not cite the contractor.

OSHA, while still failing to have a 1910.120 compliance guideline or directive, has been interpreting the standard on a request-by-request basis. In June, 1990 OSHA issued an interpretation of 1910.120 which stated that hazardous waste sites could have areas which could be designated clean and not, therefore, require compliance with 1910.120. In October, 1990 OSHA issued a policy statement with regard to the interpretation of "reasonable possibility of exposure" which keyed that determination to the definition of "exposed" in the hazard communication standard. That policy however, then went on for several paragraphs explaining further what "exposed" meant to OSHA. The result is very confusing and remains so yet such is critical to worker protection requirements in Site Safety and Health Plans, Specifications, and the like.

At best, there is tremendous confusion in the field especially between site owners, managers, contractors, and workers with regard to the specific requirements of 1910.120. OSHA's fragmentary interpretation of the standard presents a less than coherent approach and often raises more questions than it resolves. Further, where OSHA has been requested to assist in such interpretations in the field response has been poor. In one specific instance OSHA simply refused to provide any guidance whatever to a group consisting of labor, contractor, and site manager. This presents serious problems to those writing specifications, managing sites, contractors, and workers as there is no clear, common basis for decision making.

Enforcement:

Enforcement of the 1910.120 regulations is the responsibility of OSHA. OSHA's failure however to issue compliance guidelines or directives has resulted in other Federal agencies and State agencies having to assume this burden. For example, on EPA managed superfund sites, EPA has had to establish it's interpretation and rules with regard to 1910.120. Likewise States which are managing superfund site activities have had to respond to these interpretation issues at the state level. At least two OSHA State Plan States in promulgating their State specific version of 1910.120 dealt with some of these issues. For example Alaska removed the scope qualifier "reasonable possibility of exposure" and required that all "in scope" operations comply with the standard. Training issues were clarified in both the Alaska and Washington regulations. In that regard, Federal OSHA interceded resulting in Washington changing their regulations to comply with Federal OSHA 1910.120. The new Commissioner of Labor in Alaska announced in March, 1991 that the State version of 1910.120 would be rolled back to the Federal Standard.

OSHA's compliance staff is suffering from a lack of guidance on this standard thus enforcement is vague and not uniform. When specific guidance is requested from field offices, the result is all to often "no guidance". In other instances, the OSHA area office is unable to provide an inspector when a complaint has been filled.

Emergency Response:

29CFR1910.120 requires that coordination occur with the local community with regard to emergencies which might occur on a hazardous waste site. The concept is to link SARA Title I and III at the local site level. A hazardous waste site contractor may provide for on-site emergency response activities thus negating the need to call upon the local emergency responders in the event of an emergency. In most instances, however, the site emergency response is usually an emergency alarm and evacuation approach with a call to the local emergency response group. Clearly, in that approach, coordination with local emergency responders and emergency medical care facilities is required in order to be prepared to respond to worker injury or acute illness events or other site emergencies. In every case with which we are familiar, the coordination with the local emergency response entity has been a source of extreme confusion, problems, and difficulty. In every instance, the local emergency response group was not properly trained or equipped to respond to an emergency at the site. Further, coordination with the local emergency response group always occurred very late in the site activity schedule often resulting in suspension of work at the site until the coordination, training, and equipping problems could be worked out. Added to this problem is the fact that no criteria exists from OSHA as to the content of emergency response training for hazardous waste site emergencies and the further fact that OSHA excluded emergency responders from the 1910.120 training accreditation proposed rule.

Interagency Coordination:

The typical EPA superfund site directly involves at least EPA, The Corps of Engineers, and OSHA from the Federal agency perspective. State and local governments are involved as well, of course. Federal agency activities specific to hazardous waste sites are normally conducted through the respective agencies regional or area offices. EPA's mandate is to protect the public health and welfare.

The Corps essentially works for EPA as site construction managers and are responsible for the preparation and issuance of solicitations and the awarding of contracts based upon previous site specific work such as the RI/FS which is normally conducted by a contractor to EPA. OSHA is responsible for the enforcement of the site worker protection standards under 1910.120. Each agency has a separate and distinct mission and area of responsibility. In theory the areas of responsibility between EPA and OSHA do not overlap nor are there major gaps in site specific responsibilities as the Corps or other site construction management firm serves as the point where the EPA public and the OSHA worker areas come together.In reality the relationship between the Corps or the site manager and EPA is not well defined with regard to safety and health issues particularly where problems arise or decisions need to be made. As is usually the case in the construction setting, the site manager acts in behalf of the owner (EPA) to meet schedules and cost criteria. Major issues arise when changes may be required that effect cost or schedule especially where safety and health issues are involved which is further exacerbated by the failure of OSHA to provide specific guidance or assistance. Compounding this problem from EPA's perspective is the requirement that EPA serves as the principal contact with the local community. When site issues arise which are not effectively handled, EPA has to deal with the community issues which often arise.

Site Safety and Health Plan Approach:

Hazardous waste site remediation solicitations take, essentially, one of two basic forms. In the first, zone designations and worker protection criteria such as levels of PPE are specified based upon the site characterization report, RI/FS, the ROD and similar information. In the second, the information is provided but the bidding contractor is responsible for specifying the details in the bid response. The first method is often preferred because it narrows the cost spread in the bid responses and simplifies the bid review process. However, when changing site conditions or questions regarding the basis for such decisions arise the resolution to these are frequently time consuming, difficult, and tend to focus more on the costs and contract modifications paperwork required than on the fundamental worker protection issues which are involved. In addition, as is the case at Baird-McGuire, where the site characterization and RI/FS were inadequate with regard to providing all of the site characterization data in a complete manner the resolution of these issues becomes extremely complex and beyond the purview of the site manager.

Carcinogens:

Unlike NIOSH and other regulatory agencies, OSHA exposure regulations often, especially for carcinogens such as asbestos, establish exposure limits at which significant lifetime risk is believed to be present to those workers exposed. Many hazardous waste sites contain known or suspected carcinogens. Construction workers, normally unaccustomed to a focus on health concerns as the construction industry in general sees injury as it major risk, do not understand the less than full commitment to protecting them from exposures to such materials in waste site operations. Similar concerns arise at the local community level with regard to the potential risk associated with the presence of carcinogens on a waste site. This concern is greatly heightened, among workers and the public, when ATSDR Health Assessments Reports are released related to sites which contain carcinogens.

This problem is further exacerbated by insensitive site managers who, in discussions with contractors seeking reimbursement for resources spent in upgrading worker protection, claim the contractor has been over-protective of workers health. The only acceptable view with regard to exposures to carcinogens, from a worker and public health protection perspective, is that no preventable exposure should be allowed to occur.

Hierarchy of Control:

The philosophy behind 1910.120 is very poorly understood from one fundamental perspective. 1910.120 essentially requires that worker protection levels be DECREASED as information becomes available to support such a determination. The 1910.120 approach requires that workers be protected at least to the Level B ensemble when hazardous materials are known to be present and the level of exposure is not known or can not be estimated with a high degree of confidence sufficient, for instance, to comply with the NIOSH Respirator Decision Logic for respiratory protection selection. In every case with which we are familiar, the opposite has occurred. That is, workers were in a lower level of protection when exposure problems developed which exceeded the capacity of their protective ensembles. Subsequently, the level of protection was increased.

V. CONCLUSIONS: LESSONS LEARNED

Based upon over two years of very active and in-depth activity at a number of our nations hazardous waste sites many of which have involved literally months of effort at a single site to resolve even the simplest of issues, we offer the following conclusions with regard to current activities pursuant to 29CFR1910.120 and specifically the worker protection aspects of that standard and such work:

1. SARA established a unique and comprehensive approach to worker and public protection associated with potential exposures arising from hazardous materials including those on uncontrolled hazardous waste sites. While that unique landmark legislation is fully encompassing of worker protection, the actual implementation of the intent of Congress is nested in several federal regulatory agencies whose jurisdictional boundaries are often not clear and precise on hazardous waste sites. While these agencies have designated regulatory responsibilities it has become increasingly evident that they were less than able to effectively communicate with each other. Further, it is evident that no one agency is "in charge" of hazardous waste operations and, thus, no one agency is "accountable". EPA, through the Special Task Force on superfund Safety and Health, has recognized this deficiency and attempted to close this gap. Recent participation by OSHA and the Corps in the Task Force is a useful emerging aspect of these areas.

2. It is increasingly evident that worker protection on hazardous waste sites is not just one of many basic items which must be completed on a project check list. Such worker protection issues are central to the hazardous waste site actively, are dynamic and are demanding of far more focused attention and concern than has been evidenced in all of the sites with which we have been involved. Failure to address worker protection concerns can have far reaching, costly effects. More than ever before, effective worker protection programs offer the opportunity for workers to be participants and partners in an important National undertaking.

3. OSHA simply has not taken the 29CFR1910.120 regulations for which it is responsible with any degree of commitment. The enforcement activity even after three years of 1910.120 is spotty and confused at best, no doubt due to the lack of compliance guidance. EPA, the Corps., labor organizations, and contractors have been frustrated by OSHA's lack of response to issues raised about 1910.120. OSHA has, furthermore, confused the intent of these regulations by issuing policy statements, Instructions, and local interpretations which have served to create confusion rather than resolve it. Indeed, many aspects of 1910.120 written in the 1980's popular "performance" language are unenforceably vague which compounds the OSHA's compliance staffs difficulties and confuses those seeking to interpret and comply with the standard.

4. Currently no criteria exists upon which routine decision making can be based with regard to what constitutes reasonable possibility of worker exposures. This deficiency, combined with the added confusion caused by OSHA which allows clean areas on hazardous waste sites and permits a lesser trained worker category, creates a significant potential for worker exposures and confuses any attendant decision making process. This is compounded by the common approach of increasing the level of worker protection at waste sites as exposures are confirmed rather than the approach required by the pro-active 1910.120. The recent development of a modeling approach by EPA and the Corps of Engineers offers the potential for coming to technical grips with the "reasonable possibility of exposure" issue.

5. The frequent approach of specifying levels of worker protection required in specification packages is deficient in that, as currently employed, the basis for such decisions is not presented and can not be verified by the bidder. Subsequent changes based upon emerging site data is, as a consequence, complex and difficult. The inclusion of requirements for designers to include site characterization specifics would help resolve this problem.

6. Workers and their representatives have a right to ask questions with regard to worker safety and health issues. The norm is no response or an incomplete response. When pursed, that such responses often take weeks or months is totally unacceptable. Workers and their representatives have a right to a courteous, prompt, and complete response to any questions raised with regard to worker safety and health issues. Indeed, much of what they frequently ask should, under 1910.120 and 1926.59, be routinely provided without the need to make a request.

7. The adequacy of worker and supervisor training programs is presently unknown and no criteria which such programs must meet is currently being used in specifications for hazardous waste work. OSHA has delayed its response in this regard despite the SARA mandate. In the interim, the NIEHS National Workshop Report provides the only guidance and it is essentially not used. As a consequence, the degree of worker and supervisor proficiency and competency varies widely resulting in increased risk to many workers and a potential threat to nearby communities. This is most evident in "open" annual refresher training programs, often conducted by the NIOSH ERC's, where the broad range of core training proficiency, or lack thereof, is very evident.

8. All to often site characterization reports, RI/FS reports, and the like are incomplete and do not contain all of the information pertinent to an effective worker safety and health program. Frequently, the identification of all contaminants found on the site and the sample locations are boiled down to "critical contaminants" and "zone boundaries". This information is further reduced and condensed in the solicitation package. The result is that all to often critical information is excluded, critical contaminant and sample locations are lost, and the basis for ongoing site activities is lacking as the focus remains on the few critical contaminants rather than the full list of known contaminants. A contractor bidding from such a solicitation package may indeed submit what is believed to be a valid proposal only to find after work begins that the situation is far different than was believed. In the process and the often protracted procedures required for changes, worker protection is at risk.

9. Based upon the current OSHA confusing information on clean zones and what constitutes reasonable possibility of worker exposure, zone designations on hazardous waste sites is very suspect. Worker protection is a key issue here as the trend portrayed by OSHA is to loosen such site criteria. The inclusion of clean areas requiring no 1910.120 training (but perhaps other training), a 24 hour worker training category, and a 40 hour worker training category

has already caused great confusion on waste sites which is being compounded by the zones and possibility of exposure issues.

10. Emergency responders remain a serious issue at hazardous waste sites. Two issues are of importance. First, appropriate and adequate response to protect workers and the public from the hazards associated with an on-site emergency. Second, prompt and professional response to the site in response to the severe injury or illness of a site worker. Both of these issues present a serious threat.

11. Superfund remediation activities are expensive and time consuming. Yet it appears that once the remediation work begins, cost control becomes extremely important and is vigorously enforced by the site manager. In this regard, hazardous waste site work is not unlike the typical construction contract work; i.e., if it isn't in the contract, you don't get paid for it. Worker protection suffers under this approach as appropriate worker protection measures can only be justified in these terms if the problem one was seeking to prevent occurs because the desired protective approach was not used. The view expressed by at least two site managers that such issues often represent overconcern for the workers is dangerous: to workers.

12. Hazardous waste site remediation work often involves three Federal agencies but at a minimum involves at least an environmental government agency and an occupational governmental agency. These two governmental entities do not share overlap in areas of responsibility. The occupational entity governs the site and the environmental the area outside the site. They deal with different regulatory philosophies, differing target populations, differing risk levels at which they regulate, different enforcement procedures, widely different enforcement powers, etc., etc,. Yet much of what the environmental agencies require for site activities affects workers and what is done on the site in response to occupational regulations impacts the local community. No one is responsible for these overlap areas and for sorting out the conflicts in worker and public protection which can and do arise. EPA, through the Special Task, is beginning to address these issues.

13. Worker protection is a key aspect of hazardous waste site work. Properly addressed, a safe, productive, and cost effective remediation or removal project can occur which assures the health and wellbeing of the workers involved and the protection of the nearby public. Improperly addressed, worker confidence and public trust can be seriously eroded resulting in a wide range of unnecessary complexities and costs. Not withstanding the lack of details from OSHA which are needed with regard to 1910.120, the technical expertise and resource materials do largely exist to provide effective worker protection. The results of the EPA Task Force efforts and changes the Corps is initiating are critically important indicators of recent progress in addressing these issues. Other hazardous wastes activities would benefit by using this information.

Crisis in the Fire Service

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INTRODUCTION

In addition to the inherent hazards of their work operations fire fighters suffer a number of administrative and management difficulties. These are a result of the unique characteristics of employment, perceived obligations to function in all hazardous conditions, and lack of regulatory support. After all, fire fighters are those people who come when you summon them with a 911 call. Unfortunately, in Kansas City when the fire fighters responded to a construction site fire it was considered routine, although typically hazardous, but it turned out to be tragedy for the families of six fire fighters. Explosives were stored on the site, without any indication of the nature of this class of hazardous material, and when fire detonated it six fire fighters died. Hazardous waste clean up sites represent a class of exposure with a high element of the unknown.

Fire fighters are typically municipal employees or non-compensated individuals (volunteers) with an obligation to function in the same fashion as paid municipal fire fighters. The use of the phrase fire fighter shall include both compensated and non-compensated personnel.

The Fire Service, through their independent efforts, have developed substantial technical advances in the safe remediation of emergency situations. The consolidation of these processes and life saving techniques was greatly advanced by organizations such as the International Association of Fire Fighters and the National Fire Protection Association. The International Association of Fire Fighters has developed a number of training aids, such as audio visual training packages, for use as teaching aids in Hazardous Waste and Material topics. A study conducted by Johns Hopkins University has verified that over 50,000 fire fighters have been trained in the Tier I, First Responder at the Awareness level, program. The IAFF Tier II, Operational Level training program has recently been released and it is anticipated that the training numbers will be as impressive as they are for Tier I. Regulatory and legislative emphasis has traditionally centered on pro-active topics. Building codes and safety and health standards are written with the intention of preventing emergency situations. Dealing with crisis situations has been mostly left to the Fire Service and their own resources.

For many years the traditional role of the fire fighter was to extinguish fires and rescue endangered people. Gradually their role expanded to include all emergency situations, such as homeowners with flooded basements and even rescuing cats from trees. Fire department service charges have been implemented in many communities to discourage the request for frivolous services such as pet rescues. Preventive measure activities were significantly improved by involvement in pro-active goals such as Fire inspections, community training and standards development. While the great traditions of the fire service span over centuries it is only in the past twenty years that the major progress has been accomplished in the emergency medical care provided to victims of emergencies. Formerly injured persons were extricated from the scene and transported to medical treatment facilities. Now victims are rescued, receive medical stabilization at the site, and are transported in vehicles while providing continuing medical care until arrival at a shock trauma hospital unit. In fact in many communities the crisis is simply a medical emergency and the fire department operates within the framework of the medical care establishment.

The advances in the fire service were quite supportive of other progressive actions dedicated to making the work place, home and general environment safer. These apparently parallel ambitions may now be on a collision course due to the differing concepts involved. EPA developed SARA and included ample provisions for contingencies that may occur during clean up on a hazardous waste site. Title I, Section 126, promulgated requirements for health and safety for employees involved in hazardous waste operations and response to hazardous material incidents. Protection, liaison, communications, and responses within communities were further promulgated in Title III. In both of these programs the fire department was an important integral part of the system.

Yet, in a real world situation the implementation of the elements of these plans fall far short of regulatory intentions. A classic example is the Baird-McGuire Superfund Site in Holbrook, Massachusetts. This site, under the management of EPA and the Corps of Engineers, failed to adequately conduct a comprehensive site characterization study. As a result of considerable urging a recharacterization study was completed and areas previously designated as "clean zone" were reclassified as contaminated.

Even though EPA's own Health and Safety Audit Guidelines clearly stated the need for evaluation of local community response capabilities this was not done. The Holbrook Fire Department is fairly small but has trained all its' personnel at Tier I, Awareness Level. Their statutory responsibility for Emergency Response includes light rescue, heavy rescue, fire suppression and emergency medical services. The Holbrook fire department has neither the resources to provide additional training nor the equipment necessary for a response to the Baird-McGuire site. As the system states "Evaluate the emergency response and medical resources available for hazardous waste site emergencies".

BACKGROUND

OSHA: In 1970 the Occupational Safety and Health Act (PL91-596) was enacted. The OSHAct mandated the minimum standards for safety and health performance. Where states provided their own standards that were at least equivalent to the federal requirements they operated their own programs. Otherwise the federal programs applied. Two important distinctions in the OSHAct dramatically affected the Fire Fighters Service.

COVERAGE: The act excluded coverage (requirements) for state, municipal and local government employees. Subsequently in many states the provisions of the Act did not cover fire fighters.

EMPLOYEES: The act is directed for implementation in the work environment where an employer/employee relationship exists. Non-compensated (volunteer) individuals do not fall under the provisions of the Act.

Although the original OSHAct and standards did not have much impact on the fire service subsequent performance requirements promulgated do dovetail with fire fighter work activities. In addition to OSHA, the Environmental Protection Agency and US Department of Transportation have promulgated safety and health standards that affect the fire service. The standards that were written did not directly address professional fire fighters, and created a new phrase - Emergency Responders. A needs assessment by OSHA justified the development and implementation of new standards dealing with job performance elements that closely paralleled those of the fire fighters. However, fire fighters were not covered by these standards in many states. Standards development resulted in the publication of the following OSHA standards:

29CFR1910.155 (SUBPART L): Standards were published covering private fire departments within that class of industry that maintains an on-site first line of defense. Typically they were known as Fire Brigades but have subsequently been expanded into special teams such as Hazardous Material Response crews, Chemical Spill response teams, etc. This standard deals mainly with fire emergency situations.

29CFR1910.1200: The Hazard Communication standard was promulgated to assure that workers would understand the hazards of the materials they may work with, or be exposed to. Many states enacted legislation with a similar intent which also protects the general population and which is commonly known as the "Right to Know" laws.

29CFR1910.120: This standard was developed in response to identified needs and in collaboration with the Environmental Protection Agency. Commonly referred to as the HAZWOPER standard, it provided requirements for preparation, protection and clean-up processes at hazardous waste sites. Paragraph Q addresses Emergency Response activities which closely parallel the class of activity that may involve fire fighters. In fact, since the OSHA act, and subsequently OSHA standards did not apply to municipal employees it was necessary to instruct EPA to develop a similar standard which would apply to municipal fire fighters. The two standards are identical, it is only the authority for implementation that is different.

TRAINING: A critical element of the standards is a requirement for training. HAZWOPER, Right to Know, and Hazard Communication sections all contain detailed descriptions of the training needed. In the five tiers of competency training required under the HAZWOPER (paragraph Q) standard are specific measurement levels (ie - hours of training) and refresher training.

FIRST RESPONDER - AWARENESS LEVEL: Shall have sufficient training......

FIRST RESPONDER - OPERATIONS LEVEL: Shall have at least eight hours training......

HAZARDOUS MATERIAL SPECIALIST: Shall have at least twenty four hours training..........

HAZARDOUS MATERIAL TECHNICIAN: Shall have at least twenty four hours training............

ON SCENE INCIDENT COMMANDER: Shall have at least twenty four hours training...........

TRAINERS (29CFR1910.120 (q)(7) shall have satisfactorily completed a training course for teaching the subjects, such as the courses offered by the U. S. National Fire Academy, or they shall demonstrate competency via academic credentials and experience of an equivalent nature. For comparison purposes the OSHA Construction Standards require training for asbestos clean-up workers in a course at an EPA Center or training equivalent to that presented by EPA (29CFR1926.58(e)(6)(iii).

A proposal is being developed by OSHA whereby training required by the HAZWOPER standard be via an OSHA certified training course. This would exclude the training required under 29CFR1910.120(q) in that OSHA has announced an intention to NOT review or certify training courses for First Responders (fire fighters). Of course it is possible that OSHA recognizes the historical competency in emergency response situations that the fire fighter possesses. Subsequently the experience and training that fire fighters possess prior to undertaking of the curriculum delineated in the OSHA standard places them in an advantageous position. Although the Fire Service has utilized protocols, established SOP's, and generally conducted Emergency Response activities for years the new emphasis on chemical emergencies is treated as if it is a new concept.

EMERGENCY RESPONSE ACTIVITIES

The Fire Service has generally kept current with technology developments in all areas of emergency response. Consider the following activities that were in place long before the requirements of SARA and HAZWOPER were promulgated in 1986.

- o EMERGENCY MEDICAL CARE: In almost every community the emergency response medical care provisions have been maintained by the Fire Department. Where the fire department formerly provided simply transport (ambulance) services they now provide on-site medical care, in transit medical care and transportation of the victims. Staffing has now improved from simple ambulance drivers to Emergency Medical Service Technicians (EMT) to Para-medics and communication systems have developed access to shock trauma units.

- o SPECIALIZED RESPONSE UNITS: Many municipal fire departments developed special units for responding to emergencies such as trench failures and transportation incidents involving chemicals. Where applicable the municipalities have maintained response units capable on reacting to waterway incidents, helicopter units, and the like.

- o INCIDENT COMMAND SYSTEM: An integral part of the fire service is the System management of all incidents within the structure of an Incident Command System. It establishes the protocols and Standard Operating Procedures (SOPs) to be followed in an emergency response situation. As part of the system it ties in to other activities such as Pre-incident planning, Recognition and Identification, Training, etc.

- o PRE-INCIDENT PLANNING: In a way this might be described in the same vernacular as the EPA developed site characterization process. It is a substantial effort - fire fighters do a lot more than just battle fires. Of course this effort is on a community scale. In the simplest of methods a pre-incident plan might state that all alarms at hospitals or hotels would involve response by two engine companies and a ladder company. The fire service also has a process called "pre-firing a building". By simulating various incidents the response protocols are designed and if the actual incident takes place the plan, personnel and equipment are up and functioning without delay. System safety processes such as fault tree and failure effect mode are adaptable to analyzing and developing response protocols. While hazardous waste sites employ a process plan for clean-up which contains the elements of safety, health and community protection, the emergency responder must deal with potentials which are saddled with uncertainties. Pre-incident planning turns possible chaos into a manageable response activity.

  An emergency response is not a simple containment or extinguishment function. Other considerations are included in the pre-incident plan. The following case scenario will illustrate the essential need to operate under a pre-plan concept supported with a high level of data accumulation.

SHERWIN-WILLIAMS FIRE

A huge complex operated by a major paint manufacturing firm caught fire. Although the building was protected with sprinklers and major fire divisions were provided with standard separations the fire grew unabated. When the first responding units arrived on the property there was substantial involvement in the structure and contents. A major component in the fuel was combustible and flammable liquids in both large and small quantity containers. As the heat caused rupture of the containers the liquids spread like a lake, under fire doors and into adjacent fire divisions. The ignition traveled along with the fuel and soon the total building was involved.

Traditionally the fire department will give priority to rescue of endangered personnel, next establish a containment process and finally enter into the extinguishment phase of the operation. The first two goals were quickly accomplished but extinguishment posed a major problem. There were enormous quantities of unburned solvents serving to fuel the continuing fire. The complex was located on a parcel of land with a major influence on the water shed and next to the body of water that provided municipal water supplies. Should the fire department apply hose streams to the fire the water would serve to transport the contaminant into the community water supply; or at least dilute it so it would enter into the ground, unburned, and affect the water shed properties. Subsequently the decision was made to let the fire burn out and exercise a containment protocol. Naturally, the final result was the total loss of the major buildings and stock at this complex and a dollar loss in the vicinity of One Hundred Million Dollars.

The fire department's sensitivity to issues other than the traditionally steeped process of attacking and extinguishing fires is a tribute to their flexibility in developing protocols concerned with community and environmental factors. Where it was common for the fire department to dispatch a pumper to the scene of a vehicle accident simply to hose down the roadway to remove spilled fuel or other contaminants they now conduct an evaluation to determine if the contaminant should be washed away or contained.

The Fire Service has clearly demonstrated a positive reactive progress in adjusting their protocols, processes and responses in order to keep in step with both fire fighter safety and environmental concerns. It is somewhat enigmatic that OSHA develops a standard for an industry that it did not previously regulate, and even after publishing the standard (29CFR1910.120(q)) it is necessary for EPA to publish the same standard in order that it would apply to most fire fighters. Most large municipal fire departments have followed the concepts of what OSHA has termed voluntary compliance. The Voluntary Protection Program (VPP) activity encouraged by OSHA is exactly what has been happening in many major Fire Departments throughout the country. However, this process has been going on for years - long before OSHA was even created.

Fire Departments, and Police Departments, have a structured personnel recruitment policy. Even after selection the fire fighter must undergo extensive training and orientation. During the history of the fire fighter's employment they are required to continue with refresher and upgrading training. Promotions frequently involve additional training. With the development of Hazardous Materials Response Teams members were exposed to frequent detailed training in most, probably all, of the elements covered in the OSHA, EPA and FEMA prerogatives.

The growth of competency and proficiency of fire fighters has not been in an isolated environment. Collaboration and assistance by Federal Agencies such as the National Fire Service Academy and FEMA has been important and valuable. Development of structured training programs with funding from the National Institute of Environmental Health Sciences(NIEHS) served to codify and structure many of the training programs being utilized by the various fire departments. Unfortunately, there are parallel developments by other groups with similar goals but somewhat different approaches.

Many years ago this country determined that standards were essential and organizations, such as The Bureau of Standards, were created to develop standards for screw threads, nails, lumber sizes, etc. In the development of standards for Emergency Response we have an emerging science where different groups do almost the same thing but call it some thing else. In 1984 the Fire Fighters identified the need to develop a standard for Competency of Responders to Hazardous Material Incidents and Recommended Practices for Responding to those incidents (NFPA472/NFPA471). These standards were finalized and approved by NFPA in 1988. The process within NFPA and ANSI is to continue review and republish new versions every three to five years. Subsequently NFPA 472-1989 indicates by date the particular version in use. Contrasting that are the OSHA Standards with their review and updating system running years behind changing technology. Consider the National Electrical Code - OSHA adopted the 1970 issue, which remained in force for the next fifteen years, even though during that period there were five major reissues of the standard by ANSI/NFPA.

During the period that NFPA was developing NFPA 471 & NFPA 472, NIOSH was developing a Guidance Manual along the same lines in collaboration with OSHA, USCG and EPA. At the same time OSHA was developing the HAZWOPER standard. The undeniable value of each of these documents is only clouded by the use of differing terminology to say the same thing. Illustrations are:

OSHA/EPA	FIRE FIGHTERS
Vapor Protective suit	Level A
Splash Protective suit with SCBA	Level B
Splash Protective suit	Level C*
Exclusion Zone	Hot Zone
Decontamination Reduction Zone	Warm Zone
Support Zone	Cold Zone

* Level C involves the use of protective clothing and an Air Purifying Respirator (APR). Fire fighters rarely use APRs.

EMERGENCY RESPONSE TO HAZARDOUS WASTE SITES

Emergency response to an unregulated hazardous waste remediation site is an activity that may be safely accomplished. Conditions that generally are the basis for classification as a hazardous waste site are fully investigated. This data is essential to three processes used by the fire department. In responding to an emergency situation the fire department first completes a Recognition and Identification (R&I) operation. Extensive training has taken place to develop competency in this activity. Recognition and Identification is a process whereby the fire department will evaluate the available data and conditions at the emergency scene. In preparation for this the fire fighters are trained in a variety of technical subjects such as:

o Vehicle classifications, shapes, markings, etc: The shape of a tank car is an indicator of the commodity that may be involved. Department of Transportation markings and the UN Classification System placards will indicate the class of commodity that a vehicle is transporting.

o NFPA Marking System (NFPA 704) is a system whereby hazardous materials within a fixed establishment are identified indicating their hazard classification and severity.

o Basic chemistry, reactive qualities of chemicals and warning characteristics of hazardous materials are categories of learning that are essential to the fire fighter.

The list of topics is endless and varies from community to community. Pre-incident planning adds information to the data matrix which guides the fire fighter in recognition and identification. Sometimes the name of a company will suggest the product line, such as Xpolsives Inc would recommend caution in responding to the plant or vehicle emergency. However, AAA Manufacturing Inc gives little warning as to the product and materials and this data might be available in the pre-incident plan.

Obviously, the Site Characterization work completed on a Hazardous Waste site is an excellent resource for the Fire Department Recognition and Identification process. It is essential for pre-incident planning and Incident Management System (IMS) program implementation that all the data is available and acted on. Typical emergency response incidents have visible conditions alerting the fire fighters to the nature of the hazard. Fire, smoke, vapor, overturned tank truck, spilled liquid and even odor are warning signs. However, a response to a hazardous waste remediation site might be a medical emergency and the classic warning signs might not be present. Knowledge of the availability of site characterization studies and the presence of a Site Specific Safety Program will dramatically influence the fire fighter's decision making abilities.

Another process commonly utilized by the Fire Department is Pre-Incident planning. Although it is not possible to anticipate every class of emergency that may take place in a community the fire department utilizes a system safety concept to catalogue most of the potential emergency situations. Information is gathered from various sources and activities to develop the pre-incident plan. EPA with all their sophistication in developing protocols fails to use the local resources. As the Baird-McGuire clean up plans grew no effort was made to develop liaison with the Holbrook Fire Department. A community liaison officer would have gone a long way in ensuring that should a need arise for emergency assistance that the resources would be suitable for the site. Funding assistance is available to local communities under Part 310 (CERCLA). In the case at Holbrook a complete pre-incident plan would have identified the need for additional training and equipment.

Community inspection programs are intended to gather information about the nature of hazard levels in the plants, stores, etc. Naturally there is an added benefit in ferreting out apparent violations of local community rules and regulations.

Local rules and regulations frequently require businesses to obtain permits for storage and use of hazardous materials. For many years this permit system applied mainly to flammable and combustible liquids. With the increased environmental concerns, and recognition of other hazard classes such as poison gas, the nature of pre-incident planning escalated. EPA published standards for reporting of chemicals that have high hazard classifications and the minimum quantities that will trigger the reporting requirements. The intention of these regulations is to make the information available to the local Fire Departments and Emergency/Civil Defense organizations.

Liaison with local high risk facilities establishes a communication link. Naturally the fire department has community maps but in some instances, such as a Health Care Facility, a more detailed site plan would be needed. These locations might have separate buildings which contain storage of hazardous materials, even a hazardous waste staging area, and other structures requiring a high priority of rescue and evacuation. Many of us might think that house numbering is a convenience for visitors, deliveries, etc; but, it actually is a fire code requirement to assist the emergency responder to quickly identify the location where an emergency exists. Where a large facility might have only one street number there is a requirement to number each building on the site.

Many communities have a system of permitting facilities with fire protection devices and alarm systems to connect to the fire department. Pre-planning will take into consideration the nature of the protection and locations within a facility. While the facility might have a zone alarm system the signal to the fire department is basically a location alarm. Subsequently the pre-plan may designate the central location for the alarm panel to be the first area to be reached when responding to an alarm notice. Obviously if the emergency is quite visible (smoke, fire, etc) this may change immediately on arrival at the scene. In most areas when the water supply is temporarily cut off for repairs, or sprinklers are shut off for service the facility is required to report this to the fire department. The fire department will then place a special tag on the facility plan to indicate a modification in the pre-plan.

Pre-planning is an integral part of fire department planning. Naturally it includes response protocols, and a priority system. Staging of equipment is important. When the emergency apparatus arrives at the scene the pumper would position it self in direct line with the municipal water supply (hydrants) and siamese building connections. Staging of the fire apparatus is an important element so that madly arriving fire engines wouldn't block access and egress from the site. It certainly would be ineffective if a fire engine blocked the entrance to a site. Every detail is planned in advance to maximize the effectiveness of the response activities. In an emergency situation time is always the greatest enemy. A quick response, well planned and executed will minimize the extent of the emergency.

The many elements involved in pre-incident planning are intended to dovetail with the operations of the fire department. Extensive training is undertaken, on a continuing basis, by all fire fighters to develop proficiency in emergency response and the pro-active functions. As the emergency starts to develop the next Fire Department system is implemented. Small or large, any incident needs a management system. In the fire service this is termed Incident Management System (IMS); occasionally also known as the Incident Command System (ICS).

The purpose of an Incident Management System is to provide structure and coordination to the management of emergency incident operations in order to provide for the safety and health of fire department members and others involved in the incident. The system consists of four major components; each with integral sub-elements with a proven history of effectiveness.

ADMINISTRATION: The overall fire department plan places the management of an IMS in the Administrative function. An overall administrative activity involves all the day to day operation of the fire department and includes elements such as recruitment, training, management of benefit programs, etc. The implementation of the IMS is directed as an administrative requirement.

STRUCTURE: The fire department will develop a plan taking into consideration the size and complexity of the available resources. It will take into consideration such elements as COMMAND STRUCTURE, TRAINING, INTERAGENCY COORDINATION and other QUALIFYING FACTORS. The flexibility of the program is obvious. Larger fire departments with many tiers in the command structure would have the plan developed to take into account the First Response command structure and subsequent changes in command as other senior officers might arrive on the scene. In localities where there may be hazardous waste remediation sites, facilities controlled by government agencies and other local Emergency or Disaster Councils the interagency coordination with these groups is worked out in advance.

Many years ago, in the early days of World War II the world's largest Ocean going liner, the Normandie, was at a pier in New York City undergoing renovation. A welding torch started a small fire below decks. Unfortunately, there was no IMS in effect and a great deal of time was lost in coordinating with the Coast Guard and Fire department. There was a lengthy period of time that discussions took place as to who would have the overall command authority. As a result the ship was lost and laid on the bottom at the pier for the remainder of the war.

The EPA clean up site does not become an Island in the Sky. Although the Site Clean-up program is fairly structured with an identified command structure the variables that will take place during an emergency incident must provide for partial transfer of command in pre-identified areas. At the Browns Ferry Nuclear Plant fire many years ago the local fire department arrived quickly, laid hose lines and prepared to conduct suppression operations. However, the plant personnel insisted that water should not be applied to the fire. The fire continued to grow as dialogue became heated between the fire fighters and plant management. The facility was almost lost, with some significant radiation contamination possible, when the major decisions were assigned to the fire department and the incident was terminated without a major nuclear incident.

A natural coordination system that exists in almost every instance is the collaboration with the local police department in traffic control and community evacuation. A Liaison is established to assure that requests for assistance are coordinated.

The Incident Command System shall provide a series of supervisory levels that are available for implementation to create a command structure. Naturally it will be dependent on the size of the department. The modular sectioning of this structure will allow for application of only those series of supervisory levels that may be required for a particular incident.

The major system component is at the Operational Level. The operational level consists of those units that are directly involved in rescue, suppression and other primary missions. Part of the operational level are the HAZMAT teams, EMS (ambulance) and specialty teams such as a support function for refilling SCBA bottles. The HAZMAT team has both operational and support functions. The support function would be involved in decontamination and logistical support. The basic system components are:

- Operational
- Incident Commander
- Command Staff
- Planning functions
- Logistics
- Communications
- Staging
- Finance

The Incident Commander shall be responsible for the overall coordination and direction of all activities at the incident scene or the major liaison where management of an incident is controlled by another agency - such as EPA or the Coast Guard. In any event the Incident Commander is in charge of all fire department personnel and in a coordinated effort he will direct his personnel. His command staff will consist of supervisory personnel in charge of operational components and planning, logistics, communications, staging and finance.

The Fire Department administrative, management and operational activities have been tested and proven on a daily basis throughout the United States. The system approach works well on small incidents, such as a home fire, as well at larger incidents at chemical plants. To date the typical response to hazardous waste sites has been for medical assistance. On these sites ordinary injuries occur and those incidents of heat exhaustion and heat stroke take place as a result of working in protective clothing.

There is a potential for a major incident at a hazardous waste remediation site and pre-planning is essential. Most sites consist of ground and water contamination. The remediation process consists of collecting and disposing of the hazardous chemicals. In this process there is a possibility of bringing the contaminant to a collection area, increasing concentration levels and thereby increasing the potential for area involvement.

The Fire Department has one final process in incident management. Small incidents are ended with the Incident Termination - that being the time when all activities are concluded and they leave the scene. The Termination Process also includes some post-incident activities. Information is collected on the incident and processed for various follow up functions. One is simply for debriefing purposes - the operational teams, etc, will review the incident to evaluate how it went. Improvements and changes detected as a result of a review of the incident can then be incorporated into the training process, review of Recognition and Identification, and Pre-Incident planning systems to determine if they were effective.

In some communities there is a fire department charge for services and ambulance (EMT) services. The Termination Process will include documenting the incident to assure that charges are made and submitted. An interesting old law is the Fire Fighter's Rule. In many states the fire fighter who is injured while responding to an emergency incident cannot sue the individual or entity whose negligence caused the incident. There are some exceptions to the rule, notably those injuries or fatalities that may take place as the result of a negligent release of a hazardous substance. In the Termination Process a compilation would be completed regarding the expenses of dealing with the incident. Where negligence is of such a nature as to grossly disregard responsibilities the fire department would be prepared to document the charges and submit a bill to the offending parties. Fire departments are a public service supported by the tax dollars but irresponsible behavior which drains the resources of a community must be paid back. Many communities have adopted a rule that if your fire alarm keeps malfunctioning and sending out false alarms you will be penalized $50, perhaps more, after the second false alarm.

The system approach used in the fire service is very effective. Protocols are developed for every category of emergency including those anticipated at a hazardous waste remediation site. "Fools rush in where heros fear to tread". An entry to an emergency incident can be accomplished safely when all data is available and a pre-incident plan coupled with an Incident Command System is employed. Fire fighters are trained, competent experts in their field. Three fire fighters died in a high rise fire in Philadelphia in February 1991. The unexpected took place in that fire. Elevators didn't work, water pumps failed or were out of service and the difficulties grew because the building was not in compliance with local ordinances. It is sad to hear of these stories; explosions in Kansas City, High-Rise fires in Philadelphia; but it is time for recognition that the fire department is more than a group of people at the end of a 911 telephone call. A system safety approach deals with probability and possibility. The most effective program reduces possibility and probability to a low level; but, incidents should not be unexpected, just unwanted.

VI. POLICY/MANAGEMENT ISSUES

Superfund-Program Standardization to Accelerate Remedial Design and Remedial Action at NPL Sites

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INTRODUCTION

In response to persistent criticism regarding the slow pace of the Superfund Remedial Program, EPA has developed the Alternative Remedial Contracting Strategy Contracts (ARCS) to accelerate the progress of the remedial program and maintain control of project costs while ensuring the protection of human health and the environment through effective, high quality response actions. Another goal of the ARCS contracts is the rapid preparation and assembly of bid packages to complete the remedial design and to expedite remedial actions.

The concept of Superfund Program Standardization (SPS) is to support the attainment of the ARCS common goals to optimize quality, timeliness and cost-efficiency of the remedial response program. EPA Region II, under the ARCS II Program, has developed various generic technical documents and drawings to facilitate the preparation of documents and drawings efficiently and cost-effectively. The standardized documents will technically provide consistency and uniformity of general requirements and eliminate duplication and uncertainty thereby resulting in a significant savings of time and cost in remedial design and remedial actions.

The generic technical documents and drawings were developed based on previous experiences and the existing database, files and documents accumulated under both the REM III and ARCS programs. They utilized the experience gained on previous RD/RA, and the similarities with conditions at previous sites and combined with a good understanding of the capabilities of remedial technologies. They serve as a proper technical tool employed to ensure that sites of similar complexity are remediated in a comparable manner to avoid the fatal flaws impacting remedial response actions.

This paper briefly describes the EPA Region II SPS background and discusses each standardized documents for RD and RA and other generic documents for RI/FS. In addition, the general approaches to utilize these standardized generic documents are also presented.

BACKGROUND

In late November 1989, EPA Region II tasked Ebasco Services Incorporated (Ebasco) under ARCS II Contract to undertake the Program Standardization. The purpose of the program standardization project was to develop the generic technical documents and drawings which are commonly applicable to the ARCS II Superfund Program. The most useful documents of general applicability and commonly utilized technologies were selected for this standardization program. The SPS was conducted in two phases. Higher priority standardized documents were prepared during Phase I activities. The Phase II activities were put off for future implementation. Table 1 presents the scope of work and associated standard documents.

Ebasco completed the Phase I activities and submitted all standardized documents to EPA for review and comment in June 1990. Since then Ebasco has used these draft standardized documents in the preparation of remedial design and remedial action documents as well as RI/FS reports. These documents were provided to other ARCS II contractors for appropriate utilization.

DISCUSSION

The standardized documents and drawings provide a unified support basis for preparation of RD specifications and drawings, RA plans and other RI/FS reports. The major components and utilization of these generic documents are briefly discussed as follows:

A. REMEDIAL DESIGN SPECIFICATIONS AND DRAWINGS

1. GENERIC REMEDIAL DESIGN SPECIFICATIONS (GRDS)

The GRDS are prepared in accordance with the Construction Specification Institute (CSI) format which is subdivided into 16 Divisions. These divisions form the framework of the specifications and contain the technical requirements for the category of work within each Division. Each Division is then subdivided into three distinct groupings of related information (i.e. Part 1-General, Part 2-Product and Part 3-Execution).

The GRDS is designed in a template format so that the boilerplate sections (Part 1-General) with generic description can be easily used in site-specific documents with minor changes. The standard sections (Part 2-Product and Part 3-Execution) can be incorporated by filling the site-specific information in the blanks. All generic documents are available in PC diskettes in order to minimize typing requirements.

GRDS of Carbon Adsorption Units includes Division 1-General Requirements, Division 2-Equipment and Division 3-Mechanical as shown in Table 2. The primary section is Section 11255-Activated Carbon Adsorption Unit which includes Part 1-General, Part 2-Product and Part 3-Execution. Part 2 describes specifications for equipment, material, fabrication and accessories. Part 3 includes specifications for erection/installation, testing and inspections. Section 15010-Basic Mechanical Requirements provide the support for carbon adsorption unit fabrication and specifies piping, fitting, hangers/supports, joints, sleeves, cutting and patching.

GRDS of Packed Column Air Stripper includes the primary Section 11230-Packed Column Air Stripper. Part 2 of the Section specifies the equipment components and leaves blanks for site-specific dimensions. The major equipment components include column structures and internals, water distributors, air exhaust ports and moisture separator, Subpart 2.02 specifies column materials and packing materials. Subpart 2.03 specifies the fabrication requirements of all column elements and accessories.

TABLE 1

PROGRAM STANDARDIZATION SCOPE OF WORK AND ASSOCIATED STANDARD DOCUMENTS

PHASE I - COMPLETED

Task	Standard Documents
Remedial Design	Generic Remedial Design Specification of
1a	Carbon Adsorption
1b	Packed Column Air Stripper
1c	Pumps
1d	Site Work
Remedial Design	Generic Remedial Design Drawings of
2a	Carbon Adsorption System
2b	Packed Column Air Stripping System
2c	Pump Configuration
2d	Extraction and Reinjection Well Details
2e	Capping, Fence and Gate Details
Remedial Action	
3a	Generic Health and Safety Plan for Remedial Action
3b	Generic Quality Assurance Plan for Remedial Action
3c	Generic Community Relations Plan for Remedial Action
3d	Generic Bid Evaluation Procedures for Remedial Action
RI/FS	
4	Generic Work Plan
5	Generic Field Sampling and Analysis Plan
6	Generic RI Subcontract Bid Package of
6a	Drilling Services
6b	Survey Services
6c	Removal and Disposal of RI Wastes
6d	Fence and Gate Installation
6e	Cost Estimate Database for Cost Screening for Feasibility Study

PHASE II - FUTURE

Task	Standard Documents
Remedial Design	Additional Remedial Design Specification of
7a	Concrete
7b	Masonry
7c	Metals
7d	Moisture (Dewatering)
7e	Finishes (Painting/Coating)
7f	Reactor/Clarifier/Thickener
7g	Mixing Tank
Remedial Design	Additional Remedial Design Drawings of
8a	Butler Building Details
8b	Erosion and Sediment Control Details
8c	Access Roads and Temporary Storage Area

TABLE 2

GENERIC REMEDIAL DESIGN SPECIFICATION OF CARBON ADSORPTION UNIT

TABLE OF CONTENT

TABLE 2 (Cont'd)

GENERIC REMEDIAL DESIGN SPECIFICATION OF CARBON ADSORPTION UNIT

TABLE OF CONTENT

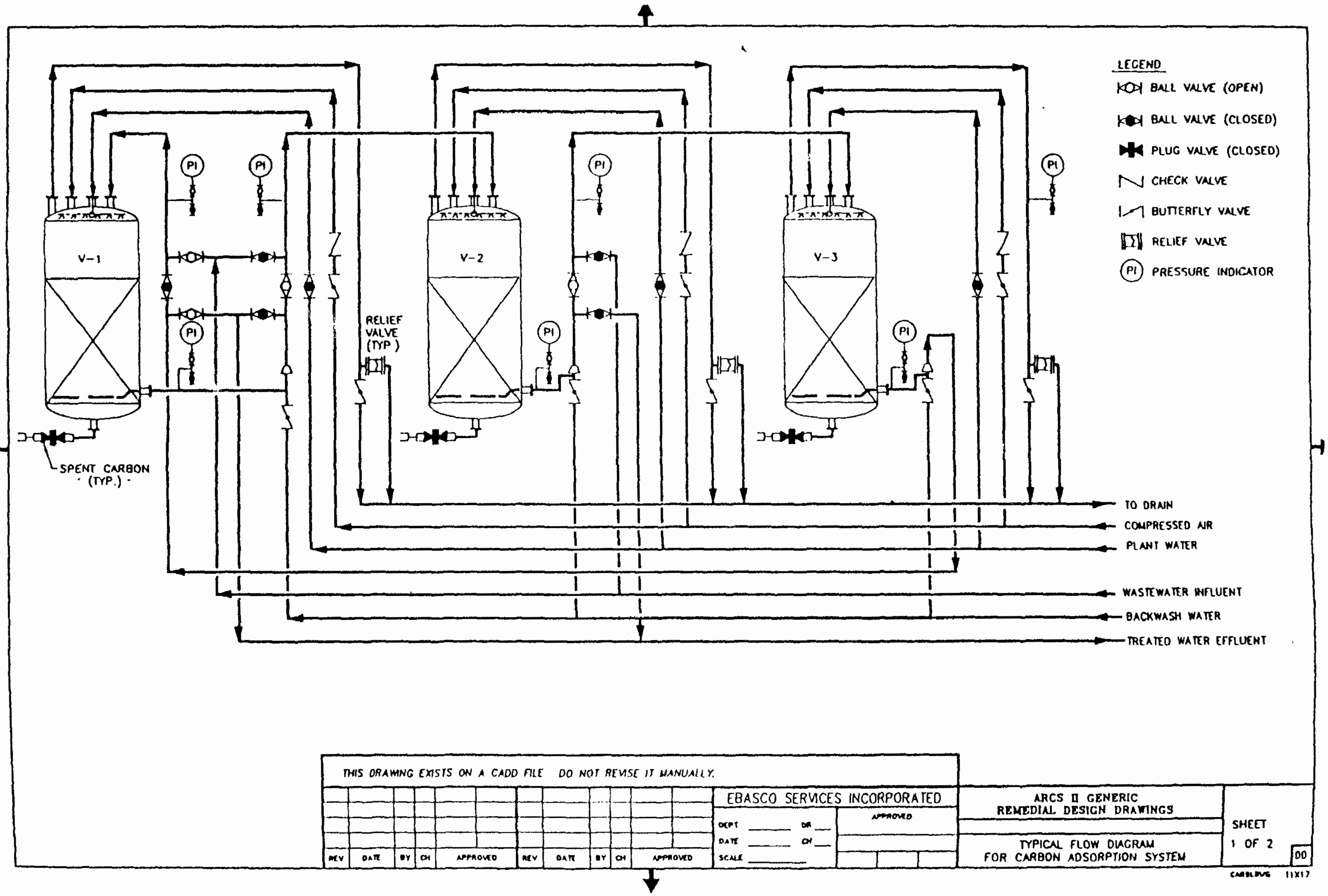
GRDS of Pumps includes the primary Section 11211-Submersible Pumps, Section 11212-Sump Pumps, Section 11213-Horizontal Centrifugal Pumps, Section 11215-Vertical Turbine Pumps and Section 11216-Sludge Pumps. The key part of each pump section is Part 2-Products which specifies the requirements of equipment and accessories with blanks for site-specific information and dimensions.

GRDS of Site Work includes Section 02040-Dust and Vapor Control, Section 02090-Off-Site Transportation and Disposal, Section 02140-Aqueous Waste Handling, Section 02200-Earthwork, Section 02210-Placement of Material and Final Cap, Section 02220-Asphalt Cutting, Removing and Surfacing, Section 023600-Steel Piling and Section 02900-Restoration of Site Vegetation. The primary part of site work specifications is Part 3-Execution which specifies the construction requirements and procedures. For example, the aqueous waste handling specifies dewatering, off-site aqueous waste transportation/ disposal and on-site aqueous waste treatment/disposal.

2. GENERIC REMEDIAL DESIGN DRAWINGS (GRDD)

The GRDD are intended to develop an Automatic Computer Aided Design and Drafting System (ACDD) incorporating the standard details common to most remedial designs in the acceptable design drawing formats and files. These standardized drawings were developed based on the existing drawing file of the previous RD/RA work with any necessary modifications. The GRDDs completed in the Phase I assignment include the detailed figures for a carbon adsorption system, packed column air stripping system, pump configurations, extraction and reinjection wells, capping, and fence/gate details.

As shown in Figures 1 and 2, the GRDD for the carbon adsorption system presents a typical flow diagram and associated general equipment arrangement for a two-train-3 vessel operation system. This GRDD shows all configurations of drainage, compressed air, water inlet/outlet, wastewater and backwash water but leaves the blanks for site-specific dimensions. The GRDD for the packed column air stripping system shows all figures for the nozzle, stripping column, water distributor,


LEGEND
BALL VALVE (OPEN)
BALL VALVE (CLOSED)
PLUG VALVE (CLOSED)
CHECK VALVE
BUTTERFLY VALVE
RELIEF VALVE
PRESSURE INDICATOR
PI
V-1
V-2
V-3
RELIEF VALVE (TYP)
SPENT CARBON (TYP.)
TO DRAIN
COMPRESSED AIR
PLANT WATER
WASTEWATER INFLUENT
BACKWASH WATER
TREATED WATER EFFLUENT
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FOR CARBON ADSORPTION SYSTEM
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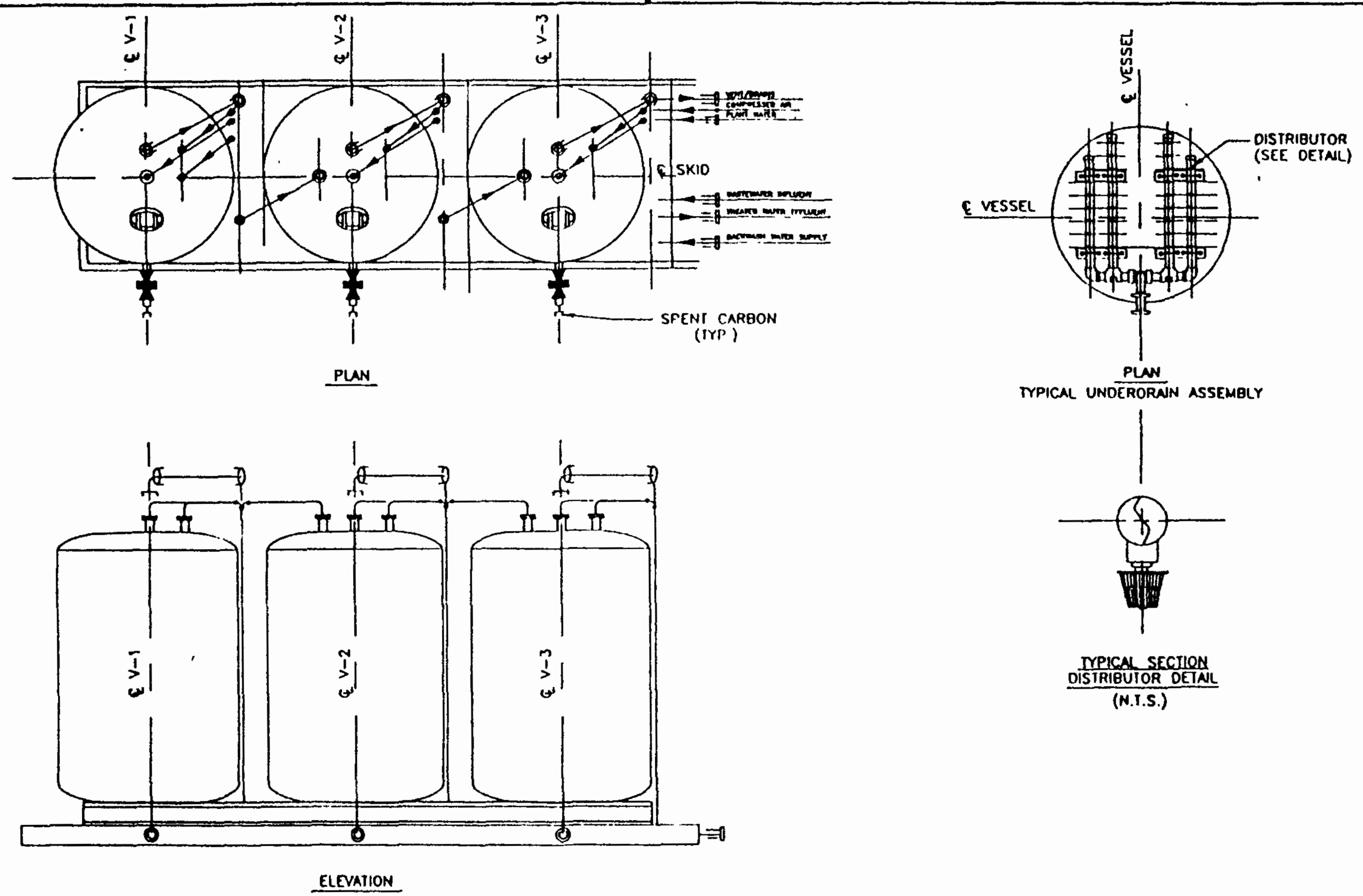

NOTE:
1. INSTRUMENTS AND VALVES NOT SHOWN FOR CLARITY.

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APPROVED

ARCS II GENERIC
REMEDIAL DESIGN DRAWINGS

TYPICAL GENERAL ARRANGEMENT
FOR CARBON ADSORPTION SYSTEM

SHEET
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CARB2.DWG 11X17

air blower, mist eliminator and electric/control panel. The GRDD for pump configurations present most components of motor, pump, coupling, suction/inlet, discharge, and pump base for centrifugal pump, submersible pumps, sump pumps and vertical turbine pumps. The GRDD for extraction wells and reinjection well shows details of bottom cap, pump, well screen, gravel filter, bentonite plug, borehole limit, well riser and valve box. All dimensions are left as blanks for site-specific information. Typical capping types and details include engineered soil cap, engineered soil cap with synthetic liner, and pile supported structural cap. Each type of cap shows the recommended thickness of the uppermost layer and vegetative cover, drainage layer, impermeable layer, and compacted fill. The GRDD for typical chain link fence and gate details present all components and standard dimensions for gate post, concrete base, latch rod, wire fasteners, chain link fabricated mesh, end post and turnbuckles, etc.

B. REMEDIAL ACTION STANDARDIZATION DOCUMENTS

1. GENERIC HEALTH AND SAFETY PLAN (GHSP) FOR REMEDIAL ACTION

The GHSP is developed to inform site construction personnel of the known hazards associated with the RA and to ensure that the construction health and safety program is performed in compliance with Federal, State and local laws including those set forth by OSHA. The GHSP establishes consistency by listing of sections that are common to all sites and are sufficiently flexible to enable the development of HSP for divergent sites and hazards. The GHSP addresses the potential hazards, protective measures, emergency response procedures, equipment required on site and specific roles and responsibilities of site personnel.

2. GENERIC QUALITY ASSURANCE PLAN (GQAP) FOR REMEDIAL ACTION

The objective of the GQAP is to ensure implementation of the engineering/design criteria and specifications in accordance with the contract procedures and requirements by the contractors. The GQAP will serve to help contractors expedite the preparation of construction QAP with more consistency and uniformity. The GQAP provides detailed sections of contaminant migration, decontamination, control and shipping of hazardous materials, performance verification, field testing, inspection, deficiency control, sample validity and subcontractor control and surveillance.

3. GENERIC COMMUNITY RELATIONS PLAN (GCRP) FOR REMEDIAL ACTION

The GCRP addresses site background, community profile/concerns, key issues and community relations activities prior to and after remedial action. The GCRP serves to aid construction management in preparation of site-specific CRP to keep local public well-informed about the remedial action.

4. GENERIC BID EVALUATION PROCEDURES (GBEP) FOR REMEDIAL ACTION

The GBEP provides a reliable and acceptable methodology and evaluation criteria for procuring a RA contract through (1) one step competitive negotiation turnkey procedures, (2) two step sealed proposal/bidding and (3) a combination of one step and two step approaches. The technical evaluation merits include contract management plans, project experience, sequence of construction and construction schedule. The proposal price is factored into the quality score. A cost/technical score ratio or total point score forming the basis for recommending contract award.

C. REMEDIAL INVESTIGATION AND FEASIBILITY STUDY DOCUMENTS

1. GENERIC WORK PLAN (GWP) AND GENERIC FIELD SAMPLING AND ANALYSIS PLAN (GFSAP)

The GWP is organized according to the table of contents presented in the EPA's April 1989 RI/FS Guidance (Reference 1). The GFSAP has been developed based upon the ARCS II Field Technical Guidelines (Reference 2) and EPA Region II Quality Assurance Manual (Reference 3). Both documents are not intended for use as a site-specific WP and FSAP, rather, they shall be applied as boilerplate material to facilitate the WP and FSAP development processes. They shall be edited as necessary to satisfy the site-specific conditions. The GWP addresses site background, scope of work, field investigation, feasibility study, project organization and schedule. The GFSAP addresses general requirements of field sampling and analysis program, statement of procedures, QA/QC, sampling packaging and shipment and field changes/corrective actions.

2. GENERIC REMEDIAL INVESTIGATION SUBCONTRACT BID PACKAGES

The generic RI subcontract bid package consists of complete non site-specific RI subcontract service inquiry documents which have been developed for drilling services, removal/disposal of RI wastes, survey services and fence/gate installation. The generic subcontract bid packages are intended to minimize duplication of effort and uncertainty surrounding the content and format of RFPs.

The generic RI subcontract inquiry contains two major portions, i.e., contractual requirements and statement of work. The contractual requirements include the general specifications of instruction to bidder, subcontract agreement, representatives, certifications and other statement. The statement of work consists of technical specifications and requires various levels of site-specification input. A typical outline of the drilling services solicitation package is presented in Table 3.

The major technical specifications for drilling services include a generic statement of work of soil borings and monitoring well installation, well development and decontamination/containment. The survey services technical specifications include sample and well location survey, topographic survey/mapping and survey report. The major RI waste removal/disposal technical requirements include sample collection, waste characterization, manifest form, transport/treatment/ disposal of bulk materials and drummed materials.
Hazardous and non-hazardous material classification and associated ultimate disposition are discussed for each RI waste. Waste types, such as F, P, K, etc. and applicable disposal technologies or landfill types, either RCRA Subtitle D or Subtitle C are also described. The major fence/gate installation technical specifications include new fence installation, existing fence repair, existing fence relocation and fence materials such as ports/rails, fence fabric, tension bars and gates, etc.

A cost estimate database was developed based on Ebasco internal data, published literature (e.g., EPA's CORA Model) and available vendor information for cost screening purposes in the preparation of feasibility study. Cost data is presented in

TABLE 3

GENERIC DRILLING SERVICES SOLICITATION PACKAGE

OUTLINES OF CONTENT

I. SUBCONTRACT AGREEMENTS

II. STATEMENT OF WORK AND PROPOSAL REQUIREMENTS

- A. Project Description
- B. Special Conditions
- C. Technical Specifications
  - 1. Codes and Standards
  - 2. Soil Boring and Monitoring Well Installation
  - 3. Decontamination
  - 4. Well Development
  - 5. Containment
  - 6. Rejected Borings and Installations
  - 7. Portable Water Supply
  - 8. Record
  - 9. Price Proposal Form
  - 10. Engineer's Control

ATTACHMENTS

- A. Health and Safety Plan
- B. Quality Control Forms
- C. Subcontractor's Medical Surveillance Program

a unit cost form, in terms of dollars per unit operation. The report also discusses a variety of factors influencing these unit costs. The cost database presents cost data for treatment technologies most commonly applicable to source control and management of migration as shown in Table 4. A hypothetical case is presented to demonstrate the application of the cost estimate database.

D. UTILIZATION OF PROGRAM STANDARDIZATION DOCUMENTS

In general, the various sections of standardized documents are grouped in three categories: boilerplate sections, standard sections and explanatory sections. Boilerplate sections contain non-site-specific text that has been used previously and can be used directly without revision. Standard sections are designed as a template format having standard sentences and wordings common to most sites with blanks that need to be filled in or revised to reflect site-specific conditions and specific project approaches. Explanatory sections identify for the preparer the site-specific information that would need to be included in the respective sections. An example is usually provided for the explanatory sections.

The generic remedial design specifications (GRDS) are also facilitated by three types of guides, i.e., a general statement, a specific statement and an explanatory statement. Common information is consolidated in general statement, where as site-specific information is provided in specific statement. The GRDS is written in the imperative mode and, in some cases, in a streamlined form. The imperative language is directed to the subcontractor, unless specifically noted otherwise.

The generic remedial design drawings (GRDD) are developed using a computer based model, an Automatic Computer Aided Design and Drafting system (Auto CADD). All data input is filed into the CADD so that it can be extracted for graphs and tables with modification. The Auto CADD standard details, drawings and files can be retrieved for ease of reference and/or modified for new drawings. Any site-specific data such as dimensions and sizes are not included in the GRDD and will be provided by design engineers based on site requirements. The filed standard details can be easily reviewed, updated and revised to reflect the site-specific conditions.

CONCLUSION

The program standardization documents were developed, consolidating the similarities with conditions at previous sites and taking advantages of experience gained on previous RDs and RA. From an environmental standard, the GRDD and GRDS have addressed all necessary environmental elements and are in full compliance with ARARs. From a technical standard, the GRDD and GRDS have met all performance standards with high constructi- bility, practicability, clarity, biddability and acceptability.

These standardized documents can be used as an effective tool to coordinate interaction among all disciplines involved in the project. They can be used as a basis to ascertain the RD and RA requirements resulting in minimal review, modifications and revisions. They would compensate for learning curves and inexperience which in turn would enable the engineers to focus on the site-specific appropriate, substantive problems. The use of standard documents would avoid time and cost delays, last minute disagreement and misunderstandings.

All the documents described above are available in Word Perfect format or Auto Computer Aided Design and Drafting (CADD) format for expeditious adoption to the Region specific site situations.

REFERENCES

1. Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, EPA OSWER 9355.3-01, April 1989.

2. Field Technical Guidelines, ARCS II Program, EPA Contract 68-W8-0110, June 1989.

3. CERCLA Quality Assurance Manual, EPA Region II, Final Copy, Revision 1, October 1989.

TABLE 4

COST ESTIMATE DATABASE FOR COST SCREENING FOR FEASIBILITY STUDY

SOURCE CONTROL AND MANAGEMENT OF MIGRATION TECHNOLOGIES

I. SOURCE CONTROL TECHNOLOGIES

A. No Action

B. Containment
Capping, Vertical Barrier, Excavation

C. Physical Treatment
Mechanical Aeration, Enhanced Volatilization, In-Situ Soil Flushing, In-Situ Vacuum Extraction

D. Chemical Treatment
Chemical Stabilization and Solidification, Chemical Extraction

E. Thermal Treatment
Incineration, In-Situ Vitrification

F. Biological Treatment
In-Situ Biodegradation

G. Disposal
Off-Site Waste Landfill, On-Site Waste Landfill

II. MANAGEMENT OF MIGRATION TECHNOLOGIES

A. Groundwater Extraction

B. Physical Treatment
Coagulation/Flocculation/Precipitation, Air Stripping, Clarification, Filtration, Ion Exchange, Carbon Adsorption, Reverse Osmosis, Sludge Dewatering

C. Chemical Treatment
UV-Chemical Oxidation

D. Biological Treatment
Aerobic Biodegradation, Anaerobic Biodegradation, In-Situ Biodegration, Powdered Activated Carbon Enhanced Activated Sludge

E. Discharge
Off-Site Discharge to Publicly Owned Treatment Works (POTW)

Environmental Protection Agency
Indemnification
for
Remedial Action Contractors

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DISCLAIMER

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We encourage your comments on the utility of this paper and how it might be improved to better serve the Superfund program's needs. Comments may be forwarded to the attention of Kenneth Ayers, Design and Construction Management Branch, USEPA, Mailcode OS-220W, Washington DC 20460.

INTRODUCTION

As of the last update on February 11, 1991 (56 FR 5598), 1,189 hazardous waste sites had been incorporated into the National Priorities List (NPL). These 1100+ sites represent the most serious threats to human health and the environment from uncontrolled hazardous wastes discovered to date. Remedial investigations and feasibility studies (RI/FS) are currently on-going at over 700 of the sites. Remedial designs are under development at approximately 200 additional sites. Finally, remedial actions are under construction at another 225 sites. The cost of this work to date is over $7.4 billion with an estimated additional $25 billion needed to complete the work at sites presently listed on the NPL.

To perform this work, EPA relies heavily on assistance from response action contractors (RAC). In providing the assistance to EPA, these RACs perform site assessment work, conduct RI/FSs, develop remedial designs, and oversee and implement remedial actions. As with any engineering or construction activity, there are elements of risk associated with each of these activities. One of the primary risks associated with work at hazardous waste sites is the accidental and uncontrolled release of toxic compounds from the site to the surrounding environment.

To provide protection against losses due to claims for damages resulting from their activities, most firms purchase liability insurance policies which transfer, for a cost, the risks of loss from the company to the insurance underwriter. However, in the hazardous waste field, adequate and affordable insurance is not available to cover claims for environmental and health damages resulting from releases caused by work at Superfund sites. To enable contractors to work for the Agency under the Superfund program,. EPA is authorized to provide indemnification (Indemnification is an agreement whereby one party agrees to reimburse a second party for losses suffered by the second party) to RACS for negligence against pollution liability claims arising from remediation activities.

BACKGROUND

Section 119 Response Action Contractors, of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)(PL 96-510), as amended by the Superfund Amendments and Reauthorization Act (SARA)(PL 99-499), authorizes EPA to provide indemnification to response action contractors performing work at NPL or removal sites. Section 119 was added to CERCLA by Congress as part of the 1986 amendments in response to an outcry from the RAC community for pollution liability protection. This outcry arose due to the unavailability of pollution liability insurance from private sector sources.

In defending their lack of participation in this segment of the market, the insurance underwriters cited a number of reasons for their unwillingness to provide pollution liability coverage. The major reason was the risk of large claims for "catastrophic" failures resulting in extensive damage to human health and the environment. Their fear was that these types of failures could easily result in claims surpassing $100 million per incident. When this fact was coupled with the litigious nature of the environmental field, many underwriters declined to issue pollution policies.

A second and equally formidable reason cited by the insurance industry was the imposition of strict liability standards by the courts. Under strict liability, any entity involved in "ultrahazardous" activities at the site of a release may be held liable for all costs associated with the release without a judgement of negligence against them. Damages associated with the release may have occurred on or off the site. The insurance companies feared that in the future strict liability judgements could render them the only viable "deep pocket" for legal actions stemming from the site.

Finally, many underwriters expressed the fact that reinsurers had withdrawn from the market due to record losses posted by the industry in the early 1980s. This resulted in a down turn in the industry with firms declining to underwrite relatively small high risk portions of the insurance market such as hazardous waste remediation.

In addition to the lack of pollution liability insurance, RACs also cited several other reasons for indemnification. The first was the technical risks the RACs accept when they work at a Superfund site. These include:

1) Work with hazardous and toxic compound and mixtures of these compounds,

2) The uncertainty of innovative or untried technologies,

3) The inherent uncertainty associated with underground work, and

4) Political pressures from outside sources.

As with the insurance companies, RACs face the prospect of law suits being brought against them by third parties for damages associated with their work at a Superfund site. In addition to the potential for strict liability, negligence, or theories of liability, RACs may be jointly and severably liable. This means if the RAC is found to be liable for a portion of the damages, the plaintiff may collect the entire judgement from him.

SECTION 119

Prior to the enactment of SARA, RACs working for EPA were indemnified through EPA's inherent contracting authority. This was very limited indemnification for third party liability and defense costs and did not cover gross negligence or willful misconduct.

It was in this uncertain environment that Section 119 of SARA was enacted. While Section 119 attempted to remedy many of the RAC complaints, it did not absolve the RACs of all potential liabilities. The amendment to CERCLA did provide the following:

1) Exempted RACs from strict liability under all Federal laws for injuries, damages, costs, and other liabilities related to release of hazardous substances, pollutants, or contamination, unless RAC was negligent, grossly negligent, or guilty of intentional misconduct,

2) Established a negligence standard for RAC liability under Federal law,

3) Provided discretionary authority to extend indemnification against pollution liability for negligence, and

4) Established a funding mechanism.

Equally important is what Section 119 did not do:

1) Pre-empt State strict liability, and

2) Provide coverage for treatment or disposal facilities governed by the Resource Conservation and Recovery Act (RCRA).

Section 119 also specified the requirements that a RAC must meet to be eligible for EPA indemnification. The three requirements listed are:

1) Potential liability exceeds or is not covered by adequate insurance available at a fair and reasonable price,

2) The RAC must have made diligent efforts to obtain pollution lability insurance, and

3) If the RAC is working at more than one facility, it must perform diligent efforts each time it begins work at a new facility.

The final requirement of Section 119 was that the President (EPA) would promulgate regulations under the section. Prior to promulgation of the regulations, the President (EPA) would develop guidelines for the implementation of the requirements of the section.

INTERIM GUIDELINES

OVERVIEW

On October 6, 1987, EPA's Office of Solid Waste and Emergency Response (OSWER) issued OSWER Directive 9835.5 "EPA Interim Guidance on Indemnification of Superfund Response Action Contractors under Section 119 of SARA" to establish temporary procedures to provide indemnification to RACs under the authority of Section 119. The guidelines, issued under the authority of Executive Order 12580 (52 FR 5923, January 29, 1987 which delegated authority to indemnify RACs from the President to EPA, were distributed as interim to allow EPA to provide indemnification under Section 119 while proceeding in a deliberate manner to establish final guidance.

The interim guidelines were developed around four key points:

1) The combination of protection from Federal strict liability and RAC indemnification would provide adequate incentive for contractors to work for the Superfund program,

2) The indemnification would be an adequate substitute for insurance,

3) Indemnification would be an interim measure until the private insurance market rebounded, and

4) The indemnification did not create a disincentive to the private insurance market.

These points were to also form the basis for the formulation of the final guidelines.

PROVISIONS OF THE INTERIM GUIDELINES

The interim guidance stated that EPA had determined that adequate private insurance was not available at a fair and reasonable price, thus the Section 119 basic requirement that private sector insurance be unavailable for RACs to be eligible for EPA indemnification was satisfied. Additionally, the guidelines established no upper limits for claims under Section 119, prescribed a $100,000 deductible for each claim filed, and did not establish any term of coverage or "tail" for EPA indemnification to expire once it was granted. In addition to providing model contract clauses for indemnification, the guidelines required all contracts incorporating the model clauses under its authority to be to be modified by mutual agreement of all parties to the contract within 180 days of promulgation of final guidelines. Requirements for RACs seeking EPA indemnification were also delineated.

Requirements for RACs seeking indemnification under the interim guidelines included:

1) Written proof of diligent efforts must be provided to EPA within 30 days of contract award,

2) If insurance was purchased, a copy of the policy must be provided to EPA, and

3) Additional diligent efforts must be performed every twelve (12) months if insurance was not purchased.

The guidelines also presented mechanisms for EPA indemnification to be granted to RACs working for States, other Federal agencies, and Potentially Responsible Parties (PRPs). For sites managed for

EPA by the US Army Corps of Engineers or other Federal agencies, the contractor working for that agency would be indemnified by EPA as if the contractor were working directly for EPA.

The exclusion of treatment facilities governed by RCRA regulations was extended to Publicly Owned Treatment Works (POTWs). Although POTWs were not explicitly excluded from Section 119 coverage, EPA excluded them as a policy decision to be consistent with the intent of the RCRA exclusion.

FINAL GUIDANCE

CONTENTS

In October 1989, nearly three years after EO 12580 delegated indemnification authority to EPA, the Agency issued in the Federal Register for public comment Proposed Final Indemnification Guidance (54 FR 46012, October 31, 1989). When compared to the liberal provisions of the interim guidance, the proposed final guidance severely restricted the indemnification available to RACs. The proposed guidance limited the maximum coverage per contract, imposed substantially higher deductibles, and limited the term of coverage to ten years. The guidance called for a minimum amount of insurance to be purchased by contractors each year and that this amount increase by 25% each year with the anticipated result of the private sector eventually providing all pollution lability coverage allowing EPA to cease offering indemnification. One final provision was that all existing post-SARA indemnification agreements must be retroactively brought into compliance with the terms of the final guidance.

Some of the specific points of the proposed guidance are as follows:

1) RACs were covered if found negligent; however, if a mixed judgement (a finding of both negligence and strict liability) were handed down, the RAC would not be covered,

2) Maximum coverage for cost reimbursement contracts was set at $50,000,000 per contract,

3) Deductibles for cost reimbursement contracts were set at $1,000,000 per occurrence or claim with no aggregate limit,

4) Coverage for fixed price contracts was set on a sliding scale which was to be factored into the bid evaluation, and

5) A ten year post-completion term was established for all agreements.

Needless-to-say, the response to the proposed guidelines was overwhelming with over two hundred comments, requiring over 40 pages to document, received. Unfortunately, the comments were virtually all negative. They stated that the limits were too low, the deductibles too high, the term too short, and the fixed price proposal unworkable. Based upon this negative feedback, EPA decided to delay finalizing the proposal and to reconsider some of the elements.

CONSULTATIVE PROCESS

After completing a thorough analysis of the comments and conducting discussions with many of the interested parties, EPA decided to employ a consultative process to solicit more specific feedback. Endispute, Inc. was retained to organize and convene a one-day, facilitated session between EPA and a select group of interested and affected organizations. The purpose of this session was to attempt to clarify the positions held by each party. EPA made it clear to all participants that the use of the consultative process was not a prelude to a negotiated rule making and was for informational purposes only.

Prior to convening the meeting, Endispute interviewed members of each organization slated to attend the session. These interviews were designed to assist Endispute in formatting the meeting to allow the concerns of all parties to be expressed.

The consultative session was held in Washington, DC on November 19, 1990. Representatives from the RAC community, insurance brokers and underwriters, other Federal agencies, as well as EPA were present. The points raised by the participants were essentially the same as those offered in the written comments to the proposed final guidelines. The meeting did serve to "clear the air" and assure the RAC community that EPA was aware of their concerns and attempting to address them in the guidelines.

CURRENT STATUS

Following the consultative session, EPA reconvened its Indemnification Taskforce to revise the proposed final guidance based upon the written comments and insights from the facilitated session. The taskforce met routinely over several months and was able to reconcile many of the issues. Several issues on which the taskforce was not able to reach consensus were elevated to management for decisions. The final guidelines are currently ready to enter EPA's formal, internal review process and then will be sent to the Office of Management and Budget (OMB) for final review prior to issuance. At this time, EPA does not believe that the guidelines will be proposed for additional public comment prior to becoming effective.

In addition to the final guidelines, an accompanying set of administrative guidelines are being developed. The purpose of the administrative guidelines will be to provide the specific details and instructions necessary for EPA staff to interpret and apply the guidelines equitably and consistently throughout the program and across the regions.

Since the final guidelines have not completed EPA's internal review process, the specific details are not releasable to the public. However, some of the basic components of the package that will be forwarded to OMB for review can be discussed:

1) The final guidelines will contain well defined limits to the amount of indemnification available to RACs on a per contract basis,

2) The deductibles will be on a sliding scale with higher deductibles for higher contract limits,

3) A definite term of coverage (tail) will be set,

4) The incorporation of indemnification requests in bid evaluations for fixed price contracts has been dropped, and

5) All post-SARA contracts must be modified to include the provisions of the new guidelines.

POTENTIAL PROBLEMS

The final guidelines could have substantial impacts upon both EPA and the RAC community. First the potential RAC problems:

1) It is likely that the availability and the limits of EPA indemnification will be greatly reduced from the uncapped limits currently provided. This reduction will require RACs to rethink their current operating procedures and their future plans,

2) All RACs with current indemnification agreements must enter into negotiations with EPA to incorporate the new guidelines into their existing contracts. This will require time and effort by the RACs and may cause them to rethink their willingness to continue to work for EPA, and

3) RACs must develop a strategy to deal with any subcontractors that have been extended indemnification through the RAC's contract since the new limits will include any pass-through indemnification.

Potential problems for EPA are:

1) The time and resources to negotiate the new guidelines into all existing contracts (this includes contracts let by the US Army Corps of Engineer, the US Bureau of Reclamation, and any other Federal Agency acting in behalf of EPA),

2) The impact on the Superfund program if some of the RACs refuse to accept the new guidelines and their contracts are terminated. This could stop on-going work and cause a severe shortage of contractors for the short term, and

3) The cost of doing business could increase substantially as RACs seek to protect themselves as the risks from pollution liability are reallocated.

DEVELOPMENTS OUTSIDE THE FINAL GUIDANCE

SURETY AMENDMENT

Prior to the present construction season, the Superfund program had been experiencing a decline in the number of bidders or proposers for many of the remedial action projects under solicitation. This decrease in competition increased the costs of projects, and if not addressed, could ultimately have impacted the quality of remediation work being performed. In response to this trend, EPA tasked the US Army Corps of Engineers to explore the issue and provide recommendations for corrective actions. The US Army Corps of Engineers issued their findings in Hazardous and Toxic Waste Contracting Problems: A Study of the Contracting Problems Related to Surety Bonding in the HTW Cleanup Program. The main finding of the study was that fewer firms were competing for Superfund work due their inability to secure the necessary bonding required for the contracts. The difficulty in securing bonds was stemming from the sureties' perception of their potential liability to become the last "deep pocket" for pollution liability claims when providing performance bonds.

EPA attempted to address this issue in two ways. First, meetings were held with representatives of the surety industry to explain their liability under CERCLA when providing performance bonds and to try to allay their fears. Second, EPA, acting through the US Army Corps of Engineers, attempted to reduce the amount of bonding required to adequately protect the Governments's interests by utilizing various contract types and phasing projects. These attempts did not satisfy the surety industry.

The surety industry approached Members of Congress to amend CERCLA to allow indemnification to be extended to surety firms providing performance bonds for Superfund work. Congress agreed with the sureties' arguments and passed an amendment to CERCLA (Section 1 of Public Law 101-584) in October 1990. The President sign the bill into law on November 15, 1990. This amendment limited a surety's liability under the bond to the face value of the bond and extended eligibility for EPA indemnification to surety firms when they elect to complete the contracted Superfund work to fulfill their obligations under a bond issued to a defaulting contractor.

REVISED US ARMY CORPS OF ENGINEERS APPROVAL PROCEDURES

When potential contractors prepare proposals and bids in response to solicitations for work, they invest considerable time and money. Additionally, each proposal or bid must be accompanied by a bid bond which signifies the contractors good faith to perform the specified work and provides the government with funds to resolicit if the contractor refuses to accept the contract. One problem with this typical scenario is that for Superfund work RACs face one final hurdle they cannot control. This hurdle is approval by EPA to extend indemnification to the contractor. In many cases without EPA indemnification, contractors are unwilling to risk their corporate assets. If the contractor is the successful proposer or bidder and EPA refuses to extend indemnification, the contractor is forced to forfeit its bid bond if it refuses the contract due to potential liability.

Since the decision to extend or not to extend indemnification is out of the contractors control, EPA and the US Army Corps of Engineers have agreed to test a modification to the normal indemnification approval process to allow a contractor, providing it has met all other requirements of the solicitation, to refuse a contract if indemnification is not approved and not forfeit its bid bond. This process is being tested for one solicitation. Based upon the results of this test and the final indemnification guidance, the process will be continued, modified, or discontinued.

Under current procedures, a contract is awarded and then the contractor performs diligent efforts and indemnification is granted based upon the results of the diligent efforts. For the test procedures, potential contractors will be asked to perform diligent efforts prior to contract award. EPA will evaluate the contractors efforts and determine if indemnification will be offered prior to award of the contract. If the contractor has met all other requirements of the solicitation and EPA declines to approve indemnification for the contractor, the contractor will be allowed to withdraw from the solicitation and not forfeit the bid bond. If indemnification is approved, the contractor will be issued a letter granting indemnification immediately after the contract is signed.

DILIGENT EFFORTS

EPA has initiated two efforts to improve the diligent efforts process while awaiting the final indemnification guidelines. The first is the internal EPA approval process. Since the approval of indemnification has been delegated to the Director of the Hazardous Site Control Division (HSCD), responses to requests for indemnification and insurance purchases for contractors working directly for EPA or another Federal agency acting for EPA are now handled directly between HSCD and the contracting officer for the solicitation/contract. In the past, all correspondence was routed through the Procurement and Contract Management Division (PCMD). PCMD is now furnished with a copy of all correspondence. This streamlined approach has reduced the review and approval process by several weeks. Additionally, HSCD has provided guidance to the field on the minimum information needed to review and make a decision on extending indemnification to a contractor. This guidance has improved the submissions and allowed HSCD to respond without requesting additional information.

The other effort underway to improve the diligent efforts process is the development of a Quick Reference Fact Sheet clearly explaining the process and what is required in the contractor's submission. This fact sheet will establish consistency across contracts and assist both contracting officers and contractors in reviewing and preparing requests for indemnification.

INSURANCE

Over the last two years pollution liability insurance has become more available to RACs. Currently, two underwriters, American Insurance Group (AIG) and Reliance National Insurance (Reliance), are offering pollution liability insurance. The usual policies offered by these firms are claims-made, one year policies with no tail; however, several recent policies have offered one or two year tails. The policies have limits between $1,000,000 and $5,000,000 with deductibles of $100,000. The rates average approximately $2.50 per $100 of gross receipts for the contract covered.

In an attempt to stimulate the private sector, EPA has approved the purchase of over twenty policies over the last several years. To date most policies have been site specific; however, recently EPA has approved the purchase of contract-wide policies for several ARCS contracts. These policies provide automatic coverage for all work, except remedial actions, performed under the contract. To expand upon this trend, EPA is currently negotiating with several firms that have multiple ARCS contracts to purchase a single policy to cover all the firms ARCS contracts. These contract-wide and multi-contract policies will greatly reduce the cost of insurance premiums.

CONCLUSION

While the final picture of EPA's indemnification process is still unclear, it is certain that the new guidelines will drastically alter the assignment of risk from pollution liability suits. Until the new guidelines are finally promulgated along with their accompanying administrative guidance, the final impacts on the RAC community and the Superfund program can not be determined.

Innovative Design Review and Scheduling Tools: Potential Benefits to HTW Remedial Projects

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1 Introduction

A task of great magnitude is facing the United States for restoring its contaminated sites. Conservative estimates indicate a cost of hundreds of billions of dollars to accomplish this remedial work. Furthermore, hazardous and toxic waste (HTW) remedial projects involve several challenging characteristics: (1) the hazardous nature of handled materials; (2) the need to utilize cutting edge restoring technologies; and (3) uncertainty on the degree of contamination or amount of contaminated material.

Because of these demanding characteristics, substantial time delays and cost overruns unfortunately are common occurrences on HTW remedial projects. This paper will discuss several specific tools being developed at the U.S. Army Construction Engineering Research Laboratory (USACERL) to enhance the management of traditional construction projects and explore how these tools, if properly adapted, can help decrease the time and cost growth of HTW remedial projects.

One such tool provides all project team members with systematic access to customized checklists containing biddability, constructibility, and operability (BCO) issues which need to be examined on a project. Since BCO issues comprise 75 percent of the pre-final reviews conducted by the Environmental Protection Agency (EPA) before construction is initiated on any HTW remedial project, it appears this system will lend itself well to helping improve the execution of HTW work.

Other tools being developed at USACERL facilitate the estimation of construction project durations and the generation of construction schedules at early design stages. It is believed that the application of these same concepts to HTW remedial projects will result in improved time estimation and time control tools which will translate into cost savings on HTW projects.

2 Background

2.1 Current approach for Design Review of traditional construction

2.1.1 Problems associated with the Design Review process

Facility acquisition and/or infrastructure revitalization is a complex design and construction process that involves many specialists in widely diverse fields. The accomplishment of this process is further complicated by the unknowns of site and as-built conditions. These complexities contribute to the development of contract documents that cannot be understood, bid, administered and enforced (biddability) along with the design of facilities that cannot be efficiently built (constructibility) nor easily operated and maintained (operability).

In an effort to produce quality construction in spite of the complexities involved in the design/construction process, the U.S. Army Corps of Engineers established an aggressive manual design review program, as illustrated in Figure 2.1. This program includes (1) a technical review and a value engineering review of the design package performed by the Corps of Engineers, (2) a biddability review of the contract documents' structure/content also performed by the Corps of Engineers, (3) a constructibility review of the design package performed by the Corps of Engineers' construction field office, (4) a functional review of the design package performed by the Army agency that will be using the facility, and (5) an operability/maintainability review of the design package performed by the military post engineer, who will be responsible for operating and maintaining the facility.

COMPREHENSIVE DESIGN REVIEW PROGRAM

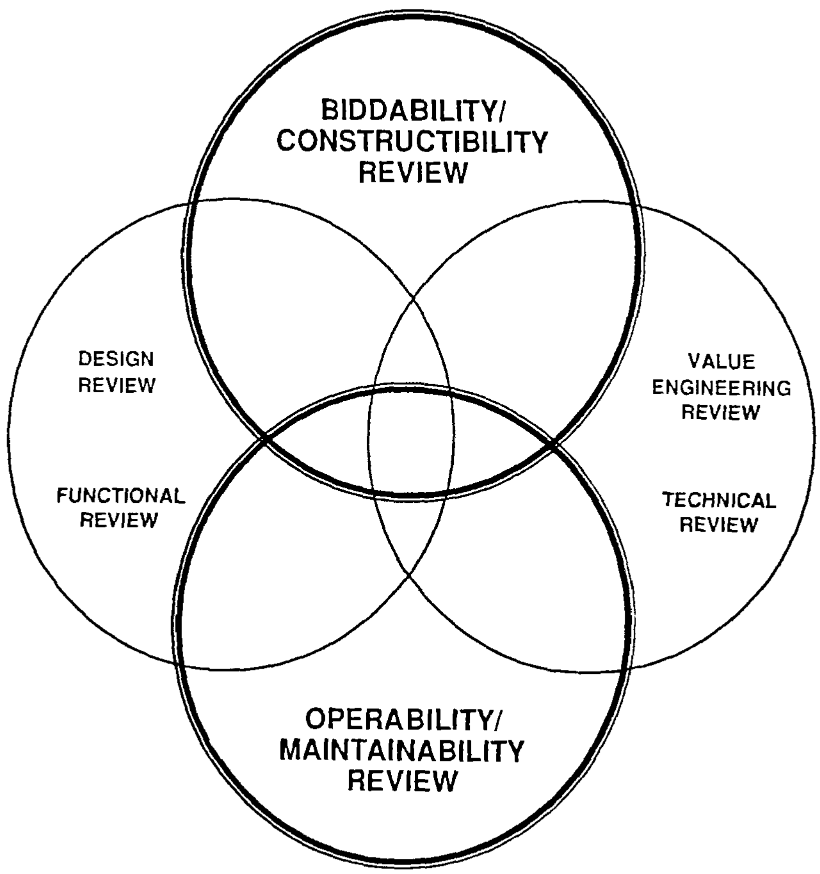

Fig. 2.1. Areas Covered by the Design Review Program

Even though the design documents pass through these multiple reviews by various design disciplines during the design process, major deficiencies still manage to be overlooked. It has been estimated that approximately half of all construction-contract modifications can be attributed to design deficiencies [Nigro 87]. The result of these errors and omissions in the plans and specifications is an increase in the construction cost and duration of projects as well as user dissatisfaction due to higher operation and maintenance expenses. Also, since a typical Corps District Office manages hundreds of designs concurrently, tracking the status of individual design reviews or checking on the actions required by individual design comments is an almost impossible task to accomplish manually.

2.1.2 Current approach for improving the Design Review process

The solution to the problems stated above is to provide the project team with the expertise needed to eliminate design deficiencies before they ever reach the construction stage. A publication prepared by the Construction Industry Institute (1986) suggests that savings on the order of 6-23% of the original project estimate are achievable through proper design review [Publication 3-1]. In an effort to realize this solution, the Corps of Engineers has developed two systems to improve the management and performance of the design review process: (1) the Automated Review Management System (ARMS) and (2) the Biddability, Constructibility and Operability (BCO) Advisor system.

ARMS is a minicomputer-resident program that provides solutions to many of the problems associated with the scheduling and management of multiple simultaneous reviews on different projects and with the disposition of the comments generated [Kirby 88]. ARMS allows design reviewers and managers to both obtain review assignments and enter review comments in an electronic format. Workload information, assignment scheduling information and the ability to retrieve review comments are available to all level of users. The minicomputer- (or local area network personal computer) based ARMS interconnects all reviewers and managers allowing real-time review management and comment retrieval.

BCO Advisor is a microcomputer-resident program that addresses the performance of the design review in regard to biddability, constructibility and operability topics. It is an automated review guidance checklist system that assists project design reviewers in performing their task more accurately and efficiently. The system also facilitates interaction among project team members and captures "lessons learned" for application to future projects.

The use of the BCO Advisor system as an integral part of the Corps' comprehensive design review program will help to reduce BCO design deficiencies early in the life of a project, which is when correct decisions have the greatest beneficial impact on the final cost of a facility. By emphasizing BCO issues during the design and planning process, contractor productivity will be ensured, construction cost and time growth will be minimized, unnecessary changes and claims during construction will be avoided and safe efficient operations by the user will be ensured.

The BCO Advisor system helps to generate the review comments that are managed by ARMS. BCO Advisor can be used integrally with ARMS or it can be used as a stand-alone system (i.e. in cases where ARMS is not being used). Section 5 of this paper discusses the potential benefits the BCO Advisor system can provide to the management and execution of HTW remedial projects.

2.2 Current approach for Duration Estimation and Construction Scheduling

2.2.1 Problems associated with Duration Estimation and Construction Scheduling

The approach normally followed to estimate overall construction duration and evaluate contractor submitted schedules is described below:

- A/E is required to submit a time estimate of construction contract duration. However, the A/E's expertise resides on the design phase as opposed to the construction phase.

- Corps construction personnel manually review and evaluate contractor submitted schedules. This review demands a substantial time investment of a highly qualified and experienced reviewer.

- weather impact is assessed in a non-standardized manner, following a manual approach.

This approach requires improvement because time growth of construction contracts is a common problem.

2.2.2 Current approach for improving the Scheduling practice

Research work is in progress at USA-CERL to develop enhanced schedule support tools that contribute to a reduction in construction time growth.

The objectives of these research projects are fourfold:

a. improve the ability to estimate overall construction duration prior to starting the construction phase

b. provide enhanced tools for evaluating the reasonableness of contractor submitted schedules

c. improve the monitoring and control of schedule progress

d. provide enhanced ability to acquire and represent, in a reusable form, scheduling information and experience gained in construction projects in order to apply the lessons learned to future projects.

It is important to note that there are computer-based tools, commercially available, that provide some support to construction scheduling. These are the so called 'Project Management Systems' (PMS's). PMS's however, provide limited help. They only provide support for a CPM representation of project activities, and the capability of producing schedule reports (bar-charts, arrow and network diagrams, tables). The research work in progress at USA-CERL goes beyond the abilities of PMS's. The objective is to develop smarter tools that not only are able to store project schedule data, but that also incorporate construction scheduling experience and heuristics. This development is being accomplished through the utilization of innovative computer science techniques, namely knowledge-based systems (KBS) techniques.

The current focus of this research work is on building construction. However, the concepts developed can be expanded to other project types, including HTW remedial projects, as discussed in Section 5 of this paper.

3 BCO Advisor

3.1 Description

To ensure that a comprehensive review of a project is accomplished, especially by reviewers who have little or no BCO background or who tend to concentrate on their own area of expertise, a guide is necessary to direct reviewers through the complete review process. This guide is typically in the form of written checklists; however, checklists for conducting BCO reviews have had a fundamental conflict: ease of use versus comprehensiveness. An easy to use checklist is short, simple and requires little time to utilize but, such a checklist cannot be very detailed nor provide much useful information for detailed reviews. A comprehensive checklist, on the other hand, can cover numerous items that should be examined, but this type of list is difficult to use effectively and also requires considerable time to review each item on the list.

The BCO Advisor utilizes a knowledge-base system shell called KnowledgePro. This shell successfully combines two current technologies, expert systems and hypertext, which are able to eliminate the previously stated difficulties associated with the use of hardcopy BCO checklists. This software allows the establishment of checklist interrelationships, and controls the level and direction of the information presented. Hence, the BCO Advisor can present various levels of advice and guidance without excessive or unwanted detail. Also, the hypertext feature provides a capability to explain terms that are used in the questions or checklists but only if the user requests these definitions.

3.2 Development process

Development of the BCO Advisor began in late 1988 and initially involved the examination of many sources of information, within the Corps of Engineers as well as private industry and academia, to determine if they contained relevant BCO review information. After studying the various methodologies and checklist sources of BCO review guidance, work began on the development of a prototype program. Utilizing the expert system and hypertext technologies offered by KnowledgePro, a basic framework for the program was developed that reflected review techniques currently in use by Corps of Engineers' District and Division offices.

Based upon comments and suggestions from these Corps review offices and from several user group workshops held at USACERL, a final system design iteration was undertaken over the last half of 1990. The system structure and input/output requirements were finalized and several new requested features were incorporated into the program. In addition, an extensive data collection effort was undertaken to build the checklists contained within the program.

The current program format, as illustrated in Figure 3.1, classifies review topics according to the type of review being conducted (i.e. 35% Concept Review or 95% Final Review) along with a Special Issues Review category.

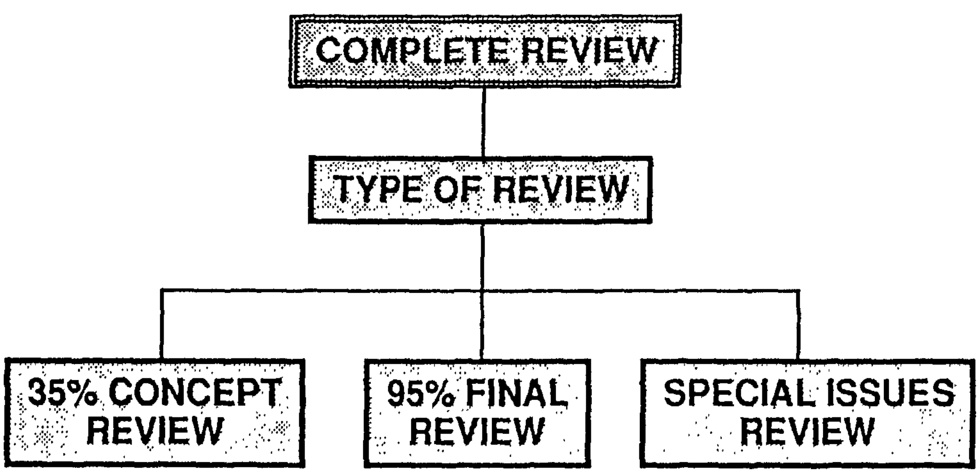

Fig. 3.1. BCO Advisor Logic Tree

The 35% and 95% review categories are divided into seven basic design disciplines, as illustrated in Figures 3.2 and 3.3. The disciplines under 95% are further split into their applicable Construction Specifications Institute (CSI) Divisions due to the availability of more detailed design information. Each discipline (35%) or CSI Division (95%) contains its own set of review guidelines to which the reviewer refers while checking the contract documents.

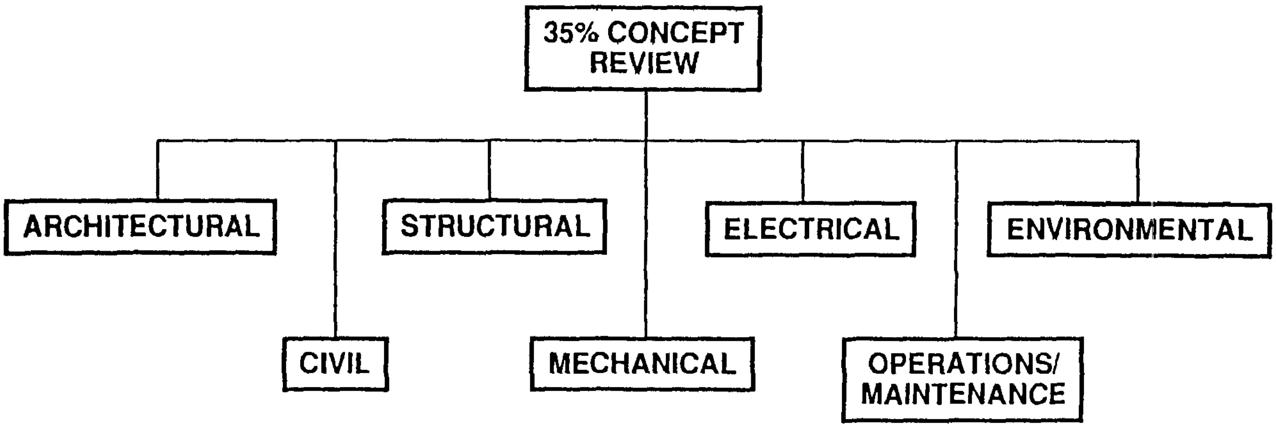

Fig. 3.2. BCO Advisor Logic Tree (35%)

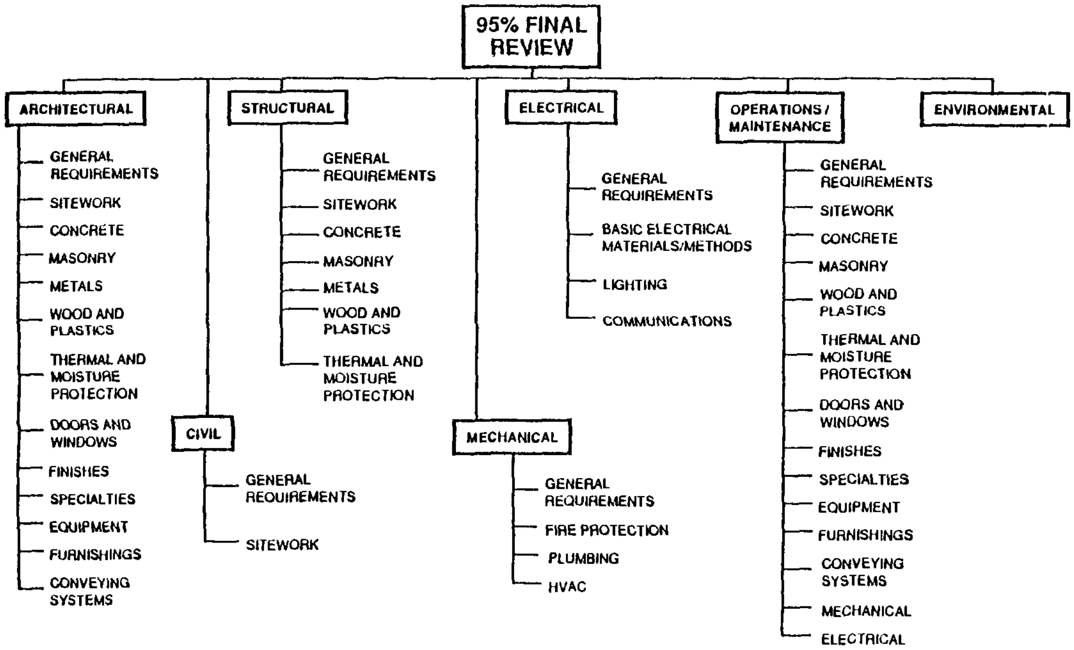

Fig. 3.3. BCO Advisor Logic Tree (95%)

This breakdown reflects the manner in which construction drawings are normally arranged and distributed to various reviewers. It also allows for the concurrent review of drawings and specifications, the typical and most comprehensive approach to reviewing a particular design project. Only the Special Issues

Review, as illustrated in Figure 3.4, uses its own unique classification of review topics.

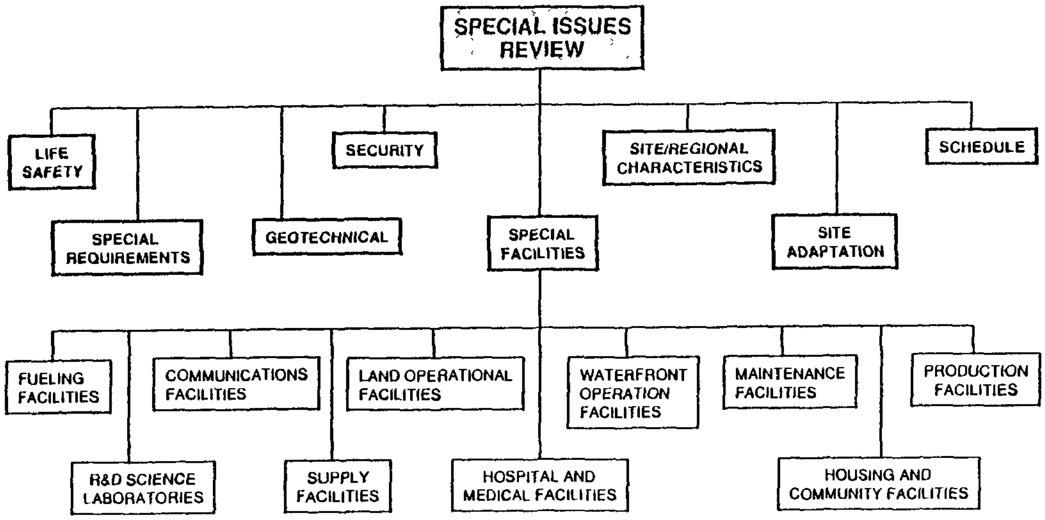

Fig. 3.4. BCO Advisor Logic Tree (Special Issues)

These topics are usually very project-specific and are most likely to be customized to the differing needs of each Corps' District and Division office. They are provided for experienced reviewers who do not need to be "led by the hand" through either the Concept or Final Design Review but require information on BCO issues encountered on an infrequent basis.

3.3 How BCO Advisor works

Figure 3.5 illustrates how a typical review session has the reviewer requesting guidelines within a particular review category from a series of menus.

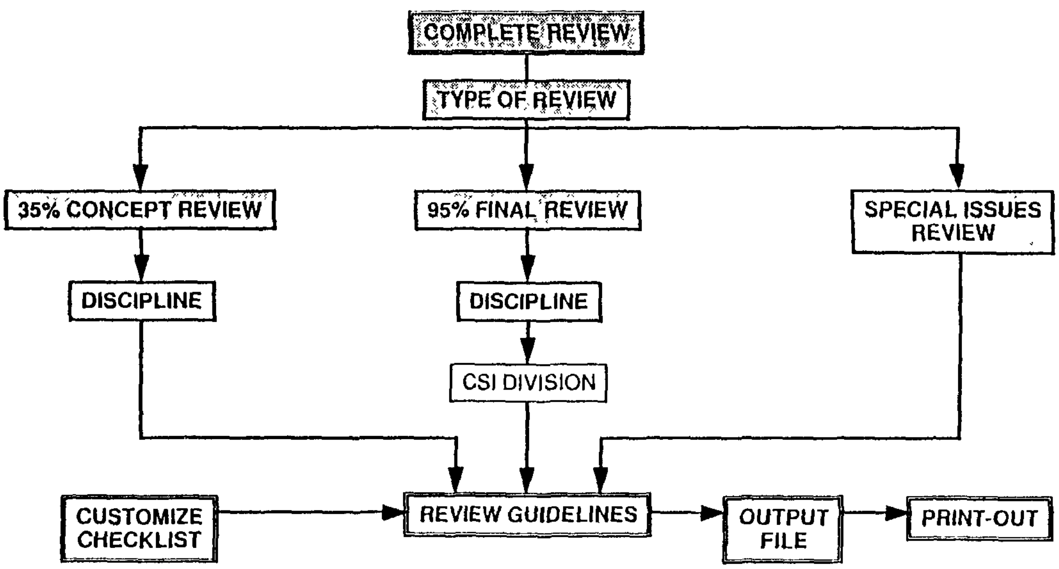

Fig. 3.5. BCO Advisor System Structure

The guidelines provided by the program are then used as a basis for checking for deficiencies in the contract documents. The complete review involves examining the documents following the guidelines listed under the applicable topics of the BCO Advisor. Within every checklist the reviewer has the option to export any relevant guidelines to an output file and to edit those guidelines into specific review comments pertaining to the particular project being reviewed. When more than one session is needed to completely review a set of contract documents, the same output file can be used, with additional comments merely appended to that file. The system also allows for cross-checking between disciplines at the Final Design Review stage, thereby ensuring a more complete review. Each discipline can query the system for guidelines that are outside their area of expertise but are relevant to reduce conflicts among disciplines. Also, this system allows each reviewer to customize the checklists to fit their own particular needs.

The system initially asks the user for information about the project to be reviewed as well as for the name of the file that will store the comments gathered from the review session. After this information is entered, the computer is ready to run the program.

3.3.1 Main Menus

Figure 3.6 shows the first menu encountered by the user which gives choices for the type of review to be undertaken.

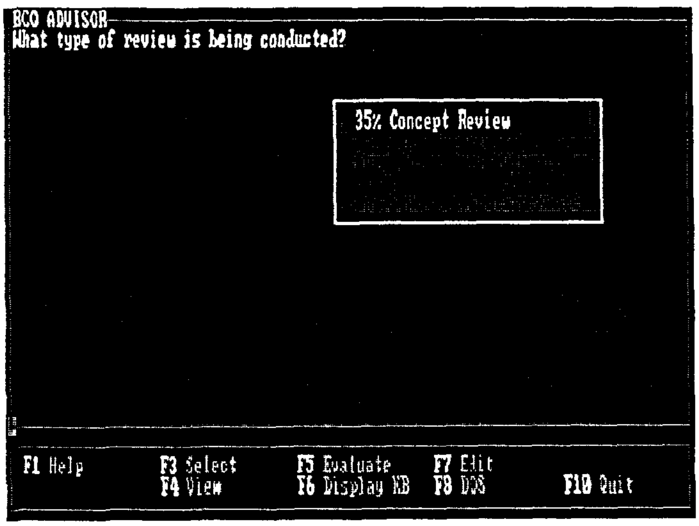

Fig. 3.6. Type of Review

The 35 percent Concept Review covers general issues which need to be caught in the early design stages. The 95 percent review covers issues found on the final set of plans, specifications, and bid documents. The Special Issues Review deals with specific items which must be addressed on a project by project basis.

When 35 percent Concept Review is selected from the main menu another menu appears, illustrated in Figure 3.7, which outlines the seven disciplines that contain checklist guidance.

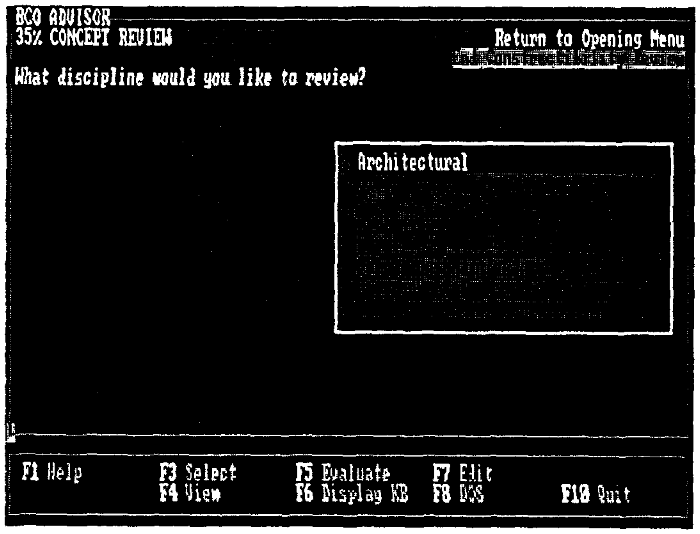

Fig. 3.7. 35% Concept Review Menu

Choosing any one of these seven disciplines (Architectural, Civil, Structural, Mechanical, Electrical, Operations/Maintenance or Environmental) will produce a checklist dealing with that topic and level of review.

When 95 percent Final Review is selected from the main menu, the same seven disciplines are displayed as contained under the 35 percent Concept Review. Picking one of these disciplines produces another menu, illustrated in Figure 3.8, which has the appropriate portions of the sixteen category CSI breakdown for that discipline.

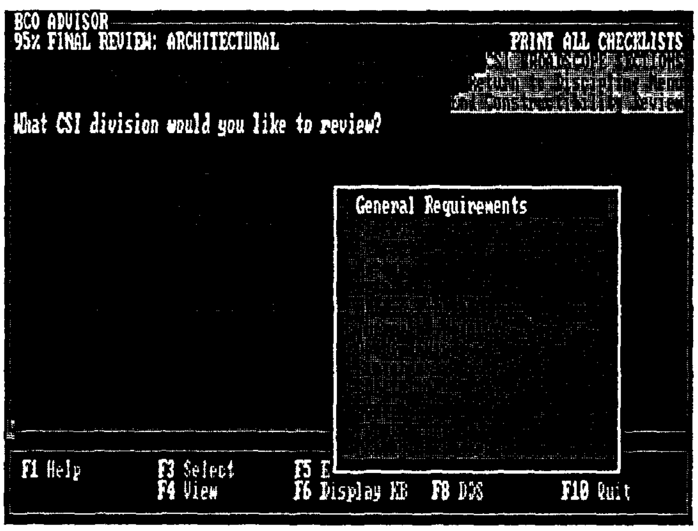

Fig. 3.8. 95% Final Review CSI Divisions Menu

Choosing one of these categories produces the checklist from which comments can be exported.

The categories under Special Issues Review, as illustrated in Figure 3.9, are: Life Safety, Security, Schedule, Special Requirements, Special Facilities, Site/Regional Characteristics, Site Adaptation and Geotechnical.

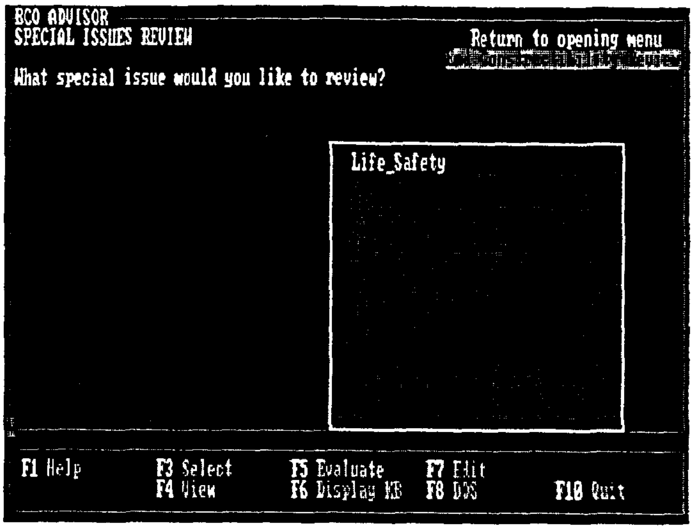

Fig. 3.9. Special Issues Review Menu

Selecting any one of the first three categories of the Special Issues Review menu produces checklists; however, choosing any one of the last five categories produces another menu with sub-topics. These sub-topics can be edited to indicate specific localities or facility types and customized checklists can then be provided under each sub-topic.

3.3.2 Output procedures

The intent of BCO Advisor is to guide and assist project review team members in producing comments which are sent to the project design team members for plan, specification and bid document modification. This intent is fulfilled more through the structure of the program rather than the content of the checklists. Each checklist has been prepared as generic as possible but the capability exists to make them specific to each project. Each checklist contains information to remind the user of items to be reviewed. When an applicable issue is found, the reviewer can export that comment to a file which is printed at the end of the review period and sent to the designer for incorporation into the project.

Each checklist has "hypertext" choices located along the top of each page of comments. The options available within the 35 percent Concept Review checklists (Special Issues Review is similar) are EXPORT COMMENTS, PRINT CHECKLIST and EDIT CHECKLIST, as illustrated in Figure 3.10.

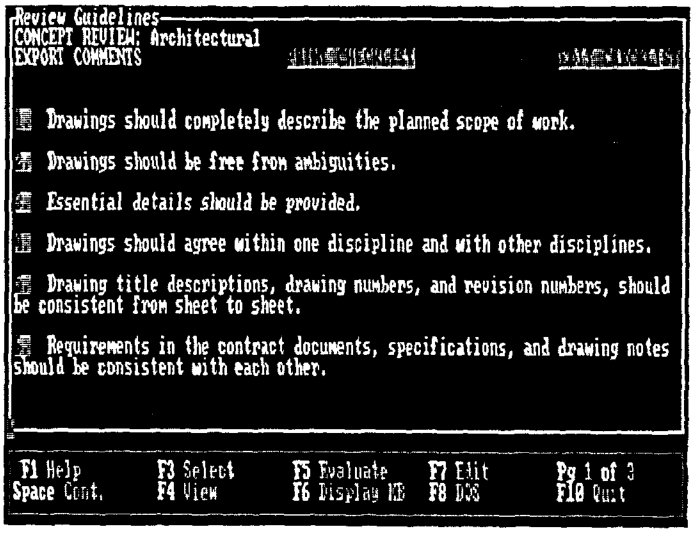

Fig. 3.10. 35% Concept Review Checklist

The EXPORT COMMENTS option is used to select comments from the checklists which are then stored in the output file. After a comment is chosen for export to the output file, the program allows the user to customize the comment without changing the generic checklist. If this option is selected, the computer functions like a word processor. Comments can be overwritten, added to or annotated. After each comment is edited, the program asks for a page or sheet number. This information designates either a page of the specifications or a sheet of the drawings which the comment refers to. In the next step, the computer requests a detail or room number of where the problem might exist. A specifications paragraph number may be used instead of a detail or room number. Therefore, a reviewer can generate specific comments based on the generic guidance furnished by the BCO Advisor system to clearly indicate problems to the designer which need to be corrected.

The PRINT CHECKLIST option allows the user to obtain a hardcopy printout of the entire checklist for a particular discipline being reviewed. Once the checklist is obtained, comments can be marked and edited manually for later input into the computer.

The EDIT CHECKLIST option is provided for a user that may desire to make permanent changes to the checklists. The generic list may be altered or added to in order to remind a user of repetitious problems or lessons learned that are specific to their location. Again, the computer functions as a word processor to accomplish this task.

An additional hypertext pick, RELATED INFORMATION, is included at the top of each checklist for the 95 percent Final

Review checklist, as illustrated in Figure 3.11.

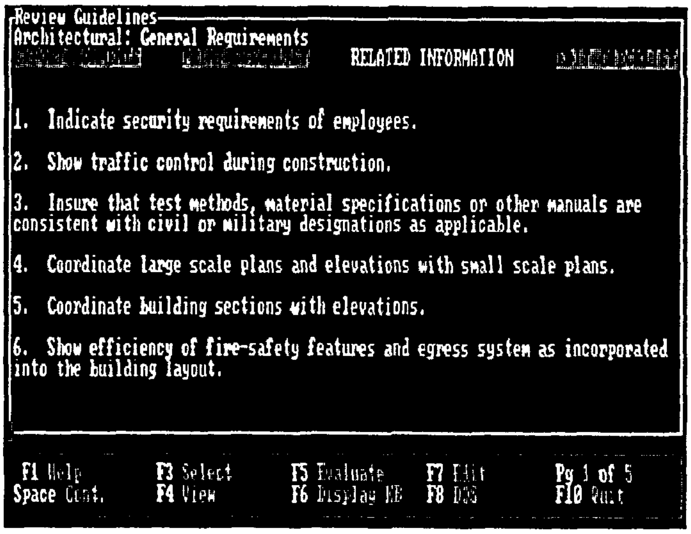

Fig. 3.11. 95% Final Review Checklist

This option indicates that other checklists within the 95 percent review level may contain relevant information to the discipline being reviewed. The program allows the user to review related checklists from other disciplines that may be affected by the design discipline being reviewed. Comments from that checklist may be exported and edited or the entire checklist may be printed.

The final option available to the user of BCO Advisor is the editing of menus. The 35 percent Concept Review, 95 percent Final Review Architecture, 95 percent Final Review Civil, 95 percent Final Review Structural, 95 percent Final Review Mechanical, 95 percent Final Review Electrical, 95 percent Final Review Operations & Maintenance, 95 percent Final Review Environmental, Special Issues Review, Special Requirements, Site/Regional Characteristics, Site Adaptation, Special Facilities and Geotechnical menus can be edited for specific needs. This feature allows the user to adapt the headings of menus, along with the checklists contained under those headings, to their specific requirements. Therefore, the system's expertise can always remain current for the type of review being performed by each user.

3.4 Status

Field testing of the prototype system is scheduled to begin in late April 1991. A user's manual is currently being written and the system is due to be installed at nine Corps of Engineer District offices. Field testing will last approximately four months.

3.5 Finalization and Future Efforts

Based on results from the field testing, the full scale BCO Advisor can be developed into its final format. Fielding strategy for the system will be completed in 1992 and Corps-wide implementation is expected in the latter part of that year.

Currently, additional effort is being expended to develop an environmental compliance module to the BCO Advisor system (BCO-E). This module will attempt to assure that the project design complies with all applicable or relevant and appropriate environmental and public health requirements along with the utilization of currently accepted environmental control measures and technologies. It is believed that BCO-E will produce a more thorough review of project designs for environmental compliance which will lead to a lessor number of contractor claims and change orders, less cost growth during construction and the provision of safety to workers and adjacent personnel. This sytem will also enhance the efficiency of the review by providing ready access to appropriate regulations and by allowing a cross-check of environmental issues between design disciplines.

Section 5 of this paper provides evidence for the applicable benefit of the BCO-E Advisor system to HTW remedial work.

4 Computer Assisted Scheduling

4.1 Description

Research progress to present addresses all the issues introduced earlier in this paper in Section 2.2.2. A tool is in development to improve the ability to estimate overall construction duration. A prototype system named CODES (Construction Duration Estimating System) is in the process of being validated and tested. Work is also underway to develop a computer-based construction schedule generator. An initial prototype (CASCH, for Computer Assisted Scheduling) has been developed that is able to generate schedules for building construction. There is also research work being performed to improve the consideration of weather impact on construction schedules.

4.2 Development process

As mentioned, the research strategy for computer assisted scheduling is to generate smarter tools that not only can represent project data, but also can incorporate and use some scheduling knowledge. This goal is achievable through the utilization of innovative computer technologies that allow the representation of knowledge consisting of: (1) facts, for example 'unprotected exterior concreting activities are sensitive to weather'; and (2) heuristics, like 'if a component covers work to be inspected, wait until after inspection to install it'.

The acquisition of the scheduling knowledge is therefore of paramount importance. Several avenues have been pursued to acquire construction scheduling knowledge. The most relevant ones are discussed in the following paragraphs.

4.2.1 Knowledge acquisition

A series of structured interviews with experienced construction schedulers from different construction firms was conducted. Five construction schedulers from four construction firms were interviewed during a period of 18 months in order to acquire construction scheduling knowledge. This knowledge acquisition process was complemented with input from Corps of Engineers experienced construction personnel which was acquired through two workshops and informal communication.

The acquisition of construction knowledge with the above mentioned schedulers was performed in several different ways, described in detail in [Echeverry 91]. Only a brief summary of the knowledge acquisition process is provided in this paper.

Two approaches were utilized to interact with the experienced schedulers from the private firms: (1) development of a schedule for an example building for which complete drawings and specifications were available; and (2) discussion sessions based on previous construction schedules developed by the participating schedulers.

Also, a number of publications related to scheduling were reviewed, listed in [Echeverry 91] and [Steen 91]. This review complemented the interaction with the schedulers. Especially relevant information was obtained from a review performed on the Corps of Engineers Construction Specifications to identify the sensitivity of construction materials to weather [CEGS 90].

4.2.2 Summary of acquired knowledge

Schedule Production Phases

Two major phases were observed that comprise the schedule generation process. The first phase consists of the assimilation and understanding of project information by the scheduler. The second phase is the actual production of the schedule.

The experience of the scheduler is useful at the information assimilation phase in identifying project features that are common (typical) and features that are unique to the project (project specific). Most of the effort in this phase is spent by the scheduler in examining those unique project features and determining how they might be installed and procured.

The schedule production phase is accomplished in two steps. The first one has a qualitative emphasis and includes: (1) a breakdown of the project construction into activities; (2) a preliminary logical sequencing of the defined activities; and (3) a preliminary consideration of activity durations based on approximate quantities. The second schedule production step consists of an iterative process of adjusting and refining the schedule. Issues considered in this step include: (1) procurement lead times; (2) crew design and productivity estimation; (2) expected weather impact; (3) owner occupancy requirements; etc.

Activity Sequencing

Through the interaction with the construction schedulers and the literature review, several key factors that govern activity sequencing were identified. Table 4.1 provides a summary of these factors.

GOVERNING FACTOR	GENERAL DESCRIPTION
Physical Relationships Among Building Components	Building components are spatially restricted, weather protected or gravity supported by other components. Activity sequencing has to respond to these inter-component relationships.
Trade Interaction	Activity sequencing also responds to the different ways in which the different crews and their processes/tools/equipment affect each other during the construction phase.
Path Interference	Building components have to be moved around the job-site in order to be installed. Activity sequence has to guarantee an interference-free path for the displacement of any component and its installing crew and equipment.
Code Regulations	Activity sequencing is also responsive to construction phase safety considerations, and to inspection/acceptance requirements.

Table 4.1. Identified Categories of Activity Sequencing Factors

The following examples illustrate the application of the acquired knowledge:

- Weather sensitive components (dry wall or ceiling tile, for instance) are installed after the building enclosure is in place because the enclosure weather protects these components (the enclosure and the weather sensitive components are physically related by the 'weather-protects' relationship).

- The slab on grade is installed after the utility pipes are in place, because the slab on grade covers the utility pipes.

- The finishes of the first floor, or lobby area, are normally completed after the rest of the building is finished because this is typically the access area for all crews and equipment working inside the building. This circulation of people and equipment can likely damage the finishes of the access area if they are completed.

Estimation of Preliminary Activity Durations

Heuristic knowledge was acquired to estimate preliminary building construction durations based on approximate quantities. For example, it was identified that the pace of progression of the structural frame erection normally controls the pace of progression of following work (rough-in work, wall studs, etc.). This controlling of the pace happens because the frame erection provides the areas (floors) where most of the work that follows is performed.

Activity Weather Sensitivity

A review of the Corps of Engineers Guide Specifications, and of relevant prior studies, is in progress to identify and compile activity weather sensitivity knowledge. Also, discussions with experienced field personnel have been performed to complement this weather sensitivity information. This information gathering is presently addressing weather limits for which work is normally interrupted. The effect of reduced productivity levels because of less than ideal weather circumstances will be addressed in future research efforts. There are three major areas where weather sensitivity information acquisition is in progress: (1)material sensitivity; (2)operation sensitivity (high winds sensitivity of structural steel erection, for example); and (3)labor and equipment sensitivity. A current compilation of results is available in [Steen 91].

4.2.3 Prototype systems for scheduling assistance

Part of the acquired construction scheduling knowledge described in the previous section has been incorporated in the form of computer systems. Currently these systems are at the prototype level. Validation and testing of these prototypes is in progress.

CODES

This is a prototype system for construction duration estimation. It incorporates knowledge about: (1) commonly found major activities for building construction (e.g., structural frame erection, exterior walls installation, etc.); (2) preliminary duration estimation for these activities; and (3) a default logic (or precedence relationship) based on common building construction practice. The objective of CODES is to assist in performing reasonable estimations of overall construction duration, based on a few input building parameters (number of floors, type of frame, type of enclosure, etc.). CODES is described in more detail in [Sun 91].

Figure 4.1 shows one of the CODES input screens.

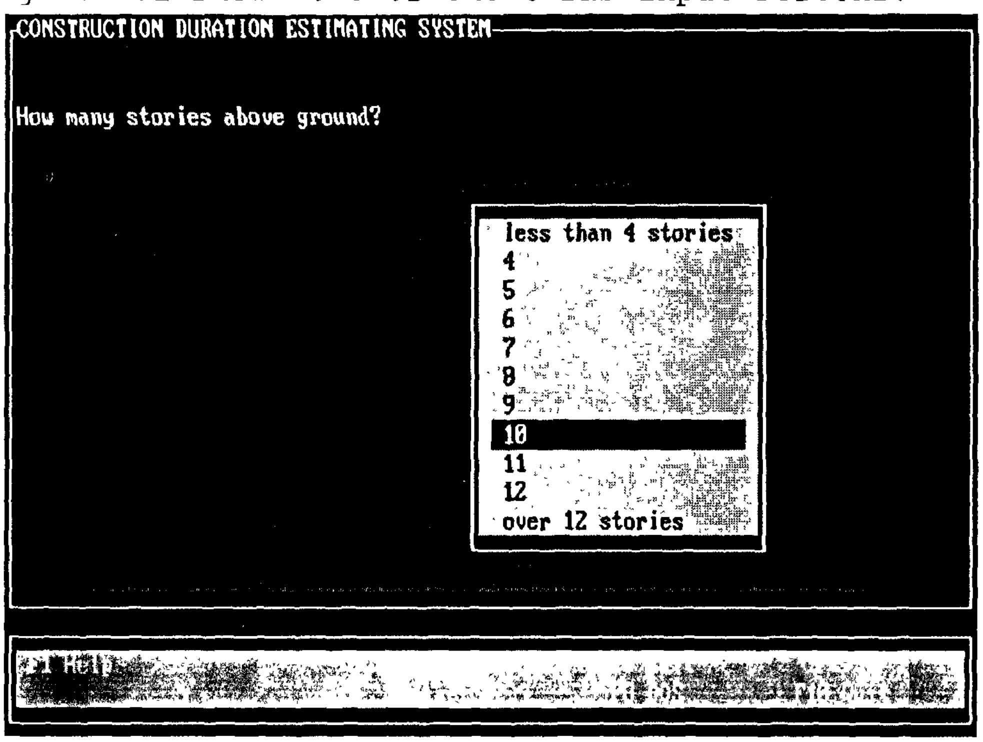

Figure 4.1. CODES Input Screen for Number of Stories

Figure 4.2 illustrates the output that CODES provides. In this case, a barchart of major construction activities was produced for a ten story building with one basement, and a typical area per floor of 10,000 sqft.

```
     ACTIVITY/WEEK        5    10    15    20    25    30    35    40    45    50    55    60
  --------------------------------------------------------------------------------------------
        mobilization**
     site&foundation  ******
          erect_frame       ***********
     erect_roofframe                   *
    place_concr_deck           ***********
        fireproofing             ***********
             roofing                    **
     instal_elevator                      **************************
            rough_in                 ***********
           enclosure                 ********************
    int_finish_fl_b1                     ********
     int_finish_fl_2                       ********
     int_finish_fl_3                         ********
     int_finish_fl_4                           ********
     int_finish_fl_5                             ********
     int_finish_fl_6                               ********
     int_finish_fl_7                                 ********
     int_finish_fl_8                                   ********
     int_finish_fl_9                                     ********
    int_finish_fl_10                                       ********
     int_finish_fl_1                                         *********
            clean_up                                                  *****
      demobilization                                                       **

  --------------------------------------------------------------------------------------------

  Start date: Tuesday 10/1/1991
  Duration: 55 WEEKS, 385 CALENDAR DAYS, 275 WORKING DAYS
  Finish date: Monday 10/19/1992
```

Figure 4.2. Example of CODES Output

CODES is currently able to provide weather related warnings, as illustrated in Figure 4.3.

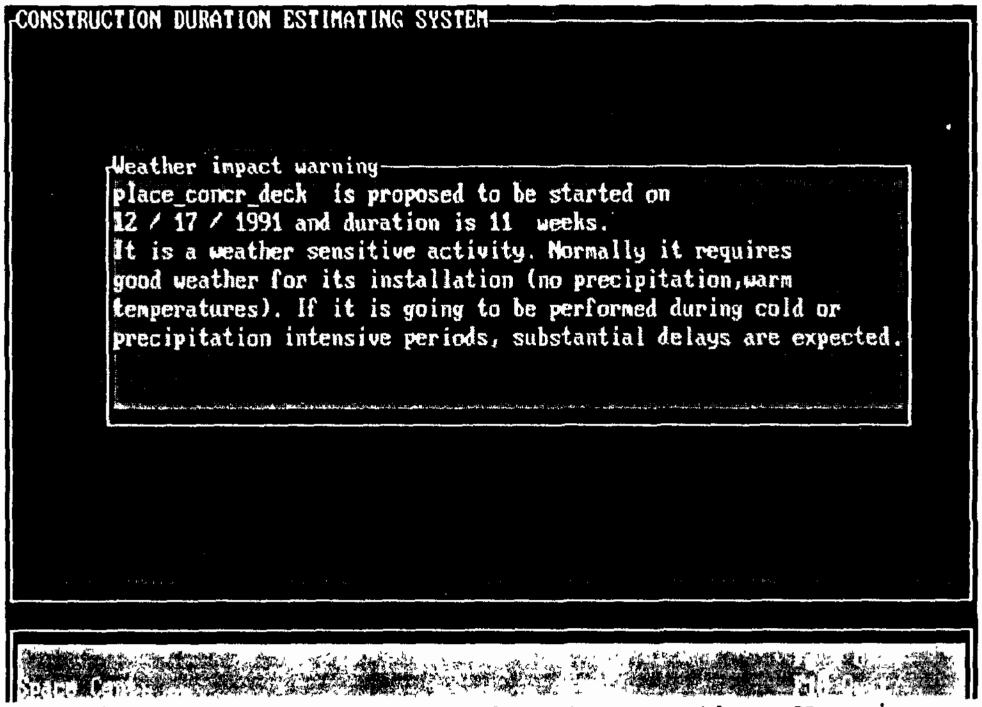

Figure 4.3. Example of CODES Weather Warning

However, its weather knowledge is limited to Mid-west weather patterns.

CASCH

This is a prototype system that incorporates knowledge to: (1) breakdown building construction into activities at three levels of detail; (2) sequence construction activities responding to some of the factors summarized in Table 4.1 on page 17; and (3) estimate preliminary durations for the defined activities. The objective of CASCH is to assist the planner in developing building construction schedules in a fraction of the time required to do manually. The approach is for CASCH to request information about general building parameters and quantities to develop a schedule based on common construction practice. The user then refines and adjusts this result with project specific features not considered by CASCH. CASCH is described in more detail in [Echeverry 91].

Figure 4.4 shows an overview of the operation of CASCH.

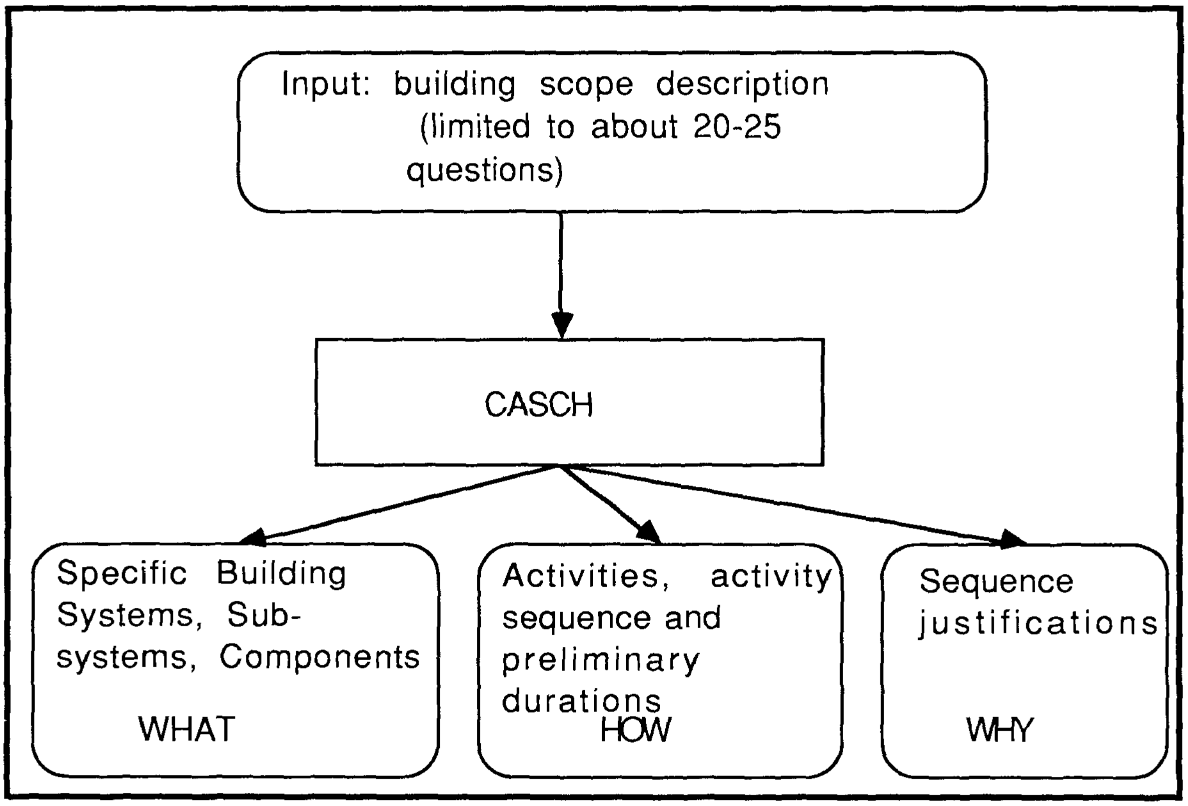

Figure 4.4. Overview of CASCH's Operation

The input required from the user is reduced to providing building system types and approximate building quantities. It is relevant that CASCH not only deduces activity sequence given its knowledge of activity sequencing, but it also stores the justification of each precedence link that it deduces.

Figures 4.5 and 4.6 illustrate some of the results that can be obtained with CASCH. They show the activities related to Site Preparation and Foundation Work, and to Exterior Skin installation for a six story building with one basement.

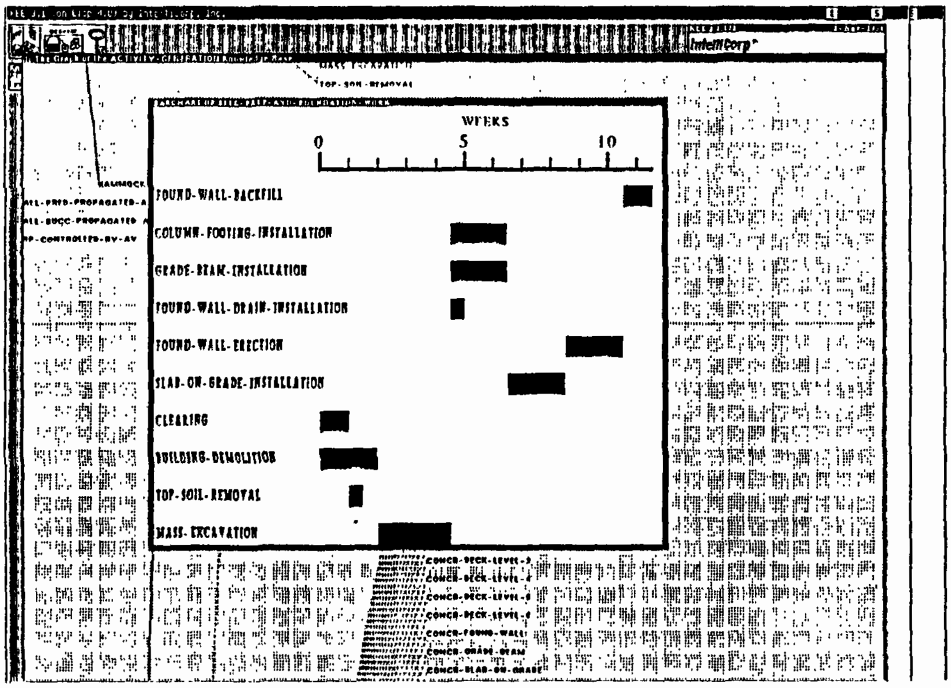

Figure 4.5. CASCH Barchart of Site Preparation/Foundation

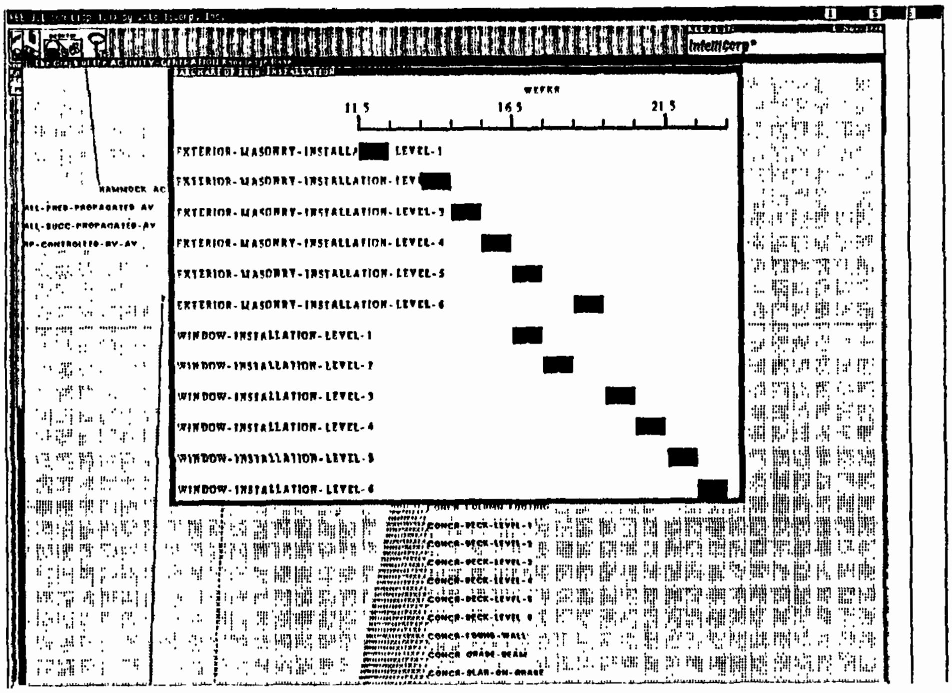

Figure 4.6. CASCH Barchart of Exterior Skin Installation

4.3 Status and projected future progress

Both CODES and CASCH are at the prototype level. CODES is being enhanced through validation and testing at the present time. The effort to produce CASCH is being complemented by an endeavor to address schedule evaluation. This development responds to the fact that the Corps of Engineers does not dictate the schedule for the construction projects it manages. The approach instead is to review and evaluate the reasonableness of contractor submitted schedules.

There is also a research effort underway to develop a computerized weather impact evaluation advisor. The planned approach is to incorporate the acquired weather sensitivity information into a computer program. This program will also contain a database of weather data. This advisor is expected to estimate the number of days lost due to weather impact on construction operations.

5 Potential application to HTW remedial projects

HTW remedial projects are deemed successful if they achieve the following results: (1) procurement protests are not encountered, (2) construction is completed on schedule, (3) a remedy consistent with the Record of Decision (ROD) is constructed, (4) a minimal number of change orders are encountered and (5) constructor claims are identified and resolved before the completion of construction. The innovative tools being developed at USACERL for design review and scheduling have great potential for being very useful in helping to achieve these five goals on HTW remedial projects.

5.1 BCO Advisor

The Army Corps of Engineers spends approximately $460 million each year in contingency, supervision and administrative costs for the acquisition of new facilities as well as for maintenance and repair of existing facilities. This money is necessary to cover the costs of change orders during construction produced by design deficiencies or unidentified site conditions.

The reduction of BCO-E related errors and omissions which develop into change orders during the construction phase of a project has substantial benefits. If the contingency, supervision and administrative costs included in a construction budget can be cut by just one percent due to a decrease in the number of design deficiencies that reach the construction stage, the Army will immediately realize a savings of $4.6 million per year. Also, if the construction contract documents can be easily understood and a quality design package is produced that can efficiently be built, there will be fewer project disruptions during construction. This situation will allow constructors to lower the contingency included in their bid prices which will translate to a reduction in initial project costs.

One proof of the potential savings the BCO-E Advisor system can produce is evident in a study that was conducted in FY89 at the Army Corps of Engineers' Sacramento District to determine if ARMS reduced construction modifications due to design errors. The study concluded that for FY88 ARMS reduced the Sacramento District construction modification amount by $1,178,545, a savings of approximately 5 percent [CESPK 88]. Since BCO-E Advisor is a system to help generate the comments (it exposes design deficiencies) that are managed by ARMS, it is reasonable to assume that at least the same amount of savings can be additionally achieved through the use of BCO-E Advisor.

This system possesses great potential for providing support to the review of HTW remedial projects. Before construction begins, these projects undergo several extensive reviews of many of the same areas contained within the BCO-E Advisor system. A biddability review is performed to ensure that the construction package is free of significant design errors, omissions and ambiguities so that bidders can respond in a reasonable manner and at a reasonable cost. A constructibility review is performed to enhance the "buildability" of a design by evaluating the technical product being delivered by the designer for accuracy and completeness along with eliminating impractical and inefficient construction requirements. An operability review is performed to determine whether the particular system or remedial facility will function optimally, as required by the design documents, and whether it can be maintained in an acceptable manner. An environmental review is performed to provide assurance that the design will meet the technical requirements of the ROD and to provide consistency between the implementation plans and the current regulatory and policy requirements. Additionally, the environmental review determines the adequacy of the documents in addressing the potential for environmental releases during construction and the contingency plans, should such releases occur.

As previously stated in Section 3, the BCO-E Advisor can easily be customized to the specific needs of each user. Therefore, biddability, constructibility, operability and environmental compliance issues can be inserted into the system which apply specifically to HTW remedial projects. Once the information is in the system it can be used to guide and assist reviewers in conducting thorough reviews of HTW remedial projects. As proven with traditional Corps of Engineers' construction, this automated review system can provide the same magnitude of savings on HTW remedial projects.

5.2 Construction scheduling assistance

The research work to present in computerized construction scheduling support has focused on building construction. It is recognized that HTW remedial projects substantially differ from traditional building construction. However, the application of a similar approach to develop tools specifically targeted to support the scheduling of HTW remedial projects is not only possible but desirable.

The overall approach followed here to produce improved construction scheduling tools is to gather experience and knowledge accumulated in the past (from experienced schedulers, and literature review), and incorporate part of this knowledge into a computer platform. This allows the production of computerized assistants that can take a more relevant role in project scheduling.

This approach is potentially very advantageous for supporting HTW remedial project scheduling. HTW remedial projects normally incorporate innovative technologies and techniques that make it extra difficult to anticipate durations and produce construction schedules. A structured effort to accumulate and store experience gained in scheduling projects that involve innovative technologies should soon provide a knowledge-base that contains the gained experience. This could translate into more accurate HTW remedial project duration estimations and improved HTW remedial project construction schedules. An added potential benefit is the increased productivity of the planners and schedulers that deal with HTW remedial projects.

6 Conclusions

The U.S. Army Construction Engineering Research Laboratory has developed several innovative systems that are being utilized by the Army Corps of Engineers to enhance the design review and scheduling of traditional construction projects. This paper has attempted to show the promising potential these tools possess for application to HTW remedial projects. BCO-E Advisor, CODES and CASCH will produce more thorough design reviews and more accurate schedules which will reduce time delays and cost overruns on HTW remedial projects.

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Basic Principles of Effective Quality Assurance

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INTRODUCTION

Typically in designing a QA program application, one must start with concepts and principles derived from vision, information, and experience. From the resulting concepts and principles, an application design is created and validated. Originally, the topic of this paper was based on a designed application for RA efforts. Our present topic, however, must remain at the concept and principle level because our study is currently in progress. One can test current applications based on these concepts and principles. Therefore, this discussion focuses on "Basic Principles of Effective Quality Assurance".

As one begins to plan the management of the quality assurance program associated with a large project, there are endless potential points of evaluation and actions to be taken. Often, the key in selecting the right QA plan is determining what must be examined and when.

BACKGROUND

The Hazardous Site Control Division (HSCD) of the EPA's Office of Emergency and Remedial Response provides support to the regional offices in a variety of areas. Part of this responsibility includes reviewing regional program activities and developing procedures to improve the overall cost, quality, and schedule of remedial projects. PDX Company is assisting the HSCD in reviewing Construction Quality Management concepts and practices with regard to EPA Regions and the Alternative Remedial Contracting Strategies (ARCS) contractors.

PDX Company has reported to the EPA on the technical quality assurance procedures currently being used by the private construction industry. Information was gathered based on our experiences as construction managers, a review of selected current literature, and a collaborative observation of a limited number of local construction contractors. Future project work with the EPA will include a broader study of private QA practices versus potential benefits to EPA operations.

PDX Company has spent significant time and effort in applying third party management (including QA) strategies. This discussion will cover some of the basic concepts and principles which have helped us to improve the effectiveness of our third party QA process.

ANALYSIS

A. Definition of Terms

The following definitions must be established:

CM -- Construction Management
A project delivery system utilizing an unbiased owner's representative (or agent). Its objectives are to minimize project time & cost while maintaining quality. Starts during preconstruction.

GC -- General Contractor
The prime or main contractor signed by the owner for construction of the entire project construction.

QA -- Quality Assurance
The process by which concerned others verify that compliance has been achieved.

QC -- Quality Control
The management process by which contractors achieve results that comply with the requirements.

When developing a QA program for a specific project, a set of requirements is identified. From these requirements, the contractor develops his/her QC plan. The design team or QA team establishes a QA plan. The contractor implements construction utilizing the QC plan to achieve results that will comply with the requirements. The QA plan is simultaneously implemented to verify the compliance of certain processes and results. Simple!

Simple, if all goes as planned. However, such is not the norm. Occasionally, the processes and results achieved by the QC program are not in compliance with the construction requirements. Hopefully, QA catches everything missed by QC. This is the expectation of QA, notwithstanding the extra degree of difficulty and cost for the QA program, to achieve the same quality as the QC program. QA is faced with the difficulties of being:

Based on auditing/sampling -- QA checks the process rather than controls the process.

Variable in situations encountered -- QA site conditions, project types and locations, teams, workers, etc., all vary significantly.

Achieved by influence -- QA does not directly control the implementation of construction activities.

Critical In Timing -- Certain key QA processes are timing sensitive.

Given these conditions, one must structure a fully reliable and cost-effective assurance plan. Because of the endless possibilities, cost effectiveness revolves around knowing where and when to look. Let us analyze several key principles.

B. Principles of Effective QA

To assist in the development of a fully reliable and cost-effective assurance plan, we have developed a few key principles:

Principle 1. Essentially, everyone wants to do a good job.

Principle 2. A normalized sampling and review program must be operative.

Principle 3. Prevention collaboration, if managed, enhances the effectiveness of results management.

Principle 4. Each significant predecessor event must be completed prior to starting its dependent event.

Principle 5. Certain stress points (Potential Breaches) cause deviation from quality -- Management of the stress points allows quality.

Principle 6. Systems are more effective than personal intervention.

In discussing these principles, we intend to discuss how to maximize known strategies rather than "what to do". We will not discuss actions for the examination or resolution process.

Before we begin the discussion of the principles, it is important to note that the foundation of a successful quality program is the QC program. A well developed, well understood, and actionable Quality Control program should have the following characteristics: self-checking, self-correcting and multi-project improvement memorizing. Most construction QC programs, however, currently need support from a QA program. With that in mind, let us analyze the aforementioned key principles.

Principle 1. Essentially, everyone wants to do a good job.

As one establishes a QA program or initiates a cause analysis, time is often wasted in chasing "do not care" attitudes among project members. Most frequently, more substantial causes exist and are not typically the result of intentional neglect or malice by project members. Finding and correcting these more substantial causes will typically have a greater benefit than resolving "do not care" attitudes among project members.

Principle 2. A normalized sampling and review program must be operative.

Two major efforts are associated with the QA process: Judgmental Review and Normalized Review. The components of each are listed below:

Normalized Review
Judgmental Review
Engineering testing/sampling
Blind sampling
Appearance modeling (mock-ups)
Unscheduled visiting
Inspecting
Preventive action planning

Although this paper primarily addresses the judgmental effort, the effective implementation of a normalized quality review process is critical.

Principle 3. Prevention Collaboration, if managed, enhances the effectiveness of results management.

In an environment of clear responsibilities and liabilities, one of the strongest assurance tools is prevention collaboration. Prevention Collaboration requires anticipation and communication to all team members of future quality dependent events in order to plan special handling as the situation dictates. If one is able to anticipate situations and facilitate proper management responses, the results will probably be in compliance and thereby will not require corrective results management. In the rare situation of uncertain relationships, it continues to be useful to discuss significant future quality dependent events. However, it is our general guideline to cautiously agree with and avoid setting the direction on how to handle these quality situations. This guideline is more important in uncertain relationships.

Principle 4. Each significant predecessor event must be completed prior to starting its dependent event

Sounds simple, but this principle is often violated, typically to maintain schedule. Such violations rarely result in time savings; substantial recycle and quality problems typically result. Violation of this principle is most prevalent as the project moves across the RD/RA interface. Obviously, this principle is critical on fast-track projects where multiple package sequencing is heavily utilized.

Principle 5. Certain stress points (Potential Breaches) cause deviation from quality -- Management of the stress points allows quality.

Often in executing a project, the quality norm for most of the project deliverables will be in compliance or will quickly be forced into compliance after start-up confusion is eliminated. Although the project team is maintaining the state of overall project quality performance at or above compliance, we have found the regular existence of pockets of wide compliance variation. These pockets are typically responding to predictable events referred to as "potential quality breach situations." If anticipated and properly managed, potential breaches are never allowed to become breaches. If improperly managed, potential breaches become breaches and remain as such until corrected by outside forces or by itself.

The following quality deviations (potential breach situations) are common to most projects:

Start-up operations
Key personnel change
Field design changes/interpretations
Significant number of project change orders
Unexpected site conditions
Significant weather changes
Schedule slippages
Financial challenges
Non-compliance material deliveries
Project close-out
O&M start-up

Each project will have specific potential breaches related to the project's deployed technology juxtaposed with the skills/experiences of the team or other special situations. Once these potential situations are anticipated, the appropriate management response (counteraction) can be established and implemented.

Principle 6. Systems are more effective than personal intervention.
As managers, we often rely on our ability to detect and facilitate correction of compliance problems. This strategy of personal intervention works well on small 5 or 10 person projects. On most projects where mass execution is in progress, however, personal intervention methodology is at a great disadvantage to systems methodology.

Therefore, we have concluded that when a quality deviation is detected, there are two necessary responses: 1) correct the problem and 2) improve the QC system. Obviously the deviation has to be corrected. But equally critical is determining the real cause of the deviation and fully correcting the QC system to prevent these types of problems in the future. It is important to note that a fully functioning, well developed QC system will correct problems that the personal intervention manager will never see, and will never need to see.

FINDINGS -- Vision of Future QA

Surely, some readers are asking "why does anyone have to verify compliance?" If we have a competent contractor, should we not expect quality results and should we not be able to save the cost of QA to obtain more RD/RA? In response, let me repeat an often mentioned vision. Today, we use QA to verify QC. Tomorrow, QC will be able to stand alone.

Upon contractors fully developing QC programs to: 1) qualify the inputs to the construction process sufficiently in advance to prevent compromise, 2) measure results and feedback that are internal to the construction process and 3) progress toward producing only quality outputs, QC will no longer require QA.

CONCLUSIONS

At what point will contractors successfully operate QC without QA when cost and schedule are given more importance than quality? QC will stand alone when contractors realize that:

1. Quality is not counteractive or subordinate in importance to cost and schedule performance.

2. Quality is equal in importance to cost and schedule performance.

3. Quality is the means by which to achieve excellence in cost and schedule performance.

The foundation of a successful quality management program is the QC program. Most construction QC programs, however, currently need support from a QA program. To assist in the development of a fully reliable and cost effective quality assurance plan, we have provided a few key principles. These principles provide the guidance by which one can test current applications.

Specifications for Hazardous and Toxic Waste Designs

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INTRODUCTION.

An essential component of any design or remedial action is the contract specifications. As technology for Hazardous and Toxic Waste (HTW) continues to rapidly progress, it is imperative that the contract specifications be accurate, understandable, and practical. The objective of this paper is to discuss how specifications are currently prepared and to detail several ways to improve them, especially when prepared for HTW designs.

Two things can be said about a HTW construction project with certainty: (1) changes will be made during the course of construction, and (2) the contract manager and the construction contractor will seldom initially agree on the effect the changes will have upon a project (Cooney, 1989). When the contract specifications are not properly written, disputes, claims by contractors, and extra costs, due to controversy, quickly materialize. Many of these conflicts would have never developed if the specifications had been properly written in a clear, concise, and understandable manner.

In order to prepare a good specification, the specification writer has numerous and assorted sources of information available. However, one tool that is severely lacking for HTW designs is the availability of current, accurate, and comprehensive guide specifications. Many HTW design specifications are prepared from "scratch" since there are no comprehensive guide specifications available for reference. Numerous HTW specifications are modified from general construction guide specifications, which do not adequately address HTW concerns. There is a need in the HTW field for specification uniformity and additional HTW guide specifications. The Corps of Engineers is currently working to prepare "Guide Specifications" particularly geared for HTW remedial designs.

DISCUSSION

Specifications are written instructions which describe all the technical requirements of a contract. In general, contract drawings show what work is to be done, while the specifications are written descriptions of the quality, performance, and workmanship of the final product. In order to write a clear and comprehensive specification, the designer should have a thorough understanding of the work to be accomplished, knowledge of the materials and methods to be used, and the ability to communicate these ideas in an understandable manner.

Perhaps the most difficult job of the engineer/designer is to translate the technical requirements of the contract into a document that can be understood by engineers, contractors, lawyers, regulatory agencies, and the public. When a specification is poorly written, claims, disputes, and controversy will certainly develop very quickly. There are national seminars conducted regularly which discuss the legal aspects of construction contracts. Many of the topics focus on dispute resolution, claims against the federal government, and new strategies in construction litigation (Muller, 1991). A large number of the disputes involve the interpretation of the specifications. It is vital that the contract specifications are as complete and thorough as possible. The suggestions which follow are intended to provide some of the basic principles of competent specification writing and to highlight some of the most common problems.

CLARITY. Specifications, whether they are for hazardous waste remedial designs or not, should be written in the clearest manner possible. Specifications should be written as directions, never suggestions. Relative terms such as: "reasonable," "best quality," or "in accordance with standard practice," are indefinite and should not be used (Abbett, 1963). Such phrases leave doubt as to what work is really required. The expression "as approved by the engineer" can relieve the contractor of responsibility since the contractor has no way of knowing what the engineer will require. Other phrases such as, "The contractor shall provide all materials and perform all labor in connection with each type of construction," "in accordance with these specifications," or "as indicated on the drawings," are essentially meaningless and should not be mentioned. Unusual technical jargon should be avoided if at all possible. It is important to use words that do not have more than one meaning. The specifications should not repeat, but rather, complement the information already provided on the drawings.

The phrase "or equal" appears extensively in HTW specifications, as there are countless new and proprietary products or services available. Basically, this phrase is often inserted into a specification to allow a substitution of a different product for a specified product (Sprague, 1990). The Government is particularly interested in generating competition, therefore, if "or equal" is used, the designer should insure that there are other products available which meet the specifications. In general, the use of trade names, proprietary items, and preparing a specification by adapting a manufacturer's description of a product, should be avoided. It is preferable to specify materials or equipment by preparing a performance specification, or if absolutely necessary, to qualify a manufacturer's trade name with the words "or equal." The phrase, if used, should also require any substitutions to be approved prior to use.

Other specifications are not written in a clear manner because of excessive cross-referencing from paragraph to paragraph, or to HTW laws and regulations, ending up in a confusing run-around. There are many specifications that contain references to standard specifications or regulations which are unfamiliar or difficult to obtain. Often times when these standard specifications or regulations are obtained, they are found to be superseded one or more times. All of this forces the contractor to wade through a maze of papers, searching for the thing he "is to comply with." The following sentences, taken from a submitted specification to the Corps of Engineers for approval, illustrate this problem. "The SSHP shall serve as the Accident Prevention Plan (APP) and activity hazard analyses (Phase Plans), required by F.A.R. Clause 52.236-13, and Paragraphs 01.A.03 through 01.A.06 and Appendix Y of USACE EM 385-1-1. Thus a separate APP is not required."

CONCISENESS. During World War II, it was speculated that many specifications could have been reduced by 50 to 70 percent in length, without losing any of the essentials, by careful editing (Retz, 1943). This assumption is probably as true today as it was in 1943. Specifications should be written in as much detail as necessary without becoming too verbose. Often times a complete guide specification is used for a particular type of construction with no regard to the relative importance of that phase of the work to the job. For example, a comprehensive "grading" specification would be required and appropriate for the construction of a RCRA landfill cover. However, a complete "concrete" specification would inappropriate and unnecessary if the only concrete required on the project was to plug a few abandoned culverts. Usually, these all encompassing guide specifications are intended to be used in the design and construction of relatively large and complex structures which require considerable detail.

Another area that requires consideration when producing clear and concise specifications is the elimination of nonessential words. Goodrich provides the following sentences, extracted from actual contract specifications, which exhibit how the intended meaning is obscured by verbose language.

> Paint shall be of such character that it will protect the steel against corrosion without being injurious to the health of persons drinking the water after the latter has stood in the tank for three months.
>
> Drain piping in and about the pump room to be supplied by the subcontractor whether entirely buried in concrete or not.
>
> All material, which, subsequently to the tests at the mill and to its acceptance there, during manipulation, in the shops under shears, punch, etc., which shows it is not of uniform quality, as herein specified, and also hard spots, brittleness, cracks and other defects are developed; such material shall be rejected (p. 108).

REFERENCES FOR WRITING HTW SPECIFICATIONS.

The specification writer is often times an "assembler" of specifications rather than a "writer" of specifications. The writer often relies upon many diverse and complex sources of information when putting a specification together. This information is usually recovered from files manually or by modern computerized data systems. Regardless of how this information is obtained, the specification writer must ultimately decide which segments are to be included or eliminated. The information sources which follow are commonly used by designers when preparing HTW contract specifications.

EPA Technical Guidance. The Environmental Protection Agency (EPA) maintains a vast technical support program that is available to designers and technical personnel of HTW projects. The Office of Solid Waste and Environmental Response (OSWER) and the Office of Research and Development (ORD), within EPA, has developed a directory which provides a point of contact for obtaining technical assistance. The directory is entitled, Technical Support Services for Superfund Site Remediation and can be obtained by writing to: Technology Innovation Office (OS-10), U.S. EPA, 401 M Street, Washington, D.C. 20460.

The EPA has numerous technical guidance documents, handbooks, and publications available for designers to utilize for HTW projects. These documents are useful as references for various design considerations. There are also automated information systems such as electronic bulletin boards, data bases, and inventory systems which provide information on almost any conceivable question or problem. Although guidance documents and technical publications do provide a comprehensive source of information for the specification writer, they are often difficult to translate into specifications. One of the problems when using guidance manuals or documents to develop a specification, is that they provide only technical guidance and relatively few design specifics.

Information from Industry. One of the sources available for the engineer to utilize is the vast and remarkable supply of information and technology from private industry. Most companies are more than willing to make presentations or send technical information of their product to the engineer. Many manufacturers will provide test data, sample specifications, or samples of their products as well. All of this information is important to consider when determining if a material is appropriate for a particular project (CSI, 1975). The designer should conduct independent lab tests in order to verify a manufacturer's product performance claims.

Guide Specifications. General construction guide specifications are another source of information that is extensively utilized by specification writers. The guide specifications are prepared for adaptation to major projects of varying types and different locations in the United States. Certain requirements have general applicability to all projects, while other requirements must have blanks filled in; alternative words, phrases or paragraphs to be chosen; or special paragraphs to be added. One problem with general guide specifications is that they must be continually updated to keep up with the latest technology and they do not address HTW issues.

Sometimes a previously written specification from another project is often edited and used as a guide specification. This practice is to be discouraged as each specification should be site specific. Errors from the previous project may get passed on to the new specifications. The previous project may have used obsolete technology or cleanup methods.

HTW GUIDE SPECIFICATIONS ARE NEEDED.

Why are HTW guide specifications needed? There are many reasons why an increased emphasis should be made on producing guide specifications for HTW construction contracts. In a HTW project, there are additional considerations that must be taken into account, that a "regular" construction contract does not have. Items such as: dust control, health & safety, site control, duration of site work, and weather all require careful consideration during design. For example, dust control on a normal construction project is used primarily to prevent the dust from becoming a nuisance. However, on a HTW construction project, dust control may be critical, as the dust may be contaminated and could possibly be transported off the site. HTW guides can help to "flag" the appropriate HTW considerations to the designer. Guide specifications help to establish the format to be used, and as far as practical, the specific requirements to be included. Guide specifications are produced to promote uniformity of construction, provide requirements that have been coordinated with industry, and serve as convenient work sheets to be marked by the specification writer preparing project specifications.

HTW guide specifications are a useful tool to the specification writer. The guides provide information of a general nature on required materials and methods for a project, or several choices of materials and methods from which selections may be made. Guide specifications will require careful editing. The specifications are usually written by those considered to be authorities on the subject, and are the result of careful analysis of previous projects and industry standards. The guides usually list almost every practical alternative possible to be covered by that particular specification. In order for the guide specifications to be most valuable, they must be constantly revised and updated to keep up with the most recent technology and practical experience.

In addition to providing uniformity, HTW guide specifications also serve as a checklist for designers. Guide specifications also help to minimize the time required to develop a new specification, thus helping to reduce "reinventing the wheel." The utilization of guide specifications also help less experienced engineers put together a comprehensive specification in much less time.

WHAT GUIDE SPECIFICATIONS ARE NEEDED?

The Corps of Engineers has been engaged in formulating and preparing guide specifications that are specifically written for HTW applications. Currently, the Corps is engaged in the preparation of the following HTW guide specifications:

(1) Geomembranes
(2) Geonets
(3) Underground Storage Tank Removals
(4) Health and Safety

(5) Soil-Bentonite Slurry Walls
(6) Ground Water Monitoring Well

The guide specifications listed above are all in the draft phase at the present time. Others under consideration for further development are:

(1) Incineration
(2) Solidification/Stabilization
(3) Clay Liners
(4) Clay Covers
(5) Gas Venting Systems
(6) Chemical Quality Data Management
(7) Soil Vapor Extraction Systems
(8) Drum Removal and Handling

The eventual implementation of guide specifications like these will enable the engineer to provide a better specification for HTW design and construction purposes.

CONCLUSION

Specifications are practically useless unless they are free from the weaknesses and shortcomings that have been outlined. On the other hand, specifications can fulfill their purpose and be extremely valuable to the engineer and the contractor alike, if these deficiencies are eliminated. It makes one wonder why it seems to be common practice to produce drawings of excellent quality, yet our specifications are especially lacking. It may be that there is a lack of training on the writing of competent and complete specifications.

In addition, guide specifications may help to bridge the gap from poor specifications to good ones. It is imperative, in light of today's society, to have specifications that are not only constructible, but legally defensible as well. The technology in the HTW field is rapidly changing, and it is difficult, if not impossible to keep up with the latest innovations and techniques for removing or treating hazardous waste. Guide specifications must be continually updated in order to incorporate lessons learned from previous cleanup projects and new technology.

A necessary corollary to the writing of good specifications is that of adequate inspection and quality assurance. It will serve little purpose to have very well-written specifications if they are not strictly observed and implemented. This will only happen if there are competent inspectors at the project.

Therefore, any engineering organization that neglects to provide for adequate and complete inspection is shortchanging itself. Such inspections are as important as well prepared design drawings and specifications.

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Lessons Learned During Remedial Design and Remedial Action Activities at Superfund Sites

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INTRODUCTION

The Superfund Program has recently entered into an active phase of Remedial Design (RD) and Remedial Action (RA) at various uncontrolled hazardous waste sites. There is very little history and experience available to address the remediation of hazardous substances in various media such as soil, sediments, groundwater and surface waters. In addition, EPA's emphasis to encourage the evaluation of innovative technologies during feasibility studies and the use of Small Businesses/Small Disadvantaged Businesses places further pressure on the engineering and construction professionals to be very watchful in managing the RD and RA Projects and avoid or minimize mistakes, reduce losses and perform the RD and RA assignments in a cost effective manner. It is with these issues in mind that we share Ebasco's experiences on a limited number of RD and RA Projects which we have completed.

After the RI/FS and public input, the Record of Decision (ROD) is signed by the Regional Administrator which establishes the preferable alternative to remediate the site. If an innovative technology has been selected in the ROD, the validity of the technology is mostly based on bench scale treatability studies performed during RI/FS which then have to be supplemented by pilot scale treatability studies during the design phase. In some cases, it may happen that the pilot scale studies may provide data which cast doubts on the applicability of the chosen technology and in turn require revisiting the whole treatment concept.

Whereas the RI/FS provides information about the extent of lateral and vertical contamination at a site, further site investigations are invariably performed during the design phase to clearly identify and define the areas of contamination to be remediated and the extent of the contaminant plume. The information is used to calculate the quantities of the contaminated source materials to be remediated and to locate the extraction/injection wells for the pump and treat system for groundwater treatment etc. Engineering analysis of soils is also performed if foundations are to be designed for the building, air stripping column, incinerator or any other structure. Sometimes, for groundwater remediation, the pump test is also performed during the RD phase to determine transmissivity, and storage coefficient to assist in the design of the pump and treat system and the duration of time for which this system would operate.

In certain cases, public input becomes critical and the preferred alternative advocated by EPA is modified to take into account local concerns. These and similar other issues impact on the cost and schedules of the RD work assignment.

As regards the RA assignments, it is extremely important that the drawings, specifications, and general conditions be well written, straightforward, simple and unambiguous. Evaluation criteria and schedule of deliverables should be clear and well defined. It is very important that the communication between the EPA, the state, the contractor and the community should be initiated well ahead of the start of the remedial action and should be continuously maintained for the duration of the remedial action.

This paper discusses our experiences at several Remedial Design and Remedial Action Projects in USEPA Region II under the REM III and ARCS II Programs and focuses on the problem areas encountered at various sites and the corrective actions taken.

BACKGROUND

Ebasco Services Incorporated (Ebasco) by virtue of being a REM III Contractor (1985-1990) and the current ARCS II Contractor has worked on several Remedial Design and Remedial Action Projects in EPA Region II. The number of sites we have completed RDs and RAs is small compared to the number of sites where we have completed RI/FS work. We have completed Remedial Designs on sites where the RI/FS was performed by Ebasco and also on those sites where the RI/FS was performed by other consultants. Similarly, Remedial Action has been completed by Ebasco at sites where the Remedial Design was performed by either Ebasco or other consultants. We have selected three (3) projects to illustrate our experiences: Bog Creek Farm, Monmouth County, NJ (RD), Brewster Wellfield, Putnam County, NY (RD & RA) and Vestal Water Supply Well 1-1, Broome County, NY (RA). A brief description of these sites is given below;

BOG CREEK FARM SITE (RD)

The Bog Creek Farm Site, 12 acres in area, is a National Priority List (NPL) Superfund site located in Howell Township, Monmouth County, New Jersey. It is alleged that in 1973 and 1974, paint wastes, disinfectants and trash were dumped in a disposal area of approximately four acres in the eastern portion of the site. The major source of contaminants was located in a covered trench that ran west to east for about 150 feet. The primary source of contamination at the site was due to volatile and semivolatile organics (i.e., benzene, toluene, and xylene) located beneath the ground surface in the trench area. The leachate from this trench area contaminated the groundwater between the trench and a brook. The surface water and sediments of the farm pond and the adjacent bog were contaminated. The Record of Decision (ROD) for the first operable unit, signed in 1985, specified the excavation and incineration of the contaminated soils, pond and bog sediments and the on-site treatment of aqueous wastes. As part of the Remedial Design (RD) Scope of Work, Ebasco developed technical specifications and drawings for the Thermal Treatment of soils and water treatment including air stripping and carbon adsorption units. Additional items included in the design package were dewatering activities associated with excavation of soils and air monitoring due to the on-site incineration. Ebasco developed the technical specifications and the bidding documents for the procurement of a general contractor by US Army Corps of Engineers (COE) to provide detailed design and construction services. A schematic diagram showing various components is shown in Figure - 1.

The Remedial Action bid package was complex; on-site incineration of the contaminated soils and buried wastes had to be coordinated with the dewatering activities associated with the excavation of contaminated soils below water level and the treatment of on-site contaminated water. The discharge from the water treatment system had to meet the stringent New Jersey requirements. Also the ash generated from the on-site incinerator (i.e., the cleaned soil product) had to be monitored for the leachable fraction of heavy metals, such as lead and chromium, to ensure that the incineration process, which was designed to remove the combustible organic fractions, did not, in fact, generate new disposal problems at the site.

Ebasco also assisted EPA and the COE in developing the bid evaluation criteria and the strategy for procuring a general contractor. The procurement strategy had to be compatible with the technical

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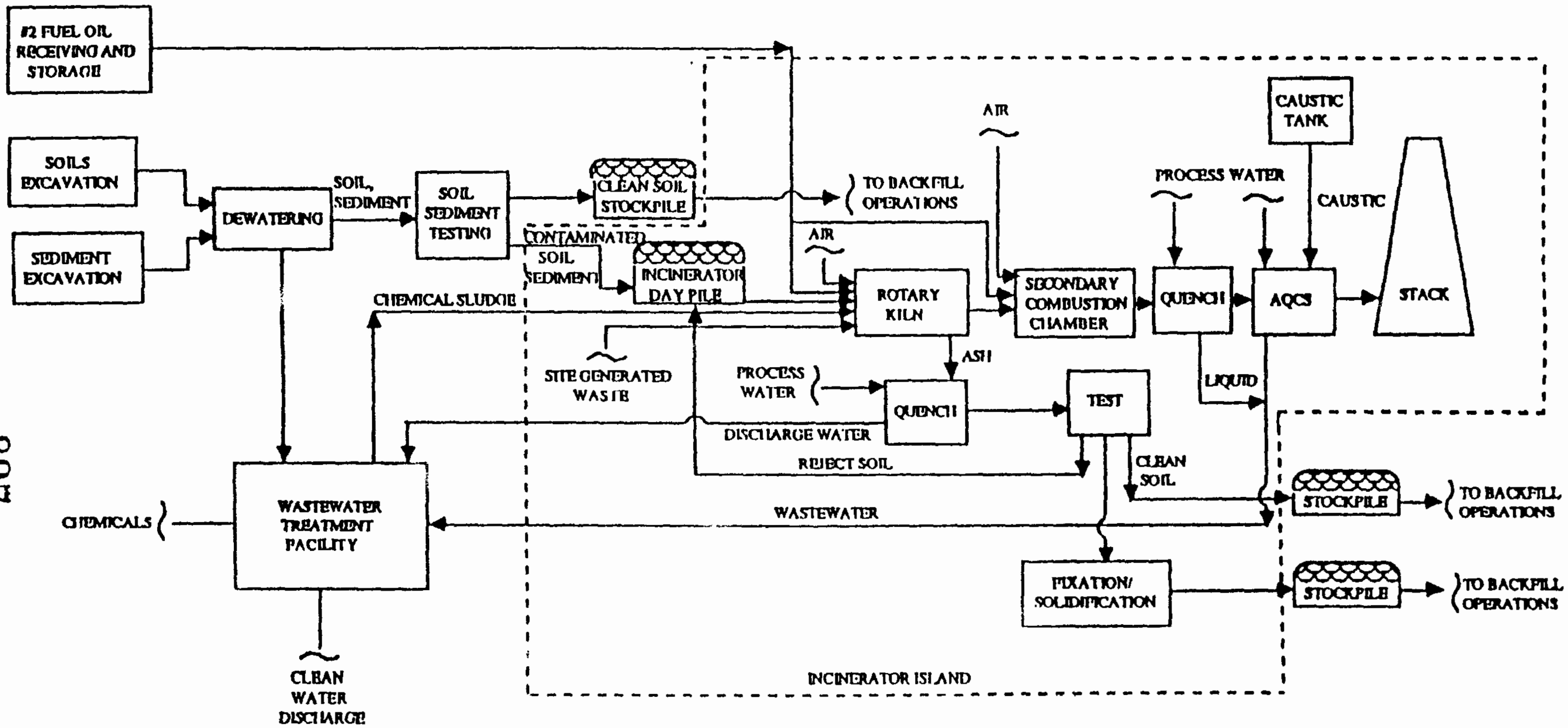


BOG CREEK FARM SITE
THERMAL TREATMENT OF CONTAMINATED SOIL & SEDIMENTS
(SCHEMATIC DIAGRAM)

FIGURE 1

specifications, ensuring that innovative technologies would not be excluded from consideration. Ebasco was also responsible for the engineering support to COE/EPA during construction activities. The engineering support primarily included review of the technical submittals by the construction subcontractor.

BREWSTER WELLFIELD

The Brewster Wellfield, which provides water to approximately 2200 people in the Village of Brewster, Putnam County, New York had become contaminated with volatile halogenated organics from a dry well located adjacent to a dry cleaning establishment. The Village, under a demonstration grant form EPA, installed a full scale stripping column which is successfully providing a water supply to the Village and meeting the applicable standards. However, source (groundwater and soils) control measures were not instituted. The RI/FS work was completed in July 1986. A Record of Decision (ROD) signed in 1986, called for the following actions:

- o Continued operation of the existing air stripping column to treat the Village's water supply.
- o Design and construction of a groundwater management system consisting of extraction wells, treatment of extracted water by a new air stripper, and injection of treated water to contain the plume of contamination and restore groundwater quality.

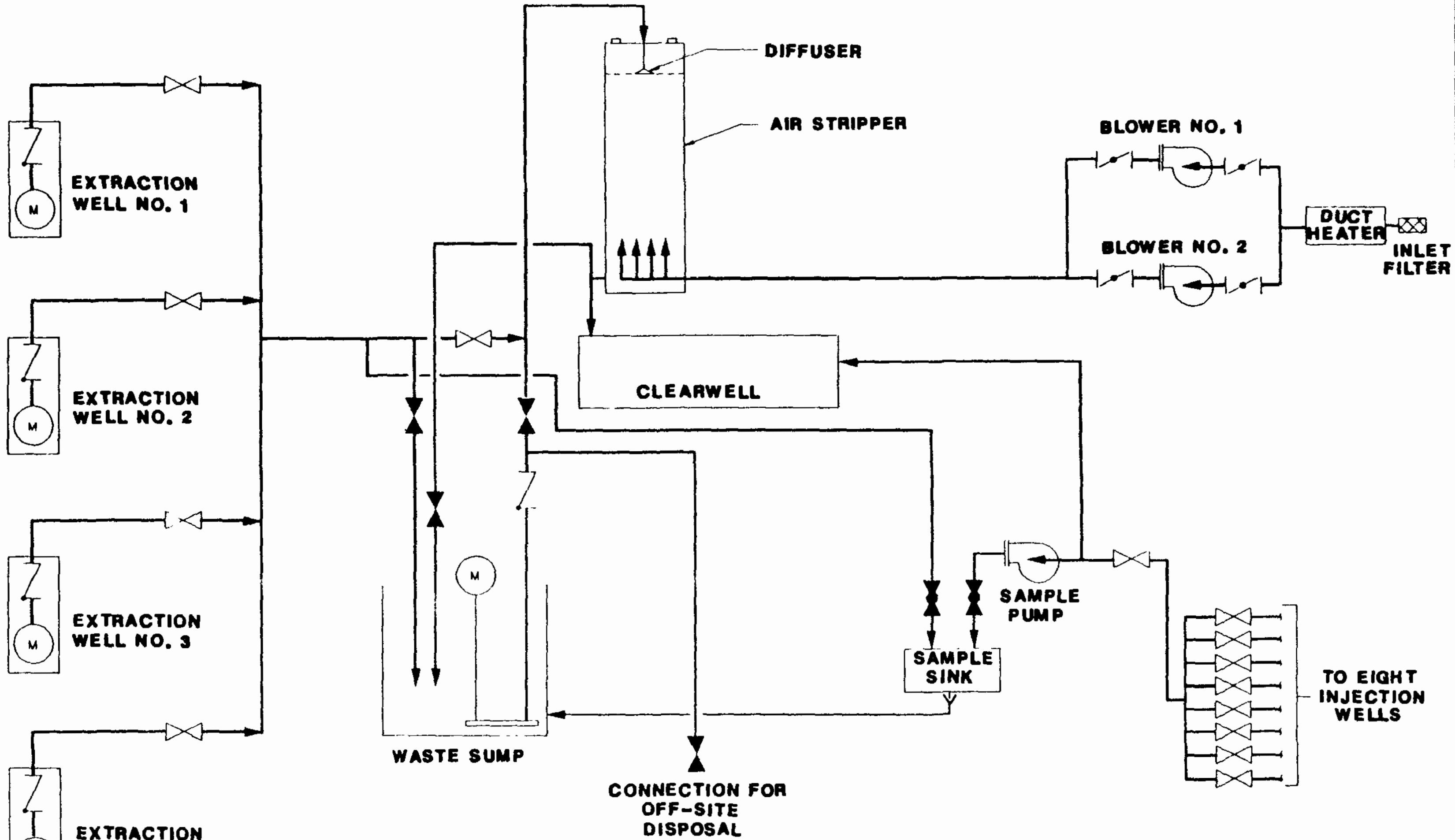
Ebasco developed the remedial design (RD) which involved detailed plans and specifications for implementing the selected groundwater management alternative consisting of extraction wells, treatment of extracted water by air stripping, and reinjection of treated water through eight (8) injection wells. The contaminated groundwater contained 6,000 ppb of VOCs such as TCE and PCE. The treatment system included four (4) stainless steel extraction wells, each containing one submersible pump to extract approximately 12 to 20 gpm, a 35 feet high and two (2) feet diameter counter current flow air stripping column and appurtenances and eight re-injection wells located upgradient of the plume and each of 8" diameter. A schematic diagram showing various components is shown in Figure - 2.

Ebasco prepared the final design drawings, technical specifications and contract documents incorporating written comments from EPA and the State of New York. A final engineer's cost estimate including O&M costs was prepared. Ebasco invited bids, selected the construction subcontractor and provided construction management services to complete the remedial action.

VESTAL WATER SUPPLY WELL 1-1

The Vestal Water Supply Well 1-1 was one of the water supply wells which provided drinking water to the Town of Vestal in Broome County, New York. The Vestal Well 1-1 is located on the south bank of the Susquehanna River. The well was contaminated with volatile organic contaminants (VOCs) such as Trichloroethane (TCA) and Trichloroethylene (TCE).

Ebasco, under the ARCS II Contract, was contracted by EPA to perform construction management services. The goal of the assignment was to reinstate Well 1-1 as a potable water supply for Vestal Water District No. 1. The design involved the installation of an air stripping column, booster pump, air blower, clearwell and process instrumentation and controls that comprise a 1,000 gpm VOC removal facility. A related objective was to deplete the contaminated underground plume by continuously withdrawing it and removing the contaminants through treatment processing. A schematic diagram showing various components is shown in Figure - 3.



BREWSTER WELLFIELD
GROUNDWATER MANAGEMENT SYSTEM
(SCHEMATIC DIAGRAM)

FIGURE 2

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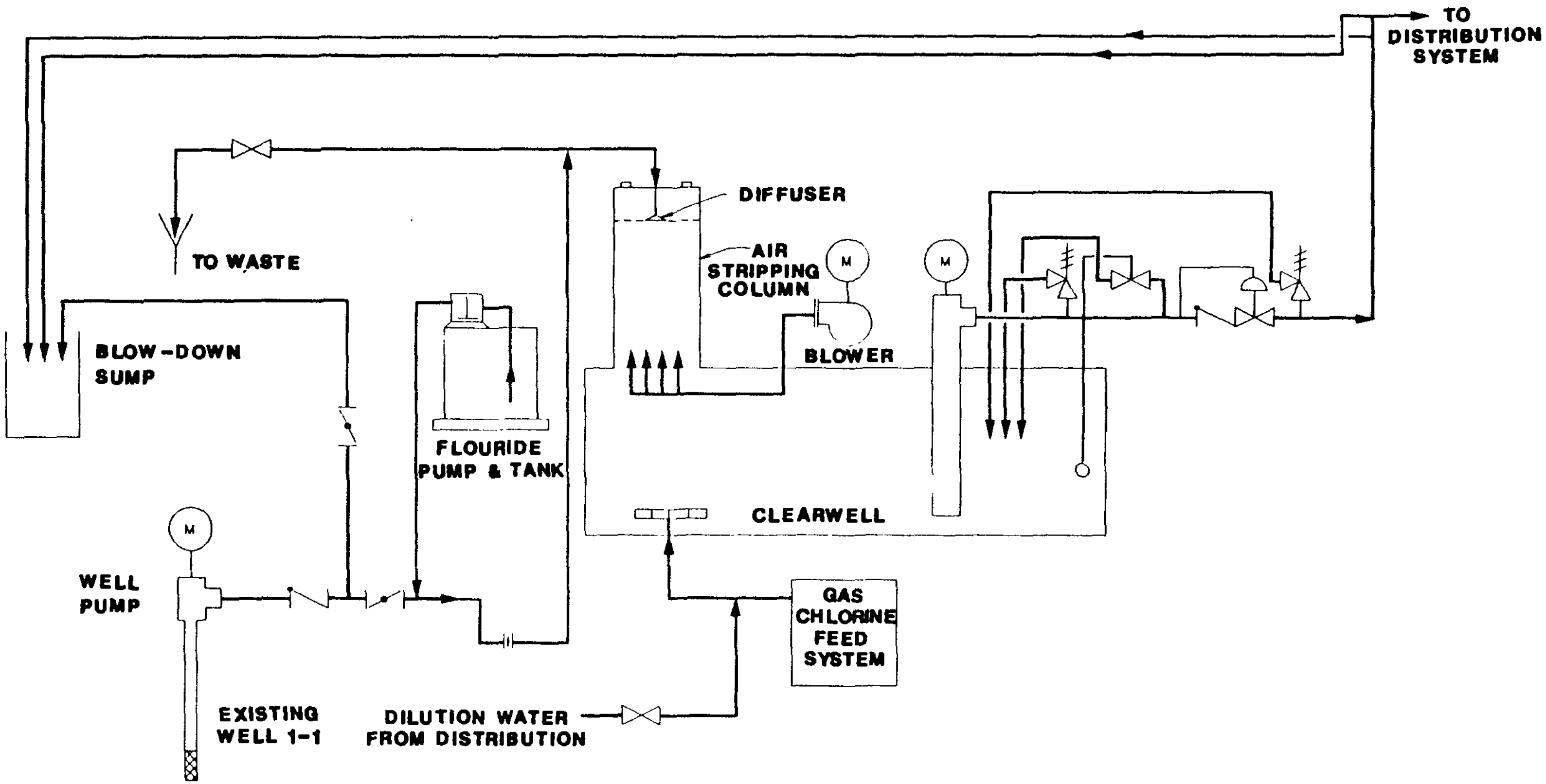

**VESTAL WATER WELLFIELD
WATER TREATMENT SYSTEM
(SCHEMATIC DIAGRAM)**

FIGURE 3

Representative Construction Management activities included, preparation of bid package, selecting the construction subcontractor, directing mobilization activities of the selected subcontractor, approving subcontractor's shop drawings and incorporating revisions where necessary, overseeing adherence to the subcontractor's approved health and safety plan and quality assurance and quality control procedures. The work which was completed included final inspection and certification, preparation of "As Built" drawings, overseeing of initial start up and trial period performance and eventually turning over the operation of the system to the State of New York/township of Vestal.

DISCUSSION

In order to ensure the completion of the RD and RA Projects under the Superfund Program on schedule and within budget, it is imperative that the specifications and drawings and the information for bidders should be complete and unambiguous and should achieve the following objectives:

- Complete Remedial Action on schedule and consistent with the ROD
- Minimize change orders
- Minimize claims and all settle claims amicably before project close out.

To achieve these objectives, Ebasco invariably performs in-house biddability, constructability and operability reviews prior to finalizing the bid package. Additionally, a site visit for all the potential subcontractors is conducted and an effort is made to answer/clarify all of their questions during and after the site visits. Addenda are issued, as necessary, to ensure that all subcontractors receive the same information so that their bid documents reflect identical scope of work and competitive prices. Ebasco follows the Construction Specification Institute (CSI) format for technical specifications and follows Ebasco Engineering Procedures to prepare design drawings, specifications and cost estimates for the RD/RA Projects.

In spite of these preventive measures and best intentions, there are always some issues/problems which require ingenuity, technical and managerial skills and perseverance on the part of site managers to successfully complete the RD/RA work assignment. Therefore, the primary purpose of this paper is to share with you our experiences on RD/RA work assignments which we have completed under REM III and ARCS II Contracts.

1. **Good planning and scoping during all phases of a project results in expedited completion as well as costs savings.**

   Good planning of RI/FS, RD and RA at a hazardous waste site is accomplished through in-house brainstorming sessions, scoping meetings with regulatory agencies (EPA, state, COE, etc.) and avoiding vagueness in the scope of work to be let out to subcontractors. In the case of the Brewster Wellfield Site, there were questions by bidders about the levels of protection, QA/QC, Health and Safety requirements, on-site storage of excavated material, size of shipping containers and sampling procedures which resulted in bids far higher than the budgeted amount. The site conditions and all these issues were discussed in negotiating sessions with the bidders and they were requested to modify/ revise their bids and submit Best and Final Proposals. These technical clarifications resulted in approximately 30% reduction in the bid price.

   The prebid meetings and site visits with the potential subcontractors should be used as an opportunity to expand on the scope of work, the QA/QC and Health and Safety requirements, and other site specific issues which could impact the schedule or cost. Good planning invariably includes assignment of experienced, competent and motivated individuals on these projects. Good planning should result in;

- Absence of bid protests
- Minimal change orders
- Minimal claims
- Project completion on schedule and within budget

2. **Sensitivity to local concerns is extremely important for the expeditious and satisfactory completion of a project.**

Non-hiring of the security guards from the local area on a site by a subcontractor resulted in material pilferage, destruction of equipment, manhandling of security guards and other incidents. Discussions with local officials and the Mayor revealed a very hostile attitude towards EPA, Ebasco and the security subcontractor. It was extremely difficult to get the work done even during daytime. The workers were afraid to go to this site. A number of meetings were held by EPA and Ebasco with the Mayor, other local officials and the local union leaders. After a few meetings, the issue was amicably resolved and the security guards were hired from the local area.

At another site it was decided to provide alternative water supply to the residents of a community whose water supply was contaminated. The water supply to the affected residents was to be taken from another town's water supply system. The town would not allow the hook up unless EPA promised funds for the repairs and upgrading of the existing outmoded water filtration plant. A number of meetings were held with the town officials and negotiations led to the satisfactory resolution of the town's demands.

In order to avoid public meetings becoming very volatile and hostile, it is extremely important to address local concerns and plan a number of meetings with Mayor and other interested parties prior to the scheduled public meeting.

3. **To encourage participation of SBEs and SDBs, extend a helping hand to ensure successful completion of small projects.**

Based on the current understanding between EPA and COE, the ARCS contractors will provide construction management services on those work assignments where the remediation cost is less than five (5) million dollars. In this category of RA projects, a large number of projects would be within the $1 - $2 million range. In order to meet our subcontracting goals, it is extremely important that the SBEs and SDBs be encouraged to participate in the bidding phase of those projects. There is an acute shortage of SBEs and SBDs who are in the hazardous waste remediation business and those who are in this business are not well versed in the special requirements such as QA/QC, Health and Safety, etc., needed to do this work. It is therefore our responsibility to show willingness to train them and help them understand the site specific demands, if any, so that they can appreciate and properly account for various costs in their bids. In the case of Vestal, the work was allotted to a SBE based on his bid price. The contractor had no knowledge about the content or interpretation of the QA/QC and Health and Safety plans or their implementation but he was keen and cooperative to implement these requirements. Ebasco virtually prepared the QA/QC and Health and Safety plans for him, and helped him understand and implement these on site. This was a rewarding experience for Ebasco to have encouraged and trained an SBE in his pursuit of hazardous waste business.

4. **During RD, the information generated during RI/FS, if not checked, may lead to problems during RA.**

Vestal Water Supply Well 1-1 was a water supply well providing water to the town of Vestal. The well became contaminated and was out of service for a number of years. The remedial action project required pumping water from well 1-1, treating it through an air stripping column and supplying the treated water to the Vestal Water Supply System. After the treatment system was constructed and all the equipment such as booster pump, valves, air blower and process instrumentation were installed, trial run began. It was discovered that the yield of the well 1-1 after a few weeks dropped approximately 60% below the expected yield of approximately 1,000 gpm and was down to 400 gpm. The Well 1-1 was a water supply well and was previously providing 1,000 gpm to the town's water supply system. The well was contaminated with volatile organic contaminants and was out of operation for a number of years. It is presumed that the well screens got clogged during the extended period of non pumping. During the design phase the yield of the well was not tested and all the equipment was designed based on the reported yield of approximately 1,000 gpm. Since the yield during the trial run was hardly 400 gpm, it was decided to redevelop the well. The equipment was dismantled, the well was redeveloped and it was possible to bring back the yield to within 90% of the original yield. Unnecessary cost, delay in schedule and the over design of the equipment could have been avoided if the well yield had been tested during RI/FS or RD phase.

5. **Experienced construction supervisor/superintendent can save lots of agony and minimize claims.**

A majority of the remedial actions to be performed by ARCS contractors cost less than $5 million and further, most of the remedial actions in this category cost less than $2 million. It is very difficult to hire trained construction inspectors/supervisors for such small projects. We at Ebasco were fortunate in that many of the inspectors/ supervisors on the RA projects came from the Ebasco Constructors group and therefore, there were very minor problems on site and there were minimal claims from the subcontractors. Proper documentation at Brewster WellField site reduced the claims from $31,000 to $5,000. The claims were related to delays, additional out-of-scope work, and an alleged different scope of work. The Site Manager was able to deny/settle those claims primarily based on the documentation he had prepared in his files, responding to the subcontractor's claims immediately and elaborating all the circumstances which the subcontractor had knowledge of and did not take preventive measures to control the damage. However, at the same time, it should be our intention to pay the genuine claims of the subcontractors.

6. **Establishment of a credible relationship with the subcontractors always benefits the project.**

It is always beneficial for the project and the agencies if there is credible relationship and feeling of trust between the prime and the subcontractor. A positive attitude and a willingness to accommodate each others' point of view will certainly result in successful completion of the project within schedule and with minimal claims. We at Ebasco therefore go through an extensive training program of the site managers and prepare them for cooperative and sincere effort on their part to work with a multitude of subcontractors.

In addition to these site specific issues, the following are some of the general issues which should be carefully considered during RD and RA projects.

i **How clean is clean**

The issue of "How Clean is Clean" has not been finally resolved and always becomes an issue between EPA, state and the local community. It has been observed that the community wants the clean up to be performed to the n'th degree and sometimes even below the background levels. Similarly, states also want to be sure that the clean up levels being agreed to would adequately protect human health and environmental and there is a tendency to be somewhat conservative. The remediation of water or soil at the contaminated site to the condition that existed before contamination took place is a laudable goal, but can we achieve this? What is the definition of background levels and how many samples should be taken so that the results are statistically significant? These questions require guidance from EPA, the state and other agencies involved.

We have seen that if this issue is not resolved early on, the project could linger on for a long time. We have also learned that the site manager should work closely with the EPA-RPM and initiate a scoping meeting between EPA, the state, and other interested parties such as environmental groups, community leaders, etc., to start the debate on clean up levels and come up with a resolution.

ii **Performance vs detailed specifications**

Normally when there is a RD work assignment, it is expected that the specifications and design drawings would be detailed enough so that the construction can proceed. However, in the case of hazardous waste remediation projects, sometimes it is not possible to do this and we have to settle with performance specifications because;

- EPA's mandate is not to restrict to a specific treatment technology and that the competition should be open to as many technologies as possible. For example, "Thermal Treatment" instead of "Incineration" is generally specified in the technical specifications.

- The input concentration of the waste feed materials is not consistent during the treatment process operation. The contamination levels in soil and water being treated can vary drastically during a very short period. It will be therefore difficult to design a system based on a specific well defined contaminant concentration level.

- It is better to leave it to the construction subcontractor how he wants to layout his operations including the laydown area, trailers, equipment, treatment system and associated appurtenances, etc., rather than show those details on the drawings.

It has therefore been Ebasco's experience to have a mix of both performance and detailed drawings and specifications; performance specifications for treatment processes and detailed specification and drawings for items such as access roads, buildings, extraction/injection wells, pumps, blowers and other equipment.

iii **Documentation of important decision/agreements**

Particularly during the construction phase of a project, there are many verbal discussions between the engineer and the construction subcontractor, between the engineer and the lead agency and other agencies and many times agreements are reached, verbal orders are given and implemented. All these agreements should be documented and copies sent to those who participated in the agreements. Minutes of meetings should be prepared and copies should be sent to all who participated in the meeting. All telephone conversations should be properly recorded and copies of telecon sent to the other parties. Any misunderstanding and misinterpretation of agreement can result in project delays, cost increases and in some cases lawsuits.

iv **Prequalification of subcontractors**

It is very important to keep a list of well qualified subcontractors in various areas of expertise such as drilling, surveying, treatability studies, remediation, etc. A questionnaire is sent by Ebasco to the interested subcontractors to be completed. The qualifications are carefully evaluated and, if considered suitable, the subcontractor's name is added to the list. Recommendations are requested from the site managers on the performance of subcontractors on their project and the list is updated based on these recommendations. If the performance of a subcontractor is not satisfactory, his name is removed from the list.

The bid package for the construction contracts should include the following evaluation criteria in addition to price and other criteria so that well qualified subcontractor is selected and the project proceeds smoothly;

- Prior experience.
- Experience of the key personnel who will work on the project
- Equipment that will be available on site
- Agreements with haulers of hazardous waste material
- Agreements with disposal sites which will accept the waste

These criteria should be taken into account during technical evaluation of the proposals. A well qualified subcontractor will complete the project on time and within budget and would be ultimately cost effective even if his price was not the lowest.

v. **Ensuring competitive bids.**

The bid package should be well written, simple, unambiguous and the scope of work should be described in great detail so that there are no misunderstandings and misinterpretations. It may be desirable to include aerial photographs and site conditions data in the bid package. A pre-bid site visit should be conducted. The site visit should be conducted by a person who is knowledgeable not only about the site but also about the technical and contractual requirements in the bid package. All questions during the site visit should be answered as completely as possible and followed by an addendum to all the potential bidders. All questions answered on the phone to individuals should be also consolidated and sent to all the potential bidders so that all the bidders have the same information.

vi. **Minimizing claims and change orders**

It is our experience that well written, unambiguous specifications and drawings providing adequate details go a long way to minimize claims and change orders. The following suggestions are made in this regard;

- Do not leave "open ended" items; choice of materials for example, should not be left to the subcontractor.

- Be sure that the equipment and materials specified are readily available in the market

- Clearly specify the deliverables and the schedule, such as weekly reports, QA plans, shop drawings, as-built drawings from the subcontractor.

- Avoid as far as possible specialty (one of a kind) items. They are more expensive and difficult to obtain. Servicing and parts replacement may also be difficult.

- Be certain to verify that all equipment and materials received on site are in conformance with the specifications.

- Maintain logs and documentation of subcontractor's personnel and equipment on site. Spare and unneeded equipment should be noted to avoid claims later for "stand by" charges.

CONCLUSION

1. Additional investigations, treatability studies, pump tests during RI/FS or RD are good investments and can save a substantial amount of money during remedial action.

2. RD and RA at hazardous waste sites should be taken as a cooperative effort among all the participants including EPA, COE, consultants and the subcontractor.

3. The construction specifications and drawings should be well written, unambiguous, and in sufficient detail so that nothing is left to the imagination.

4. Good forward planning, selection of a competent and experienced project team will ensure smooth and successful completion of the RD/RA project.

5. Sensitivity to local concerns is extremely important for the expeditious and satisfactory completion of the project.

6. Prequalifying the subcontractors and establishing a credible relationship with the construction subcontractor benefits the project.

7. Early resolution of some of the issues such as "How Clean is Clean" would avoid unnecessary delays and keep the project focused on clean up goals.

8. Documentation of decision/agreements reached during verbal discussion, telephone conversations or during project status meetings is very important and will minimize claims.

Forecasting Staffing Requirements for Hazardous Waste Cleanup

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INTRODUCTION

The Directorate of Civil Works of the U.S. Army Corps of Engineers (USACE) needs to be able to forecast the staffing levels required to establish procedures for cleaning up hazardous waste sites and supervise the contractors who perform the cleanup. The Corps performs those tasks in support of the U.S. Environmental Protection Agency (EPA). The forecasts are used to plan for future work and to report environmental staffing needs to the Office of Management and Budget.

The Logistics Management Institute (LMI) developed a Civil Works' Superfund staffing requirements model based on a statistical analysis of historic workload data [1]. In developing the model, we assume that the size and complexity of future cleanup programs will be related to the size and complexity of past programs. While a wide variety of factors affect staffing levels, we found that the two most important ones are total project cost and project type or complexity. By dividing the Corps' programs into different types of work, we can reliably relate total project costs in dollars to hours worked. The three types of work we use in our model are remedial design, supervision of remedial construction, and additional technical assistance to the EPA.

We used historical data to determine (1) the relationship between total project cost and hours expended for various types of work; (2) the distribution of project sizes, durations, and start dates; and (3) the functional relationship between time spent and work accomplished. Those relationships and distributions are embodied in a computer program – the Superfund staffing model – that takes multiyear program dollars as its primary input and produces multiyear forecasts of staffing levels as its primary outputs.

Because the Corps' Superfund program is relatively new, however, and the volume of historical project data incorporated in the model is currently very small, we recommend that the prototype model be used with caution. For that reason, we also recommend that USACE collect additional project data annually from its divisions and districts at the same time that it collects the annual inputs for the staffing model. It can use that additional project data to refine the prototype model.

BACKGROUND

In cases in which EPA is unable to locate a primary responsible party (PRP) for the cleanup and in cases in which the PRP is unable to pay the cleanup costs because of bankruptcy or for other reasons, EPA assumes the PRP's role. Those cases are called Federal lead Superfund projects. Instead of merely monitoring the process to ensure that the cleanup meets EPA standards, EPA must award the contract and directly supervise the site cleanup.

When Superfund was new, EPA attempted to use its own in-house personnel to supervise the design and remediation actions. As the number of sites increased, the tasks of engineering, contract administration, and contract supervision soon overwhelmed EPA's internal staff, which then turned to other agencies for help. Since both parts of the remedial action stage – engineering and construction supervision – are similar to the type of work that the USACE Directorate of Civil Works carries out in the normal course of its business, EPA turned to the Corps for help in the remediation stages.

USACE now aids EPA in three major areas. First, it carries out design and engineering in house for remediation actions and it supervises architect-engineers who are under contract to perform such work. Second, it supervises construction companies that perform the actual removal or remediation. And, third, it provides technical assistance to EPA, an effort that is less intensive than design or construction but that requires the technical expertise of USACE engineers. Most technical assistance projects for EPA to date fall into two categories: feasibility studies and hazardous waste enforcement support.

When EPA assigns a Federal lead Superfund project to USACE for design and construction, USACE first provides technical assistance by reviewing the feasibility study that decided on the chosen cleanup technology. When providing hazardous waste enforcement support, on the other hand, USACE monitors PRP-led cleanup projects. In this role, USACE does not directly supervise the project because that is the PRP's responsibility. Instead, it "looks over the shoulder" of the PRP and its contractor to ensure that the project is carried out properly and that the site is cleaned to the desired levels.

DISCUSSION

Use of Historic Data

The purpose of the Superfund staffing model is to be able to reliably forecast the staffing levels needed by USACE to support the EPA's Superfund work several years into the future. We base that forecast on the statistical analysis of historical data. The historic approach is sound if two conditions hold: past work was performed efficiently and future work will continue to be similar to past work.

Predictive factors developed from historic data that include inefficiently managed projects will simply perpetuate those inefficiencies. However, since USACE's costs for design and construction management services have been shown to be comparable with those of other Federal, state, and local Government agencies and with large private-sector companies [2], which provide a measure of USACE efficiency, we can use properly sampled USACE data to develop predictive factors that reflect general industry standards. If we assume that USACE carries out Superfund work at the same level of efficiency as its other work, then historic USACE Superfund data can similarly be used to develop predictive factors for efficient restoration work.

In addition, we can account for changes in USACE's program mix over time by dividing the workload into different types of work. Thus, when the mix between those types of work shifts, the model will continue to predict staffing reliably. For example, by separately forecasting staffing needs for in-house design, design contracted out, construction, and different types of technical assistance, we can continue to forecast future needs even if the program moves from an emphasis on remedial design to an emphasis on remedial action (construction) as more Superfund sites move from the planning and design phase to the cleanup phase.

Within work types, we assume that future work will be similar to past work. However, since the Superfund program is relatively new, the nature of the work will possibly change in the future. For example, EPA – USACE's customer – is moving from a reliance on traditional construction contracting to a greater emphasis on cost-plus, or reimbursable, contracting. Cost-plus contracts cannot be as closely specified as conventional contracts and require more USACE supervision. We have attempted to account for that difference by dividing construction work into reimbursable and nonreimbursable work.

Because the Superfund program is relatively new, the volume of past work is just barely sufficient for statistical analysis. In addition, much of the available data was incomplete, further restricting our ability to generate sufficient sample sizes (and, consequently, restricting our ability to subdivide the work further into different types of design and construction work). For those reasons, USACE will need to continue collecting the data needed to revise and "tune-up" the prototype model, in addition to acquiring the input data needed by the forecasting model.

In developing a model based on statistics, we must be careful to choose those factors that are the best predictors of future staffing. The predictive factors must not only perform well statistically, they must also be practical. That is, they must be relatively easy to collect without having to undertake a massive annual data call. In addition, the predictive factors must be leading indicators. For example, program breakage – stops and starts in program scheduling and execution – undoubtedly affect work hours. However, changes in staffing and program breakage move concurrently; one cannot be used, in advance, to predict the other. Moreover, program breakage is already contained in the historic data so that staffing and workload factors developed from those data will include some normal or average level of breakage.

A wide variety of factors determines and influences staffing levels. Many of those factors, however, are not useful in forecasting because they move randomly over time. Since we cannot predict their behavior, we cannot use them to forecast staffing. Some factors may change very slowly so that, in practice, they have very little effect on staffing changes. Still other factors, while significant, are strongly correlated to total project cost. That is, such factors exhibit strong collinearity with the total project cost. For example, longer projects certainly require more hours of work, but they also generally cost more. Total project cost, therefore, acts as a proxy for length of time. Project complexity is another signific nt indicator of staffing requirements, and it is strongly collinear with project type.

Our past experience with USACE staffing models has shown that the two most important factors are total project cost and project type or complexity. Not only are they good indicators of staffing required, but they are also easier to use as inputs than many alternate factors.

In practice, we must choose forecasting factors that can be projected into the future. One of the advantages of total project cost is that a large portion of USACE's Superfund program in any given year consists of projects that were started in previous years. Therefore, the forecast for the next 2 to 3 years can be based partially on the existing program and partially on a prediction of the future program.

The forecasting method uses two basic types of predictive factors. First, we must "spread" the total program cost over a number of years and second, we must relate it to hours worked. While the forecasting model includes some additional subtleties, those two factors form the backbone of the predictive methodology.

Spreading the Work

Since total program cost does not translate into workload for a single year only, it is necessary to spread those program dollars over a number of years. The historic data show that all types of Superfund work include projects that take anywhere from a few months to 5 years to complete. Thus, in any given year, USACE is conducting projects that started in the current as well as in the previous 4 years.

In our model, the spreading algorithm takes three factors into account: project start date, project duration, and the relationship between chronological time and work hours. We developed spreading factors for three basic types of Superfund work: remedial design, remedial construction, and technical assistance. Ideally, we would prefer to develop spreading factors for more types of work and to check that those spreading factors are significantly distinct. However, we did not have large enough sample sizes to subdivide design, for example, into in-house design and contracted design. In some cases, we ran along the margins of statistical significance even for only three project types. Future data collection should permit more sophisticated spreading calculations by including more project types.

Table 1 presents the distribution of project starts over the fiscal year. That factor is important since even if a project takes only 6 months to complete, it will cross into 2 fiscal years if started at any time after March of the fiscal year. The data show that start dates were fairly evenly distributed over the year. (For comparison, the last column in Table 1 shows a perfectly random distribution of start dates, i.e., the distribution that would result if one project were started per day, with a total of 365 projects.) That is, the distribution shows no particular bias toward starting projects at the beginning, middle, or end of the fiscal year; projects have a more or less equal chance of starting at any time.

TABLE 1

DISTRIBUTION OF PROJECT START DATES BY MONTH

Month	Remedial design	Remedial action	Technical assistance	Random start date
October	6.45%	8 11%	12.73%	8.49%
November	3.23	10.81	3.64	8.21
December	12.90	10.81	5.45	8 49
January	9.68	8.11	7.27	8 49
February	6.45	5.40	14 56	7 73
March	9.68	8.11	10.91	8.49
April	9 68	5.40	5.45	8.21
May	9.68	10.81	10 91	8.49
June	3 23	8 11	7.27	8.21
July	12.89	8 11	7 27	8.49
August	6 45	8 11	5.45	8 49
September	9.68	8 11	9.09	8.21
Total	100%	100%	100%	100%
Standard deviation	3 07%	1.73%	3.19%	0.22%
Sample size	31	37	55	–

The second major factor in determining how the total project cost is spread is the distribution of project durations: the percentage of each type of project that took less than 3 months to complete, the percentage that took from 3 to 6 months, and so on. Table 2 shows that distribution for the three Superfund project types. Even though the duration data for remedial design are sparse, the resulting findings are reasonable: 78 percent of the projects took less than 3 years to complete, while a few have taken as long as 4 to 5 years. Interestingly, almost half of the construction projects undertaken to date have taken, or USACE expects them to take, less than a year to complete.

The third factor that must be taken into account in spreading the total project cost is the relationship between chronological time and work time. That is, even if a particular project takes exactly 2 years to complete, we cannot assume that an equal number of staff hours are spent in each of those 2 years. Figure 1 shows these relationships for the three major types of Superfund work. As the graph illustrates, technical assistance projects appear to require more hours up front, while construction work starts more slowly, gathers steam, and then tapers off toward the close of the project. While these relationships are based on relatively sparse data, they are consistent with our

TABLE 2

DISTRIBUTION OF PROJECT LENGTHS BY QUARTER

(Completion date less start date)

Project duration	Distribution		
	Remedial design	Remedial action	Technical assistance
1 quarter	0.0	16.7	7.1
2 quarters	0.0	3.3	0.0
3 quarters	11.1	13.3	21.4
4 quarters	0.0	13.3	17.9
1 year	11.1	46.7	46.4
5 quarters	11.1	20.0	10.7
6 quarters	0.0	3.3	3.6
7 quarters	11.1	10.0	0.0
8 quarters	11.1	3.3	3.6
2 years	33.3	36.7	17.9
9 quarters	22.2	3.3	7.1
10 quarters	0.0	10.0	7.1
11 quarters	11.1	0.0	0.0
12 quarters	0.0	0.0	3.6
3 years	33.3	13.3	17.9
13 quarters	0.0	0.0	0.0
14 quarters	11.1	0.0	3.6
15 quarters	0.0	0.0	7.1
16 quarters	0.0	0.0	0.0
4 years	11.1	0.0	10.7
17 quarters	11.1	3.3	3.6
18 quarters	0.0	0.0	0.0
19 quarters	0.0	0.0	0.0
20 quarters	0.0	0.0	3.6
5 years	11.1	3.3	7.1
Total	100	100	100
Sample size	9	30	28

Note: Numbers may not add because of rounding

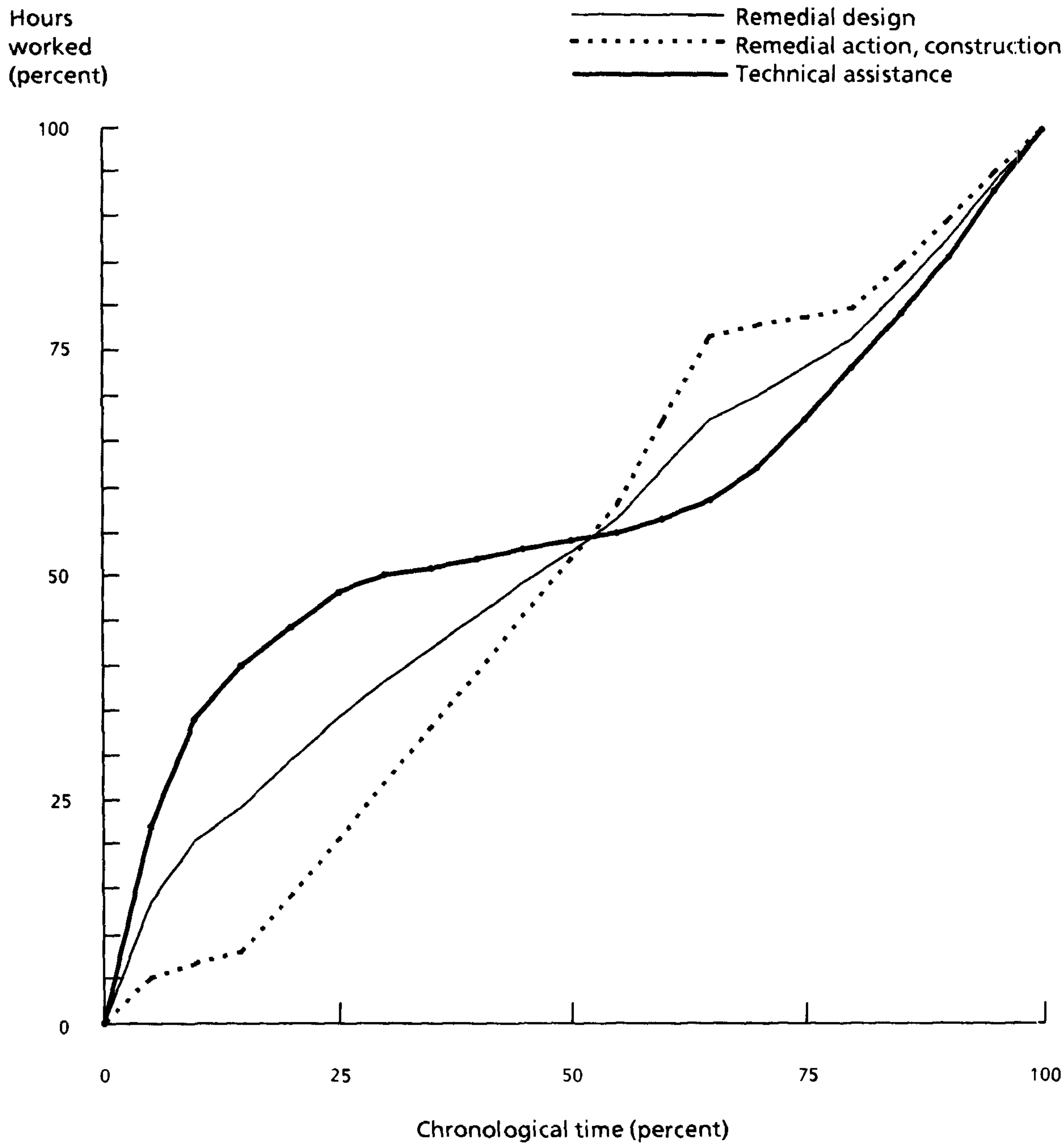

FIG. 1. WORK HOURS VERSUS CHRONOLOGICAL TIME

experience with military design and construction work. Future data will improve the prototype model, but in practice, the appearance of these relationships will probably change very little.

The model does not require all of the data just described as direct parameters because we combine them to calculate a set of spreading factors for each project type. Table 3 shows the final result, which is incorporated in the Superfund model. As shown in Table 2, projects in all types of work start in program year *N* and continue for as many as 4 years beyond it. The work accomplished in the last year for all three project types, however, is a relatively small percentage of the total; the bulk of the hours are spent in the first 2 years.

TABLE 3

SUPERFUND SPREADING FACTORS

Program year	Remedial design	Remedial action	Technical assistance
N	30.1%	49.3%	51.8%
N + 1	36.5	41.5	31.0
N + 2	20.6	7.5	9.2
N + 3	9.7	1.2	5.6
N + 4	3.1	0.5	2.4
Total	100%	100%	100%

Relationship Between Dollars and Hours

We used the statistical technique of simple linear regression to derive the relationship between workload and staffing for the various project types. Despite the scarcity of data, it was essential to divide the work into more than three types since we know *a priori*, for example, that in-house design should require more staff hours than the supervision of design contracted out. Nevertheless, the statistical measures of significance for our small samples show the measured coefficients to be statistically significant.

Workload was measured as program amount for design and as contract amount for construction. In all cases, we corrected the dollar amounts to FY90 constant dollars to maintain comparability among years. The basic linear regression equation was as follows:

$$Hours = c + a \times Workload + e$$

where

Hours = the dependent variable, i.e., the quantity we want to predict,

c = a constant term that reflects the nonvariable portion of staffing per project,

a = the coefficient of workload, i.e., the weight attached to workload to predict staffing,

Workload = the independent or predictive variable, and

e = an error term that accounts for random variation in staffing unaccounted for by workload.

The Superfund staffing model incorporates the results of a number of linear regression equations. Those results are shown in Table 4. In addition to the constant term and the coefficients, the table includes two measures of statistical significance – the t-statistic and R^2 – plus the sample size.

TABLE 4

REGRESSION RESULTS – DESIGN AND CONSTRUCTION STAFFING FACTORS

Work phase	Constant (hours/ project)	Coefficient (hours/ $ million)	t-statistic	R^2	Sample size
Design					
In house	0.0	2,562	8.6	90%	5
A-E	0 0	1,960	6 3	64	5
Construction					
100% complete	0.0	1,458	9.7	72	12
Current	0 0	1,941	7 7	67	18

Note: A-E = architect-engineer, i e , supervision of design work contracted out

The t-statistic is a statistical indicator that tests for the hypothesis that the coefficient is significant, that is, the coefficient is nonzero. If the t-statistic is greater than 2, then the probability that the variable is not zero is at least 95 percent. As Table 4 shows, all of the t-statistics exceed 2 (The t-statistic is the ratio of the coefficient to its standard error, which is a measure of the statistical variability of that coefficient.)

The R^2 is that fraction of the variance of the dependent variable that is explained by the independent variable. In terms of our model, it is the fraction of staffing explained by the dollar workload (for each particular type of project). Even though the lowest R^2 is 64 percent, each equation predicts staffing for a single project only. When a large number of projects are combined, as in the Superfund program, the equations are summed and the variance around a single project becomes far less important. In mathematical terms, the error term (e) is random; although for one particular project the error term has the potential to be quite large, the sum of all the error terms tends to become smaller as more and more projects are summed, since the individual errors cancel each other out.

The R^2 does indicate, however, that other factors in addition to total program cost influence staffing. That finding is not unexpected. More data may eventually allow us to split the work types into smaller subdivisions and increase the predictability of each equation. But it is also likely that the R^2 will not increase materially. Many factors influence staffing and not all of those factors can be built into a practical model. The coefficients, however, are an unbiased estimator of staffing and on average, given enough projects, should provide forecasts that are effective for planning purposes, particularly at the headquarters level.

The measures of statistical significance show that the estimated coefficients are reasonable predictors. However, the sample sizes were very small in all cases; ideally, the sample sizes should exceed about 20 for each linear equation. The sample size requirements are based on the central limit theorem as applied to regression equations. Nevertheless, the model should suffice as a prototype although the need to collect more data in the future to expand the sample sizes and to confirm and recalibrate the relationships is obvious.

In all cases, linear regressions were calculated for an unconstrained constant, as well as a constant constrained to zero. In each case, the equation with a zero constant term exhibited the best significance indicators and so it was adopted for the staffing model.

We explored the effects of economies of scale by trying nonlinear terms – including both logarithmic and squared terms – in the regression equation. However, the statistical indicators did not show those additional nonlinear terms to be significant.

We estimated two regression equations for Superfund construction, or remedial action, work. The first equation, labeled "100% complete" in Table 4, represents all of the completed projects for which historic data were available. The other equation represents the incomplete, or "Current," projects. Total hours were calculated for that set of projects by adjusting for percent complete.[1] The current projects, so adjusted, indicate higher staffing requirements per dollar. While the difference may be due to the small sample sizes in both cases or to inaccuracies resulting from the adjustment of hours, it is also conceivable that hours per dollar have increased because of changes in the type of work, or possibly an increase in cost-plus contracting. Again, while the results are acceptable for use in the prototype staffing model, the equation needs to be refined with additional data in the future.

Technical Assistance

The third category of Superfund work is technical assistance, which is not directly tied to total program cost. Therefore, it is not possible to derive a relationship between total program cost and staff hours. Instead, we found that average hours per project type was a good predictor.

As shown in Table 5, we found that staff hours expended on such projects differed by the type of work. That is, feasibility studies clustered around an average of 281 hours, while hazardous waste enforcement support clustered about an average of 1,147 hours. Given the limitations of sample size, both appeared to be normal distributions with relatively low variances, for which the average is the unbiased estimator. Almost no data currently exist for any other types of technical assistance work.

TABLE 5

TECHNICAL ASSISTANCE – AVERAGE HOURS WORKED

Project types	AMPRS codes	Average hours	Standard deviation	Sample size
Feasibility studies	922	281	116	16
Hazardous waste enforcement support	923	1,147	680	7
All technical assistance	All	532	547	24[a]

Note: AMPRS = Automated Management Project Reporting System.

[a] Includes all projects in codes 922 and 923, plus one project code 926, *Remedial Investigation/Feasibility Study*.

[1]We also adjusted incomplete design project hours, but the results were statistically poor.

The model, therefore, forecasts staffing for technical assistance projects based on average hours for the type of work. For technical assistance projects other than feasibility studies and hazardous waste enforcement, the prototype model uses the average staff hours for all technical assistance projects.

The Staffing Model

The staffing model takes design program amounts, construction contract amounts, and the number of technical assistance projects as its primary inputs. All inputs are split into different project types, such as remedial response and emergency response, whether or not we were able to develop different factors for those splits. That makes it easier to modify the model's predictive factors in the future as well as making it easier to audit and to modify the model inputs. An additional input is the percent of design work that is accomplished in house versus work done by architect-engineers (contractors) and supervised by USACE. Other inputs include the number of work hours per year for converting staff hours into work years.

The model first spreads the program inputs, whether dollars or numbers of projects, into multiple years before applying the regression factors (or average hour factors) to determine staff hours. The model converts all dollar amounts, input as then-year dollars, into 1990 constant dollars to preserve the original regression relationships. The coefficient for each project type is multiplied times the workload after spreading. In addition, the model multiplies the constant times the number of projects since the constant was determined for a single project.[2] The model estimates the number of projects per year by dividing the workload measure by the average project dollar size (shown in Table 6). The number of technical assistance projects, of course, is a direct input.

TABLE 6

AVERAGE PROJECT DOLLAR SIZES

Work phase	Average ($ million)	Standard deviation	Sample size
Design			
In house	1.2	1.1	6
A-E	1.4	0.9	28
All	1.3	0.9	34
Construction			
100% complete	4.8	6.9	16
Current	16.3	15.3	22
All	11.5	13.7	38

Placement is estimated by taking a percentage of program amount, after spreading. This is displayed as a model output and is also used as an input to the calculation of division and district overhead. The model outputs staffing in work years and placement in dollars after reconverting from 1990 constant dollars into then-year dollars.

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[2]Although the constant terms in the prototype model are all zero, the model retains this calculation in the event that future data produce nonzero constants.

The model also estimates the number of work years of support required for the Superfund program by Corps of Engineers divisions and districts. Since we could not measure those hours directly, we adopted the overhead factors used in the Corps of Engineers Resource and Military Manpower System (CERAMMS) [3]. We assume that the CERAMMS factors, which are based on design and construction placement, reflect efficient management and will remain substantially the same for all types of design or construction. The constant terms in the CERAMMS division and district overhead equations were set to zero, however, since additional Superfund work (or any other type of work) will add only to the variable portion. The factors are shown in Table 7.

TABLE 7

DIVISION AND DISTRICT STAFFING FACTORS

Placement type	Variable factors (hours/$ million)	
	Division	District
Design	0	765
Construction	296	422

CONCLUSIONS

At LMI, we have built other models that forecast staffing needs for USACE's military programs and for the Defense Environmental Restoration Program. Based on that experience, we found that historical data are a reasonable guide to future behavior. Relationships based upon these data can be modified to reflect process changes and efficiency improvements, when appropriate. We also found that although a great many factors affect staffing levels to some extent, the two most important factors are total project cost and project type or complexity.

EPA's Superfund efforts are relatively new and USACE's assistance to EPA started in 1983. For that reason, the small amount of project data limited our ability to analyze the data for relationships between staffing and a wide variety of factors. However, our previous experience showed that total project cost and project type were overwhelmingly the most important predictive factors for staffing.

While our statistical indicators confirm that those predictive factors work as well for the Superfund, the relatively small sample sizes mean that we have less confidence in the specific values of the coefficients that we derived for those predictive factors. If future projects continue to be similar to our sample of completed past projects in nature and labor-intensity, the coefficients will accurately predict future staffing requirements. If, however, those past projects do not constitute a truly random sample of "typical" USACE Superfund work – if, for example, they are all uncharacteristically labor-intensive – then the resulting forecasts may be too high (if the opposite, then the forecast will be too low).

One indicator that the Civil Works' Superfund coefficients are not too wide of the mark is that they are of the same order of magnitude as the coefficients derived from very large sample sizes (and subsequently validated) for various types of USACE military work. For example, the supervision of military construction work for the Army requires about 1,700 hours per $1 million compared with our coefficients for Superfund construction work of between 1,460 and 1,940 hours per $1 million.

We conclude that the USACE Environmental Restoration Division can use the prototype Superfund staffing model to produce rough planning estimates and we have recommended that it be so used. USACE divisions can also use the model to forecast their own staffing needs, but they must keep in mind that the model's results will display greater variation at the division level than at the overall USACE level. As the number of projects handled by each division grows, the individual variation among projects will become less important and, therefore, division forecasts will become more precise.

In addition, we have recommended that USACE gather more Superfund project data as additional projects are completed. USACE can use the larger sample sizes that result to rerun the statistical analyses and to refine the prototype Superfund model.

DISCLAIMER

The report upon which this paper is based was prepared pursuant to U.S. Army Corps of Engineers Contract DACW31-90-D-0076. The views expressed here are those of the Logistics Management Institute at the time of issue but not necessarily those of the Department of the Army.

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The Effects of the Davis-Bacon Act on the LaSalle Electrical Utilities Phase I Remedial Action

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INTRODUCTION

The Davis-Bacon Act is a federal labor regulation which establishes minimum wage rates and fringe benefits for workers on federally assisted projects in excess of $2,000 which are defined as construction by the USDOL. These minimum wage rates and benefits are established on a regional basis by the U.S. Department of Labor (USDOL).

The LaSalle Electrical Utilities Phase I Remedial Action (RA) was managed as a "State-Lead" project by the State of Illinois under a cooperative agreement (CA) with the U.S. Environmental Protection Agency (U.S. EPA), whereby 90% of the project costs are provided by the Federal government. Since the RA was considered to be "construction" under 40 CFR Part 33 and was funded through a CA, the Superfund procurement regulations required that the construction contractor utilize the Davis-Bacon Act to establish the wages and fringe benefits for its employees who worked on the site. The construction contractor was selected through the formal advertising process. At the time the bids were received, USDOL had not yet established worker classifications for all the types of jobs needed on the site. This situation created much confusion among all parties involved.

This paper summarizes the events which occurred and the resulting confusion regarding the applicability of, and the liability for compliance with, the Davis-Bacon Act to the Phase I Remedial Action. Based on the experience gained from resolving the Davis-Bacon issue for the LaSalle project, this paper presents three recommendations to ensure the same issue does not become a problem for future Superfund remedial actions.

BACKGROUND

The LaSalle Electrical Utilities (LEU) Superfund site resulted from improper wastes management practices by a former manufacturer of electrical equipment. The Electrical Utilities Company (EUC) started manufacturing electrical capacitors at the site prior to World War II and continued until 1981, when it relocated to North Carolina. By the late 1940s, the company had begun to utilize polychlorinated biphenyls (PCBs) in its operation. This manufacturing practice continued until October 1978. In May 1981, manufacturing operations ceased at the LaSalle plant. Subsequently, the Illinois Environmental Protection Agency (IEPA), enforcing Section 34 of the Illinois Environmental Protection Act, ordered the production areas of the plant to be sealed. The LEU office building remained in use by a lessee until some time in the early 1980s. Since that time, the entire facility has been abandoned.

Information on the waste management practices of the company is limited. Undocumented reports allege that PCB-contaminated waste oils may have been applied as a dust suppressant both on and off the property as late as 1969. Subsequent to the federal regulation of PCBs, inventory reports document the disposal of PCBs at approved facilities.

Beginning in September 1975, numerous government agencies, including the United States Environmental Protection Agency (U.S. EPA), the IEPA, and the Occupational Safety and Health Administration (OSHA), conducted various inspections and issued numerous complaints and orders to the EUC company as a result of its manufacturing and handling practices. In 1982, a U.S. EPA Field Investigation Team contractor completed a preliminary investigation of the site. As a result, the site was proposed to be listed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), also known as "Superfund". The site was proposed for the NPL on December 30, 1982 and became final in the first publication of the NPL on September 9, 1983.

Analysis of site records revealed only one Potentially Responsible Party, EUC, from which the U.S. EPA could seek reimbursement of costs associated with the environmental remediation of the site. EUC, however, was not financially viable and had petitioned for relief under Chapter 11 of the Bankruptcy Act on September 19, 1983. Therefore, any action taken under CERCLA authorities had to be financed by the Superfund. The IEPA assumed the role of the lead agency in investigating and remediating the site and received Federal funding through a CA since 1983.

Remedial Investigation

Between 1983 and 1988, many Immediate Removal Actions (IRAs) were completed and the Remedial Investigation (RI) was conducted. The IRAs involved various measures including waste consolidation, drum removal, site fencing, and containing or encapsulating the contamination. The RI found: 1) extensive PCB-contaminated soil both on and off the site, 2) PCB-contaminated structures which also contained asbestos, 3) groundwater contaminated with volatile organic compounds and PCBs, and PCB contaminated sewer and stream sediments. By 1986, the IEPA had collected enough information to determine that the off-site PCB-contaminated soil posed an immediate threat to the public health. The U.S. EPA and IEPA decided to split the site activities into phases and conduct an operable unit to address the off-site soil contamination.

The first operable unit, or Phase I RI, indicated that off-site PCB contaminated soil existed in the following areas: along the shoulders of an adjacent road for about 1000 feet to the north and approximately 1.2 miles south of the EUC property, the residential area directly east of the site, the small commercial area south of the property, and one residence north of the site. The concentrations of PCBs found in these areas ranged from less than 0.20 parts per million (ppm) to as high as 5800 ppm. The RI also documented low levels of PCBs inside houses and commercial buildings. The highest levels detected were 0.58 ug/100cm^2 from a wipe sample and 13 ppm from a sample of vacuum cleaner dust.

Feasibility Study

The Phase I Feasibility Study (FS) included an exposure assessment to evaluate acceptable cleanup standards. The exposure assessment determined that a 10^{-6} lifetime risk level corresponded to a soil concentration range of 0.05 to 0.5 ppm of PCBs in soils. A risk level of 10^{-5} corresponded to a range of 0.5 to 5 ppm PCBs. At the time, there were no formally established cleanup standards for PCBs in soils. U.S. EPA and IEPA considered two draft policies, combined with the results of the exposure assessment, to select an appropriate cleanup level. The policies that were considered were the draft National Toxic Substances Control Act (TSCA) PCB Spill Cleanup Policy and the U.S. EPA Office of Research and Development's advisory levels for PCB cleanups at Superfund sites. After combining available information, the U.S. EPA and the IEPA selected a cleanup level of 5 ppm PCB in the soil with a minimum of three inches of clean soil cover. Below 12 inches in depth, a cleanup level of 10 ppm PCBs would be applied.

The U.S. EPA and the IEPA determined that the structures (homes and businesses) needed to be cleaned since samples had already documented low level contamination inside homes, and it was likely that contaminated particles would be blown or tracked into the structures during excavation. The draft TSCA PCB Spill Policy was also utilized to establish a cleanup level for the structures where excavation would occur. The cleanup levels for the structures were established at 0.5 ug/100 cm^2 for high contact areas and 10ug/100 cm^2 for other surfaces.

The Phase I FS evaluated a variety of alternatives for the cleanup of the site. Five alternatives (no action, off-site landfill, off-site incineration, on-site incineration, and on-site storage) for the cleanup of the contaminated soil and three alternatives (no action, conventional industrial cleaning, and specialized cleaning with replacement) for the structural contamination were evaluated in detail. All of the alternatives for the soil and structures were put released for public comment.

Record of Decision

On August 29, 1986, the U.S. EPA Regional Administrator signed a Record of Decision (ROD) selecting on-site incineration for the cleanup of the contaminated soils and industrial cleaning for all structures where excavation would occur. The IEPA had also signed a ROD selecting the same remedy.

Remedial Design

The IEPA also assumed the lead agency role for the remedial design (RD) and the remedial action (RA) for the LaSalle site. Between August 1986 and July 1987, design documents were prepared by Ecology and Environment, Inc. (E&E) for the IEPA. These documents contained design drawings and technical specifications defining the requirements for the excavation of the soil, operation of the incinerator, cleaning of the structures, sampling and analysis, and various other activities associated with the remedial action (RA).

Procurement

After the design documents were completed, IEPA proceeded to procure the RA contractor using the two-step formal advertising procurement process. Since IEPA had certified that their procurement system complied with the federal procurement regulations, IEPA completed the RA contractor procurement with little input from the U.S. EPA, except for U.S. EPA participation on the review team for evaluating the construction contractor's technical proposals in the first step of the procurement. The IEPA completed the procurement and entered into a contract with the lowest responsive, responsible bidder. The IEPA entered into the RA contract with the Westinghouse Electric Corporation (also known as Westinghouse/Haztech, Inc.) on December 1, 1987.

Remedial Action

Between December 1987 and June 1988, Westinghouse prepared all the necessary work plans, sampling plans, safety plans, etc. which needed to be approved prior to initiating field work. Actual excavation started in approximately June 1988. During the summer of 1988, the question of the applicability of the Davis-Bacon Act to the remedial action arose.

Davis-Bacon Act

The debate on the applicability of the Davis-Bacon developed from two inquiries. First, the oversight contractor inquired of the IEPA about receiving certified payrolls from Westinghouse. At this time the IEPA was not receiving certified payrolls which are required under the Davis-Bacon Act. Secondly, at the same time, a local labor union, the International Union of Operating Engineers (IUOE) Local 150, filed complaints to the USDOL in July, 1988 alleging that Westinghouse was not paying the appropriate wages to its employees working on the LaSalle project. Settling this issue went from answering a simple question to what eventually became a very complicated dispute made up of contradictions by all parties involved. The participating parties included: Westinghouse, IEPA, Region V U.S. EPA, HQ EPA, Regional USDOL, HQ USDOL, as well as many local, state, and federal politicians.

Discussion

A detailed chronology of events which occurred during efforts to settle the issue, whether the Davis-Bacon Act wages applied to the LaSalle remedial action and, if so, which party would be financially responsible to comply with the decision, is provided in Attachment A.

On July 15, 1988, the IUOE Local 150 requested that the USDOL investigate Westinghouse's alleged Davis-Bacon wage violations on the LEU Superfund remediation project. Since that day, Westinghouse, IEPA, U.S. EPA (regional and headquarter offices), and the USDOL (regional and headquarter offices) became involved in a long and complicated dispute over whether the Davis-Bacon Act applied to the LaSalle remedial action and, if so, which party would be financially responsible for compliance with the labor standard. Throughout the dispute, several other interested parties were involved in one way or another. The interested parties included: IUOE Local 150, U.S. Senator for Illinois Paul Simon, U.S. Representative for the district in which the site is located, J. Dennis Hastert, the Illinois Attorney General, Illinois Senator Patrick Welch, and both the regional and local press.

Throughout the dispute, Westinghouse maintained the position that the LaSalle remedial action did not constitute construction since the project only involved excavation of contaminated soil, incineration of contaminated soil, backfilling of clean soil, landscaping, and industrial cleaning of houses where excavation occurred. Therefore, since the project did not involve construction, the Davis-Bacon Act did not apply. Westinghouse maintained their position even though the USDOL had made the decision that the remedial action at the LEU site constituted construction and therefore the Davis-Bacon Act was applicable. Westinghouse also maintained the position that neither the Bidding Documents nor its contract with the IEPA clearly indicated the project was either considered construction or that the Davis-Bacon Act applied.

The USDOL made their initial determination that Davis-Bacon applied and directed the IEPA to amend their contract appropriately and to require that Westinghouse submit certified payrolls in December, 1988. The USDOL later confirmed its determination of the applicability of Davis-Bacon but reversed its directive to have IEPA amend the LaSalle contract in February, 1989. After further review, the USDOL concluded that the LaSalle contract and related Bidding Documents adequately referenced the Davis-Bacon Act and, therefore, the contract did not need amending. The USDOL's position was construction is defined as not only construction of structures, but includes such actions as excavating, landscaping, and earthmoving.

In January, 1989, the U.S. EPA headquarters received a request from U.S. Representative J.Dennis Hastert for the U.S. EPA's opinion regarding the LaSalle labor issue. In March, 1989, the U.S. EPA headquarters responded to the inquiry by concurring with the USDOL determination that the LaSalle remedial action was construction and that the Davis-Bacon Act applied to the contract. However, the U.S. EPA deferred to the USDOL, as the authority for defining construction and coordinating the administration and enforcement of the Davis-Bacon Act requirements in CERCLA and agreed that the IEPA contract with Westinghouse did not need to be amended.

Based on: 1) the USDOL's determination that the Davis-Bacon Act applied to the project, 2) the USDOL's opinion that the contract and related bidding documents contained the appropriate references, and 3) the U.S. EPA's acceptance of the USDOL's decision, the IEPA took steps to bring Westinghouse into compliance with the Davis-Bacon Act. Westinghouse responded to the IEPA directives by disagreeing with the USDOL finding that Davis-Bacon applied to the LaSalle project, but agree to comply with the requests for employee information and submittal of certified payrolls. Westinghouse also stated, assuming that the Davis-Bacon Act did apply, any additional costs to Westinghouse for compliance with this labor standard would be considered to be the IEPA's responsibility.

Between May, 1989 and August, 1990, the IEPA and the USDOL worked closely together to enforce the Davis-Bacon wage provisions and to bring Westinghouse into compliance. The IEPA began receiving Westinghouse's certified payrolls and in a joint effort with the USDOL, performed an intensive audit of the entire Westinghouse payroll. They jointly assigned Davis-Bacon Wage Decision IL87-13 job classifications and wage rates for all employees who had worked for Westinghouse at the LaSalle site. However it was apparent that the three Westinghouse job classifications associated with operating and maintaining the mobile incinerator could not be directly equated with IL87-13 because it made no mention of mobile incinerators. These three classifications were assigned existing IL87-13 classifications solely on a logical basis.

During this time period, the IEPA had received a copy of a Westinghouse letter to the IUOE Local 150, dated May 24, 1988, from the IUOE Local 150. In its letter, Westinghouse enclosed the agreement it had made with the union, in which Westinghouse acknowledged that its contract stipulated Davis-Bacon wages be paid for the LaSalle project and that Westinghouse intended to pay these wages to its laborers.

The three incinerator classifications and all other Davis-Bacon classifications were presented to Westinghouse. Westinghouse continued to reject the USDOL determination that the LaSalle project was construction and stated their intent to challenge the USDOL's definition of "construction". Westinghouse stated it would cooperate in classifying workers because of the IEPA's mandate from the USDOL and that its cooperation in no way altered its intent to legally appeal the construction determination. Westinghouse disagreed with most of the classifications, particularly those assigned to the three mobile incinerator job categories. It was agreed between Westinghouse, the IEPA, and the regional USDOL that the IEPA would submit a Project Wage Determination for the LaSalle Phase II remedial action to the USDOL-HQ and the subsequent determination would be utilized to settle this Phase I dispute. It was also agreed that the LaSalle laborers needed to be interviewed for their concurrence on their job description.

During its review for the Project Wage Determination for the Phase II remedial action, the USDOL-HQ was exploring possibilities for implementing the provisions of the Service Contract Act based on the determination that the IEPA could be considered an "extension of the U.S. EPA" through the cooperative agreement. thereby the LaSalle procurement could be considered to be direct Federal procurement. The Service Contract Act is also a federal labor regulation which establishes wages and benefits based on different criteria than the Davis-Bacon Act utilizes. The Service Contract Act can only be utilized for direct Federal procurement. Upon discussions with USDOL, the Region V U.S. EPA raised concerns regarding the consistency with the Phase I USDOL regional determination that the Davis-Bacon Act applied. The Region V U.S. EPA also raised objections to the determination that the IEPA could be considered an "extension of the U.S. EPA" since the U.S. EPA could not find a legal basis for such a determination, in fact, one of the provision for receiving a CA is negation of agency relationship and that neither party could act on behalf of the other. Upon further review, USDOL-HQ agreed with the Region V U.S. EPA position and issued the Project Wage determination for the LaSalle Phase II project based on the Davis-Bacon Act.

After the IEPA had received the USDOL's decision, the Project Wage Determination for the LaSalle Phase II remedial action was sent to Westinghouse and their employees for their concurrence. Westinghouse again disagreed with the IEPA/USDOL's Davis-Bacon classifications and there was no consensus among the employees who responded. Because of this response, the IEPA sent the USDOL a formal, project-specific wage decision request for the LaSalle Phase I project. The USDOL issued the Phase I determination on April 17, 1990. Again, Westinghouse protested the Phase I Wage decision in a letter to the USDOL on May 7, 1990.

Based on the official wage decision for the Phase I project, the amount of back wages and fringe benefits were calculated for all of Westinghouse's LaSalle employees.

Throughout the labor dispute, Westinghouse had maintained they would require a change order for the entire amount of the back wages if it was determined that the Davis-Bacon Act applied to the project. Westinghouse had maintained that the Davis-Bacon wages were not factored into their bid because the project was not considered to be construction. In addition, Westinghouse argued that since wage classifications were not assigned for the three incinerator categories until April 17, 1990, Westinghouse could neither have formulated the correct bid nor paid the correct wages for those categories. On the other hand, the U.S. EPA and the IEPA had consistently maintained that a change order for these wages would not be approved because the USDOL had concluded that the contract and the Bidding Documents had included appropriate references to indicate that the Davis-Bacon wage rates were applicable.

On August 2, 1990, the USDOL-HQ issued the official labor wage underpayment documents for the Westinghouse employees for the LaSalle Phase I remedial action. The documents contained 98 names and totalled $751,552.04. The underpayment of the three disputed incinerator job categories totalled approximately $423,000. The regional USDOL later issued a letter which gave Westinghouse until 08/24/90 to make the wage deficit payments to its employees.

On August 8, 1990, Westinghouse proposed to settle the Davis-Bacon dispute in two parts. In Part 1, Westinghouse requested $888,033.00 for the wage deficiency for the three disputed incinerator job categories. They then proposed to address all other labor categories in Part 2, after Part 1 was settled. The proposed Part 1 settlement included the amount of deficient wages, fringe benefits, overhead cost, and general and administrative (G&A) expenses. In addition, Westinghouse claimed they were entitled to a profit, but, in the interest of good will, they would forego the profit.

The IEPA and the U.S. EPA continued to contend that the contract and the Bidding Documents indicated that the Davis-Bacon Act would apply to the LaSalle Phase I remediation. However, since the USDOL indicated that the disputed incinerator job categories could not be equated to existing Davis-Bacon wage categories, the IEPA concluded it would be in the best interest of all parties concerned to settle the wage dispute without resorting to the threatened litigation from Westinghouse. However, the dispute was further clouded by the fact that the U.S. EPA Headquarters had published new Superfund assistance regulations in June, 1990 (40 CFR Part 35 Subpart O) which determined that the excavation and incineration of contaminated soil would be considered a "service" and not defined as "construction". The language which defined construction was never reviewed by Region V of the U.S. EPA, and if it had reviewed the language, Region V of the U.S. EPA would have never concurred with promulgation of the regulation because of the proposed definition of construction, especially in light of the two-year debate on the LaSalle project. The IEPA presented its recommendations to the U.S. EPA Region V for its concurrence. Both parties agreed that it would be in the government's best interest to seek a fair and equitable resolution of the Davis-Bacon dispute because the ambiguity of the IEPA's contract, the promulgation of Subpart O, and the lack of consistency, severely weakened any positions the agencies could have taken if Westinghouse pursued the matter in court.

The IEPA countered the Westinghouse proposal by offering to pay Westinghouse the amount resulting from Part 1 if they agreed to drop their claim regarding Part 2. Westinghouse agreed to drop its demands regarding Part 2 of their proposed settlement. The only hurdle to reach a settlement which now remained was an agreement on appropriate overhead and the G&A expenses. IEPA did not agree with the original rates which Westinghouse had proposed in their original proposal. After further negotiations between Westinghouse and the IEPA, the rates for overhead and G&A were resolved.

On October 18, 1990, the IEPA received a letter from Westinghouse in which it agreed to settle the entire LaSalle Phase I wage dispute for $823,243.23. The IEPA then requested the Region V U.S. EPA to concur with the proposed settlement. On December 12, 1990, the U.S. EPA issued written concurrence regarding the proposed settlement. The IEPA then proceeded to amend their contract with Westinghouse to reflect the agreed upon settlement.

In summary, it quickly became apparent that all parties involved were confused, or were at least presenting conflicting positions, regarding the applicability of, and the liability for compliance with, the Davis-Bacon Act with respect to the LaSalle project. Clear examples of conflicting information being communicated are given by the following:

1) The applicability of the Davis-Bacon Act was not directly addressed by the contract or the Bidding Documents and the IEPA was not requiring certified payrolls from the beginning of the contract period.

2) Initial decisions made by the regional USDOL determined that the Davis-Bacon Act applied to the LaSalle project, and the contract and Bidding Documents needed to be amended to reflect this decision. The regional USDOL later reversed its determination that the contract and Bidding Documents were deficient in covering the Davis-Bacon Act applicability and, therefore, the documents did not need to be amended.

3) Westinghouse had consistently presented their firm position that the project did not entail construction and therefore Davis-Bacon did not apply. They also claimed that if the Davis-Bacon Act did apply, Westinghouse could not have been aware of this based on the contract and Bidding Documents and, therefore, Westinghouse would not be liable for the costs of compliance. However, the Westinghouse letter to the IUOE Local 150 clearly indicated that Westinghouse was aware that the contract and Bidding Documents indicated that the Davis-Bacon Act applied and that Westinghouse intended to pay the union workers accordingly.

4) The USDOL regional office had consistently expressed the applicability of the Davis-Bacon Act for the LaSalle Phase I remedial action, but the USDOL-HQ, in its review for the Project Wage determination for the LaSalle Phase II project, initially explored possibilities to apply the provisions of the Service Contract Act for the LaSalle Phase II project, The Phase II project was very similar in scope to the LaSalle Phase I project.

5) The regional U.S. EPA had consistently agreed with the regional USDOL determinations and firmly believed the USDOL was the only Agency with the authority to make formal determinations. The U.S. EPA-HQ had responded to an inquiry from U.S. Representative J. Dennis Hastert and restated that the U.S. EPA accepted the regional USDOL determination and also deferred to the USDOL as the decision-making agency with regard to defining construction applicability and applying labor standards. However, the HQ U.S. EPA had published new Superfund assistance regulations in June, 1990 which defined "construction" in terms of Superfund remedial actions and suggested the Service Contract wages be utilized for projects which are primarily excavation and incineration of contaminated soil. These regulations further add to the confusion since the States do not have the ability to utilize the Service Contract Act, since it applies to direct Federal procurement only.

CONCLUSIONS

As a result of the experience gained from the LaSalle Phase I remedial action, the following items need to be addressed:

1) First, the definition of "construction" and the determination of when the Davis-Bacon Act applies to Superfund contracts needs to be agreed to, by both the USDOL and the U.S. EPA, to enable both the USDOL (regional and HQ) and the U.S. EPA (regional and HQ) to be consistent in applying labor standards. This would enable the U.S. EPA to accurately advise the States which have CAs.

2) Second, if the Service Contract Act applies to some Superfund remedial actions, the States need appropriate methods made available to them by the U.S. EPA for administering the Service Contract Act for "State-Lead" projects. Otherwise, the States will be restricted to only assuming the lead agency role for remedial actions where the Davis-Bacon Act applies.

3) For any Fund-financed remedial action, the correct labor standards need to be identified early so the contracts and Bidding Documents can clearly state which labor standards apply to the projects. This is a must for administering Superfund remedial action contracts.

If these steps are not followed, it is inevitable that the same disputes are likely to arise on future projects. The experience gained from resolving the Davis-Bacon issue for the LaSalle project shows that this was clearly a time-intensive issue which could have been settled before it had started. By presenting this paper, the authors hope that experience gained through the LaSalle project will be utilized to avoid some major labor disputes during future Superfund remedial actions.

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ATTACHMENT A

The following a detailed chronological list of the events which occurred during efforts to settle the issue of whether the Davis-Bacon Act wages applied to the LaSalle remedial action and, if so, which party would be financially responsible to comply with the decision.

07/15/88 The Illinois Union of Operating Engineers (IUOE) Local 150 submitted a complaint to the USDOL requesting an investigation of Westinghouse's payment practices at the LaSalle site. The IUOE Local 150 made allegations that Westinghouse was not complying with the Davis-Bacon Act requirements stated in their contract with IEPA.

10/21/88 Not seeing results from their complaint to USDOL, the IUOE Local 150 requested assistance from Senator Paul Simon's office to urge USDOL to investigate Westinghouse.

10/26/88 IEPA requested advice and guidance from the Region V U.S. EPA on the Davis-Bacon wage issue for the LEU project. This request was made in light of the U.S. EPA developing new regulations regarding construction contracts. It was IEPA's opinion at this time the Davis-Bacon Act applied to the LaSalle project.

Also Senator Simon's office responded to the IUOE Local 150 with assurances that USDOL would be contacted on their behalf.

10/28/88 Westinghouse requested a site-specific wage decision for the LEU site.

11/01/88 IEPA sent the U.S. EPA a listing of the categories of laborers for which the wages were in dispute. The IEPA requested a Federal determination on the correct wage classification for these laborers.

11/04/88 A copy of the Westinghouse LaSalle contract and excerpts from the Bidding Documents pertaining to wage rates were sent to USDOL by IEPA.

11/07/88 U.S. EPA concurred with the IEPA's determination that the Davis-Bacon Act should be applied to the Phase I RA construction contract. The U.S. EPA informed the IEPA the new Superfund regulation (40 CFR, Part 35, Subpart O), in light of the LaSalle situation, would better define when remedial actions constitute "construction". Once the new regulation had been promulgated and prior to executing the subsequent Phase II remedial action contract, the remedial action would need to be reassessed to determine if it qualifies as "construction". The U.S.

EPA also alerted the IEPA that the USDOL was sent the disputed labor categories to enlist their help in making the Federal determination requested in the IEPA's letter dated November 4, 1988.

The U.S. EPA sent the disputed labor categories to the USDOL for their review. The USDOL was requested to advise the IEPA on the correct labor classifications. It was also indicated to the USDOL that there were inconsistent opinions at the Regional and Headquarters level of the U.S. EPA on the applicability of the Davis-Bacon Act at Superfund cleanups where no tangible construction is present. The USDOL was told the U.S. EPA was presently attempting to redefine "construction" and "services" to be consistent with the Federal Acquisition Regulations in a new Superfund assistance regulations.

11/09/88 USDOL responded to Senator Paul Simon informing him their regional office had initiated an investigation of Westinghouse.

12/05/88 Several Westinghouse employees requested the Illinois Attorney General's office investigate the LaSalle labor issue.

12/19/88 The USDOL informed the IEPA that the LaSalle project constituted "construction" within the meaning of the Davis-Bacon Act and the Davis-Bacon Act did apply. The USDOL requested the IEPA to fulfill its enforcement responsibilities which included: amending its contract with IEPA to include appropriate clauses of the Davis-Bacon Act and to require that Westinghouse submit certified payrolls.

01/13/89 Westinghouse requested the USDOL to reconsider its determination that the Davis-Bacon Act applied to the LaSalle project. Westinghouse stated its position that the LaSalle project was covered by the McNamara-O'Hara Service Contract Act. Westinghouse's position was based on its argument that work being performed under its contract with the IEPA was a "service" and not "construction". It stated that the amount of work being done which could be similar to construction was negligible and the overwhelming portion of the work being performed (treatment and removal of contaminated soil) was a "service".

01/25/89 U.S. Representative J. Dennis Hastert inquired of the U.S. EPA Headquarters if the U.S. EPA accepted the USDOL determination that the Davis-Bacon Act applied to the LaSalle project.

02/13/89 After continuing review, the USDOL confirmed that the LaSalle project falls within the scope of the Davis-Bacon Act but stated that the IEPA contract with Westinghouse incorporated the appropriate clauses of the Davis-Bacon Act by reference and indicated the contract did not need to be amended. The USDOL continued their request of the IEPA to require that certified payrolls be submitted by Westinghouse.

03/22/89 The U.S. EPA Headquarters responded to U.S. Representative Hastert stating that the U.S. EPA accepts the USDOL determination and deferred to USDOL as the enforcement authority for the Davis-Bacon Act requirements.

04/26/89 The IEPA informed Westinghouse of the USDOL's decision and of the U.S. EPA's concurrence that the Davis-Bacon Act applied to the LaSalle project. The IEPA requested information on Westinghouse's employees at LaSalle and required certified payrolls be submitted corresponding to all work done under their contract.

05/12/89 Westinghouse responded to the IEPA directive stating that it disagreed with the USDOL finding that Davis-Bacon applied to the LaSalle project, but would comply with the requests for employee information and submittal of certified payrolls. Westinghouse also stated, assuming that the Davis-Bacon Act did apply, any additional costs to Westinghouse for compliance with this labor standard would be considered to be the IEPA's responsibility.

06/20/89 The IEPA informed Westinghouse that, based on the USDOL determination in its 02/13/89 letter that the contract included appropriate references to the Davis-Bacon Act, the IEPA could not accept financial for compliance with the Davis-Bacon Act.

06/29/89 The U.S. EPA confirmed its concurrence with the USDOL determination that the Davis-Bacon Act applied to the LaSalle contract. The U.S. EPA also agreed with the IEPA that the contract documents adequately covered the Davis-Bacon Act and that additional costs for compliance should not be the responsibility of the U.S. EPA or the IEPA.

07/12/89 The IEPA received a copy of a Westinghouse letter from the IUOE Local 150 in which Westinghouse enclosed the agreement it made with the union. The agreement stated: "The wages cited above are set forth in the Davis-Bacon (US Dept. of Labor) prevailing wage determination, which is stipulated in Haztech's contract with the IEPA. The parties agree that in the event the US Dept. of Labor later determines that a higher wage or benefit rated is applicable to this project, then all the affected amounts will be paid retroactive to the project starting date."

07/25/89 A meeting was held with representatives of the USDOL, U.S. EPA, IEPA and Westinghouse in an attempt to classify Westinghouse's workers in accordance with the Davis-Bacon Act. Westinghouse still did not accept the determination that the LaSalle project was construction and stated their intent to challenge the USDOL's definition of "construction". Westinghouse stated it would cooperate in classifying workers because of the IEPA's mandate from the USDOL and that its cooperation in no way altered its intent to legally pursue the construction determination. Many, but not all, laborer wage categories have been settled. The IEPA agreed to send Westinghouse a list of the job descriptions and the corresponding Davis-Bacon categories and wage rates. This list was agreed to in a joint effort between the USDOL and the IEPA on 07/24/89. It was agreed by all parties that the IEPA would submit a Project Wage Determination for the LaSalle Phase II remedial action and that the USDOL's determination would be utilized to settle this Phase I dispute. It was also agreed that the LaSalle laborers needed to be interviewed for their concurrence on their job description.

07/26/89 The IEPA sent the list of job descriptions and the corresponding Davis-Bacon categories and wage rates to Westinghouse.

08/03/89 Westinghouse disagreed with most of the Davis-Bacon job classifications and/or the wage rates suggested by the IEPA/USDOL. Westinghouse also maintained their position of non-agreement with the USDOL's construction and Davis-Bacon applicability rulings for the LaSalle project.

08/23/89 The IEPA submitted a Project Wage Determination request for the LaSalle Phase II remedial action to the USDOL in Washington, D.C. for approval.

10/16/89 The IEPA received the USDOL Project Specific Wage Determination for the Phase II remedial action.

01/19/90 The IEPA sent a formal Wage Determination questionnaire for the Phase I project to Westinghouse and to the laborers for their concurrence.

01/24/90 The IEPA received a request from the Illinois Attorney General's office for copies of all certified payrolls received from Westinghouse and the IEPA complied with the request the same day.

02/02/90 Westinghouse disagreed with the IEPA's wage proposals in a response to the IEPA's questionnaire.

02/09/90 The IEPA received the final response to their questionnaire from the laborers. There was no consensus of opinion from the laborers regarding the IEPA wage proposals.

03/02/90 The IEPA sent a formal request to the USDOL for the Phase I remedial action which acknowledged that three of the Westinghouse job categories were not listed in the previous determinations.

04/17/90 The USDOL issued a job-specific wage decision for the LaSalle Phase I project.

05/07/90 Westinghouse sent a letter to the USDOL protesting their 04/17/90 LaSalle Phase I wage decision.

05/31/90 The IEPA sent a letter to Westinghouse stating that the IEPA's position had not change from the position stated in its 03/02/90 letter to the USDOL.

06/19/90 A meeting was held between representatives of the IEPA, U.S. EPA, and the USDOL. This was a meeting held in preparation for a meeting with Westinghouse to be held the next day. The USDOL stated, after reviewing payrolls, ledgers, and employee surveys, the back wages owed to the direct employees of Westinghouse was approximately $792,000. The possibility of debarment of Westinghouse was discussed if they refused to comply with the Davis-Bacon Act. There also were many discussions on the recent discovery of the fact that the newly published final Subpart O Superfund regulations contained language on defining construction in conflict with the USDOL determination. The Subpart O regulation was changed after the Region V U.S. EPA had concurred with it. The preamble to the regulation states that the operation and handling of materials and operation of a mobile incinerator may be considered services. This language was never agreed to by the Region V U.S. EPA and it had caught all parties involved by surprise.

06/20/90 A meeting was held between Westinghouse, the IEPA, and the USDOL. Westinghouse had stated that it had slightly different figures than those of the USDOL and would work with the USDOL to resolve the discrepancy. Westinghouse also stated their overall costs were between $ 1-2 million, including overhead and administration costs. Westinghouse was unwilling to pay all costs associated with compliance but was now open to negotiate a settlement. Otherwise, it was prepared to pursue this matter in court.

07/90 The U.S. EPA Headquarters issued an Engineering Forum Fact Sheet containing information on the definition of construction. The fact sheet stated "Burning contaminated material and treating contaminated water are services, not construction" and that remedial actions may "be either construction, service, or both". It indicated that for construction, Davis-Bacon applies, but does not apply to a service.

08/02/90 An audit of certified payrolls by the IEPA and the USDOL was completed and agreements were made between Westinghouse and the IEPA and USDOL regarding the method of calculating back wages. Westinghouse still did not accept or acknowledge that the LaSalle project was a construction project or that Davis-Bacon applied. Westinghouse did agree that if Davis-Bacon did apply, the total back wages and fringe benefits calculated was correct as of 08/02/90.

The IEPA received the LaSalle underpayment of wages roster from the USDOL. The roster contained 98 names and totalled $751,552.04. The underpayment of the three categories of incinerator workers was approximately $423,000.00.

08/08/90 The USDOL issued a deadline of 08/24/90 to Westinghouse for making a decision of payment of the back wages.

08/15/90 The IEPA received a draft letter containing Westinghouse's request to settle the wage issue in two parts. Part 1 was to deal with the underpayment of wages for the three categories of incinerator workers and part 2 was to deal with the underpayment of wages for all other job categories. Westinghouse had requested $888,033.00 to settle part 1. The IEPA sought the Region V U.S. EPA concurrence in proceeding with negotiations.

08/28/90 Due to the negotiations between Westinghouse and the IEPA, Westinghouse agreed to pay for part 2 of the wage negotiations if the IEPA agreed to pay Westinghouse $888,033.45 for part 1. This payment included direct labor as well as fringe benefits and company overhead.

09/05/90 The IEPA received information from Westinghouse for the purpose of auditing the overhead rates covering the period of 1986 to 1989.

09/06/90 The Westinghouse overhead rate information was sent to the U.S. EPA, by the IEPA, as supplemental information in its request for concurrence for paying Westinghouse the $888,033.45. This amount was to cover the three incinerator positions not originally included in the USDOL's Davis-Bacon wage decisions.

10/11/90 The U.S. EPA verbally agreed that the IEPA proceed with the $888,033.45 payment to Westinghouse for the purpose of settling the issue without a legal battle.

10/15/90 The IEPA entered into further negotiations with Westinghouse, in which Westinghouse agreed to use the U.S. EPA negotiated overhead and G&A rates. This agreement reduced the settlement figure to $823,243.23.

10/18/90 The IEPA received Westinghouse's formal offer to settle the entire LaSalle wage dispute for the agreed amount of $823,243.23 for the three incinerator job categories.

11/28/90 The IEPA requested written concurrence from the U.S. EPA regarding the proposed settlement for the entire LaSalle wage dispute.

12/26/90 The U.S. EPA concurred with the IEPA for the settlement amount of $823,243.23.

SURETY BONDS - SUPERFUND PROJECTS

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INTRODUCTION

The purpose of this paper is to discuss and analyze the subject of surety bond requirements in connection with construction and service contracts, and particularly surety bond requirements for contracts related to the Environmental Protection Agency ("EPA") Superfund program. The need to address this subject arises as a result of complaints by private sector firms, who are interested in obtaining government contracts related to the Superfund program, that performance bonds for hazardous and toxic waste work are not readily available from corporate sureties.

BACKGROUND

Remedial actions under the Superfund program are accomplished by contracts between the United States and private sector contractors. The work to be performed can be in the nature of construction, or services, or a combination of both. The Miller Act[1] is a federal statute that requires performance and payment bonds for any construction contract exceeding $25,000. The Federal Acquisition Regulation ("FAR") implements the requirements of the Miller Act.[2] The FAR provides that the penal amount of performance bonds shall be 100 percent of the original contract price, unless the contracting officer determines that a lesser amount would be adequate for the protection of the government.[3] In the case of contracts other than for construction ("service contracts"), government agencies generally shall not require performance and payment bonds.[4] However, performance and payment bonds for service contracts may be used as permitted by the FAR[5], as follows:

(a) Performance bonds may be required when necessary to protect the Government's interest. The following situations may warrant a performance bond:

(1) Government property or funds are to be provided to the contractor for use in performing the contract or as partial compensation (as in retention of salvaged material).

(2) A contractor sells assets to or merges with another concern, and the Government, after recognizing the latter concern as the successor in interest, desires assurance that it is financially capable.

(3) Substantial progress payments are made before delivery of end items starts.

(4) Contracts are for dismantling, demolition, or removal of improvements.

The contractor is required to furnish all bonds before receiving a notice to proceed with the work or being allowed to start work.[6] In addition, the government may require additional performance bond protection when a contract price is increased. The increase in protection shall generally equal 100 percent of the increase in contract price. The government may secure additional protection by directing the contractor to increase the penal amount of the existing bond or to obtain an additional bond.[7] The performance bond required appears in the FAR.[8] The bond provides that the surety will be liable to the government for the penal sum of the bond in the event that:

(1) the contractor does not perform and fulfill the undertakings, covenants, terms, conditions, and agreements of the contract during the original term of

the contract and any extensions thereto that are granted by the government, with or without notice to the Surety(ies), and during the life of any guarantee required under the contract, and

(2) the contractor does not perform and fulfill all the undertakings, covenants, terms, conditions, and agreements of any and all duly authorized modifications to the contract that hereafter are made. Notice of those modifications to the Surety(ies) are waived.

Key to this discussion is the definition of construction and service contracts. The Service Contract Act does not define services except by exclusion. If it is not construction it is service by default. Conversely, Congressional Conference Committee reports indicate if it fits under construction, it is not service. The preference, if any, is clearly toward construction.[9] The Service Contract Act specifically exempts contracts for construction, alteration and/or repair, including painting and decorating of public buildings or public works.[10] "Construction", "building" or "work" under the FAR are broadly defined and they include such things as altering, remodeling, and installation of items fabricated off-site, painting and decorating, and transporting materials or supplies to or from a public works, buildings, or structures. Construction activity is distinguished from manufacturing, furnishing of materials, or servicing and maintenance work. The terms "building" or "work" include without limitation, buildings, structures, and improvements of all types, such as bridges, dams, plants, highways, parkways, streets, levees, canals, dredging, shoring, drilling, blasting, excavating, clearing, and landscaping.[11]

The distinction between construction and service is important because some contractors perceive that it is in the contractor's interest to have the contract characterized as a service contract rather than as a construction contract, in that, contractors believe that if a contract is designated as a service contract, a performance bond will not be required. This is somewhat of a misconception on the part of a contractor since the contracting officer may require a surety bond on a service contract if a bond is necessary to protect the government's interests.[5] The interest of contractors in having the work designated as service type work, rather than construction, is illustrated by a bid protest dealing with this very subject.[12] The facts of the protest are as follows.

The Kansas City District (KCD), solicited proposals under a competitively negotiated request for proposal (RFP) for the construction of a transportable incineration system for explosives contaminated soils at two sites ("Site I and Site II"). Basically, the work was broken down into three phases. Phase I work consisted of regulatory requirements and preparatory work efforts for construction activities. At both sites, Phase II work consisted of excavation, transportation, handling, incineration, and disposal of approximately 18,000 cubic yards of contaminated soil (TNT & DNT), as well as treatment of approximately 400,000 gallons of explosives contaminated water (TNT & DNT). At Site I, Phase III work consisted of separating, transportation, handling, incineration, and disposal of approximately 36,356 cubic yards of stockpiled explosives contaminated soil (TNT & DNT) and debris. Phase III work was a Government option.

The RFP's SPECIAL CLAUSE (SC)-44. LABOR-ADDITIONAL REQUIREMENTS, classified the incineration portion of the work as service, all other work required within 5 feet outside building lines as building construction, and all other construction not defined in the RFP as heavy construction. SOLICITATION PROVISIONS (SP) 37. PERFORMANCE AND PAYMENT BONDS, required submission, for Phases II and III, a performance bond equal to 100% of the contract price and payment bond equal to 50% of a contract price of $1,000,000 or less, 40% if in excess of $1,000,000 but no more than $5,000,000 and in the amount of $2,500,000 if the contract price exceeded $5,000,000.

An amendment clarified the classification of work, per phase, at each work site. It contained revised SC44 which classified all of Phase II at work Site I as either building or heavy construction. Phase III work at Site II was classified service for the incinerator operation, moving of existing stockpiled material, and disposition of materials. All other work at Site II was classified either building or heavy construction.

The protest consisted of three separate claims each of which will be addressed individually. The first claim was that KCD's construction classification was improper. The second claim was that the penal sums of the performance bond were unnecessarily high and would unjustifiably restrict competition to only the highest capitalized firms thereby precluding the protestor from competing for this project. The third claim was that no performance bonding should be required for any portion of the work classified as service. The protestor sought a reclassification of the construction work at both sites, a reduction of the penal sum of any required performance bond to less than 100% of contract price, and elimination of any required performance bond for service classified work.

In support of its first claim the protestor argued that there was no construction or excavation of any sort at Site II except for some insignificant construction to improve roads and construction of an administrative area. The protestor further argued that the excavation work at Site I was part of the demolition of the settlement lagoons and clearly was not Miller Act construction. Additionally, the protestor asserted that the erection and operation of the contractor's equipment was not construction work.

The FAR defined construction as "...construction, alteration, or repair (including dredging, excavation and painting) of buildings, structures, and other real property."[11] The Office of Management and Budget's Standard Industrial Classification (SIC) Manual, Part I, Division C, classified as heavy construction, under SIC Code No. 1629, (1) clearing of land; (2) earth moving, not connected with building construction; (3) industrial incineration construction; (4) soil compaction services; and (5) kiln construction. Road construction, except elevated, was classified under SIC Code No. 1611 as highway and street construction. Plumbing and electrical work, including telephone/telephone equipment installation, were each classified as construction (special trade contractors) under SIC Code Nos. 1711 and 1731 respectively. Structural steel and metal work were each classified as construction under SIC Code No. 1791. Excavation work was classified as construction under SIC Code No. 1794. The installation of conveyor systems and the erection and dismantling of machinery and other industrial equipment were each classified as construction under SIC Code No. 1796. Lastly, the building of any industrial building or warehouse was classified as general building construction (non residential) under SIC Code No. 1541.

At Site I, the solicitation required the excavation and removal of explosives contaminated soils and water from several lagoons. The material would be transported to a holding area built adjacent to an on-site industrial incineration facility. The excavation process was to proceed simultaneously with the incineration process. Following incineration, the excavated areas were to be backfilled with the cleaned soil, compacted, graded and seeded. In conjunction with the above, the solicitation contemplated the installation of an erosion and sediment control facility, construction of roads for transportation of excavated materials, construction of an on-site scale for truck weighing, construction of an on-site water treatment facility, substantial concrete foundation construction to support the incinerator, the initial on-site erection and subsequent dismantling of the incinerator requiring structural steel and metal work, the installation of an on-site conveyor system to convey the soil from the holding area to the incinerator, and installation of temporary site utilities including telephones, electrical power, sanitation waste containment and a water supply system. The entire facility covered an area of approximately five (5) acres. Therefore, a substantial amount of the work required at Site I was construction work.

The work at Site II was similar to the work required at Site I with the exception of excavation. The explosives contaminated soil and debris were stockpiled in containers stored under tent-like storage areas at the work site. In all other respects the construction requirements of Site II were similar to Site I, which were substantial.

A substantial portion of the work previously described and contemplated by the solicitation fit the FAR definition of "construction" in three specific ways at Site I and in two specific ways at Site II.

<u>SITE I</u>

(1) the work site, which is real property, would undergo significant and substantial alteration in as much as four of six

existing lagoons which were to be removed in their entirety with level, grass covered replacements left in their place. The remaining two lagoons were to be backfilled in a configuration allowing future utilization as lagoons;

(2) existing explosives contaminated soil and water would be excavated;

(3) numerous structures would actually be constructed involving work specifically classified as construction (heavy, building, or other) by the SIC code manual.

SITE II

(1) A site, which is real property, adjacent to the incineration work site would undergo significant and substantial alteration since that area was to be filled with the cleaned soil following incineration leaving a level, grass covered replacement in place;

(2) numerous structures were to be constructed involving work specifically classified as construction (heavy, building, or other) by the SIC code manual.

The designated construction classification for work at both sites conformed to the definition of the term "construction" in the FAR. A service classification for the previously identified work items was unwarranted.

The responsibility for determining whether a contract should be considered one principally for construction rests primarily with the contracting agency which must award, administer and enforce the contract.[13] Consequently, the GAO will not disturb a good faith determination by a contracting officer (CO) that a contract should be for construction.[14] The protestor presented no evidence to suggest that the CO did not act in good faith in determining that the subject contract for both sites was considered principally one for construction. Neither did the protestor show any abuse of discretion or violation of procurement regulations associated with the subject solicitation.

The second claim that the performance bond's penal sum (100%) was unnecessarily high, thereby unjustifiably restricting competition, is closely linked to the first claim. The protestor attempted to demonstrate the existence of a disparity between a high penal sum requirement and a low construction requirement. This attempt was flawed, however, given the previously shown substantial construction actually involved at both sites. It followed, therefore, that no disparity existed between the penal sum of the bond and the solicitation's construction requirements.

The FAR states that "[t]he penal amount of performance shall be 100 percent of the original contract price, unless the contracting officer determines that a lesser amount would be adequate for the protection of the Government."[3] The protestor argued for an interpretation of this language which overlooked any requirement on the part of the CO to determine initially that the penal sum should be set at 100% of the original contract price. This argument was misplaced. The CO is given a mandate to set the penal sum at 100% of contract price as the initial course of action. The language is not permissive, it is mandatory. An exception is carved out providing for the exercise of discretion where circumstances may warrant a lesser penal sum. As with any other use of discretion, its exercise will be upheld if it is devoid of abuse.[15] The CO found no reason to determine that, as an exception to the mandated penal sum of 100% of contract price, a lesser penal sum would be adequate for the protection of the Government. In an effort to persuade the CO to make such a determination, however, the protestor stated that perhaps the CO believes he did not have the authority to require a penal sum of an amount less than 100% of contract price. Accordingly, a number of examples were provided by the protestor to demonstrate the existence of authority for the CO to make the determination that the protestor desired. Authority, however, was not an issue in the case. The CO is provided unequivocal authority by the FAR to make determinations warranting an exception to the requirement for the setting of the penal sum at 100% of contract price.[3] The protestor overlooked the fact that the thrust of this particular FAR provision is to provide the Government with as much protection as needed. This is borne out by the FAR which authorizes an increase in required performance bond protection when a contract price is increased.[7] It is not the function of this FAR provision to facilitate the acquisition of performance bonds by firms that have exhausted their bonding capacity. Rather the function of the FAR provision is to provide for the Government's need to have adequate protection through the proper implementation of its regulations.

The fact that a particular contractor may be unable to obtain bonding does not make the requirement improper if it is otherwise appropriate.[16] In order to protect the United States and all persons supplying labor and materials under contracts for construction, the Miller Act[1] requires that the contract awardee furnish performance and payment bonds for all contracts which exceed $25,000 in amount.[17] Although a bond requirement may result in a restriction on competition, it nevertheless can be a necessary and proper means of securing to the government the fulfillment of the contractor's obligation under the contract in appropriate situations.[18] The bonding requirement applied to the procurement since a substantial amount of construction work would be required at each work site. In reviewing a challenge to the imposition of a bonding requirement, GAO looks to see if the requirement is reasonable and imposed in good faith. The protestor bears the burden of establishing unreasonableness or bad faith.[19] In this case, the protestor failed to demonstrate that the CO's compliance with the FAR in setting the penal sum of the required performance at 100% of the contract price was unreasonable or imposed in bad faith.

The third claim was that no performance bonding should be required for work classified as service. The FAR states that generally, agencies shall not require performance and payment bonds for other than construction contracts. However, performance and payment bonds may be used[4] as permitted in other sections of the FAR.[5] In related cases the GAO has found that although, as a general rule, in the case of non-construction contracts, agencies do not generally require bonding, the use of bonding is permissible where the bonds are needed to protect the government's interest, regardless of whether the agency's rational comes within the four reasons given for requiring a performance bond.[20] Bonds may also be required where the continuous operation of critically needed services is absolutely necessary.[21]

In this case, a performance bond was required for work classified as "service" at Site I for four reasons. First, the excavation of contaminated soils (construction) and incineration of same (service) was interwoven into an integrated work effort. As previously noted, the excavated soil was to be transported to a holding area near the incinerator. In the event of a prolonged work stoppage, the availability of a performance bond covering only the excavation portion of the project would frustrate the principal contract objective by leaving the Government without any protection for the accomplishment of that objective, that is, the decontamination of the excavated soil through incineration. Second, the problem would be further compounded by the continued excavation and stockpiling of contaminated soil, with no incineration, by a surety's replacement contractor, since the holding area for contaminated soil was not designed to contain continuously stockpiled quantities of soil. Accordingly, a spillover situation could have occurred involving a potential risk that areas outside the holding area would become contaminated as contaminated rain water runs off which could result in the leaching of contaminants into the ground. The continuous operation of the incineration services was absolutely necessary in order to guard against this potential risk. Third, the Government would not begin receiving delivery of the end item, that is, the decontaminated soil following incineration, until substantial progress payments had been made for (1) the completion of Phase I work, and (2) substantial, if not complete, construction of the entire facility. Pursuant to the provisions of the FAR, a performance bond for service work is warranted under these circumstances.[20] Fourth, Government funds were to be provided to the contractor for use in the performance of the contract. The object of the contract, incineration, could not commence until completion of construction of the facility, which would be funded by the Government. Pursuant to the provisions of the FAR, a performance bond for service work was warranted under these circumstances.[22]

A performance bond was likewise justified for work classified "service" at Site II pursuant to the provisions of the FAR since Government funds were to be provided to the contractor for use in performing the contract and substantial progress payments would be made for Phase I work and construction of the facility before commencement of delivery of the end item to the government.[23]

The Comptroller General, in denying the protest, held that the performance bond requirement was unobjectionable where an agency determines that a bond is necessary to assure the continuous operation of the process of excavation and incineration of contaminated soils, the interruption of which might result in contamination of the surrounding area, and substantial progress payments would have been made prior to completion of performance.[12]

The Comptroller General held in a subsequent decision that a performance bond requirement in a solicitation issued as part of a cost comparison pursuant to Office of Management and Budget Circular No. A-76, for facilities maintenance at an academic institution housing over 1,000 personnel, was unobjectionable where substantial government-furnished property will be provided to the contractor for performance of the contract and the services to be performed are critical to the continuous operation of the facility.[24]

The purpose of this background has been to set out the rules pertaining to performance bond requirements as those rules relate to Superfund projects. The next section of this paper will discuss the problem based on the experiences of the Kansas City District and other Corps elements with this subject.

DISCUSSION

The first indication of a problem with contractors' being unable to obtain corporate surety bonds to guarantee performance of a contract in connection with cleanup of a Superfund site came to the attention of KCD in 1988, when bids were opened in response to an Invitation for Bids ("IFB"). Three of the six bidders submitted individual surety bid bonds. Since the fee charged by an individual surety for a bond is greater than the fee charged by a corporate surety, it seems apparent from an economic standpoint, that the bidders were unable to obtain bonds from a corporate surety.

The applicable FAR provision provided that bonds are acceptable from individual or corporate sureties. Under the regulation, an individual surety was defined as a person, as distinguished from a business entity, who is liable for the entire penal amount of the bond.[25] It is the responsibility of the Contracting Officer to determine whether the proposed individual sureties are acceptable to the government.[26] This was KCD's first experience with investigating the individual surety and verifying the assets and liabilities listed by the individual. In this case, the proposed individual sureties were determined by the Contracting Officer to be unacceptable. None of the three bidders protested that determination.

Although the individual sureties were subsequently determined to be unacceptable, the bids at the time of bid opening were not considered to be non-responsive. The Comptroller General has held that a completed SF 24 is proper 'on its face' when it has been duly executed by two individual sureties (whose affidavits indicate that, subject to further investigation, they both have net worths at least equal to the penal amount of the bond), and the completed SF 24 contains no obvious facial defects, such as the omission of the penal amount, or the markup or alteration of the bond without evidence of surety approval.[27]

Rather, the individual sureties were determined to be unacceptable as a matter of responsibility, since the accuracy of information concerning a sureties' financial condition is a matter of responsibility.[28] It is within the broad discretion of the Contracting Officer to decide what specific financial qualifications to consider in determining responsibility.[29] When, as a result of an investigation, there are serious doubts raised in the mind of the Contracting Officer concerning the sureties' financial resources and there is reason to question the business integrity and credibility of the proposed individual sureties, the Comptroller General has held that given that the purpose of the bonding requirement is to provide the Government with a financial guarantee, we think it is clear that such information, which diminishes the likelihood that this guarantee will be enforceable, may be considered by the agency in determining the sureties' acceptability.[30] Where there is sufficient information to legitimately cast doubt on the integrity of the sureties, the Contracting Officer can justify a reasonable basis to question the accuracy of the financial representations and make a determination of non-responsiblity.[31]

It is quite well established that, in making a determination regarding responsibility, the Contracting Officer is vested with a wide degree of discretion and business judgment and that decision will not be altered absent a strong showing by the protester that there was bad faith by the procuring agency or that there was no reasonable basis for the determination.[31] Contracting officials are presumed to act in good faith and there must be convincing proof that the agency had a malicious and specific intent to harm the protester to establish otherwise.[32]

Often times an individual surety will offer to pledge assets that are not solely owned by the individual. In cases where an individual surety is one of several partners in a particular asset and cannot legally pledge the asset, an agency may reasonably not consider the value of that asset in determining the surety's net worth.[33]

Although a Contracting Officer may contact an individual surety to obtain additional information concerning listed assets and liabilities, there is no legal requirement for the Contracting Officer to make repeated contacts with the individual surety to verify information, particularly where additional contacts will not help to remove the doubt surrounding the veracity of the proposed surety's statement of assets and liabilities.[34]

There are times when time is critical for award of a contract, and in such cases an agency is not required to delay award indefinitely while a bidder attempts to cure a responsibility problem.[35]

New rules regarding the acceptability of individual sureties for all types of bonds, except position schedule bonds went into effect on February 26, 1990. The new rules are much more comprehensive than the former rule, and cover such subjects as acceptability of individual sureties, security interests by an individual surety, acceptability of assets, acceptance of real property, substitution of assets, release of lien, and exclusion of individual sureties.[36] Since the new rules went into effect, the number of individual surety bonds submitted to KCD in response to IFBs and RFPs has decreased significantly.

It is now appropriate to discuss statistical data, and the perceptions of the contracting industry and surety industry concerning bonding. The information on these subjects was developed by the U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources, in a study of contracting problems related to surety bonding in the hazardous and toxic waste clean-up program ("Corps Study").[37] The Corps Study included an analysis of 24 Superfund contracts awarded by the Kansas City and Omaha Districts during the years 1987 thru 1989.

The study demonstrated that the ratio of award amount to government estimate rose from .8 to 1.2. In addition, the ratio of award amount to government estimate tended to increase with the size of the project. The type of remedy that was utilized also affected the award/estimate ratio. Award ratios of 1.3 were observed for the waste containment projects, on the average, as opposed to .85 on the other extreme for alternative water supply projects. The remainder of the projects were around the 1.0 area. The conclusion drawn from this information is that there is a tendency for large projects to run at a higher ratio of award/estimate.[38]

An analysis of the contract data indicated that out of the 24 projects, four contracts involved situations where the apparent low bidder was not awarded the contract due to an inability to secure bonding. These four contracts totaled approximately $31 million. $3.9 million in additional costs were incurred because of the necessity to utilize the next low bidder. This was an average of a 14% increase in costs for the four contracts. The ratio of high bids to low bids has been found to drop from around 2 to 1 in 1987 to 1.3 to 1 in 1989. The range of bids also tends to decrease with the size of the project. The high-low bid ratio also varies by the type of project. The collection and disposal of waste products has a large variation in the ratio of the bids while the waste containment, innovative technology projects and alternative water supply products have high-low bid ratios of around 1.2.[39]

To determine if the bonding issues had contributed to any reduction in the competition for Superfund projects, the bids for the 24 projects were examined. The number of bids decreased from 6.2 on the average in early 1987 to 4.6 in late 1989. The number of bids also tended to lessen somewhat as the size of the project increased. The latter phenomena is also experienced on all large construction projects. The type of project also influences the number of bids received. Waste containment projects received the most bids, followed by alternative water supply and soil waste water treatment projects. The least number of bids was received on the innovative technology projects. These projects received an average of only two bids.[40]

There is considerable variation in the distribution of contracts among HTW contractors. In the Kansas City District, about 400 firms are on the bidders' mailing list for all construction, including HTW contracts. In 1987 through January 1990, 24 contractors competed in the HTW program, and 14 were awarded contracts. Five contractors, individually or in partnership, have received 78% of the HTW contract dollars. Five of the 14 firms obtained approximately 58% of all the projects. The firms receiving awards are, for the most part, large firms with experience in waste handling in general.[40]

There have not been any Superfund projects that could not be placed under contract due to the unavailability of bonding. The study showed, however, that corporate surety participation is confined to a few companies. Six surety firms bonded 83% of the total Superfund project dollars, and 71% of the projects were bonded by five surety firms.[41]

The perception of the problem in the contracting and surety firm sector was also studied by the Corps. From the point of view of the contracting industry, a major problem in the HTW program is that many contractors competing for contracts are unable to obtain the required surety performance bonds for construction contracts. Some contractors are unable to secure bonds due to the surety's perception of liability risk at HTW projects and some contractors have exhausted their bonding capacity. Contracting firms maintain close contact with the surety industry and routinely seek information relative to bond availability. They are aware of the surety industry's stated reasons for not providing surety bonds. However, contractors assert that corporate surety decisions on providing bonding are not uniform. Consequently, bonding may be provided in some instances based on the surety's relationship to the contractor rather than on purely objective standards. Remedial action contractor (RAC) associations point out that there are many firms that are interested in participating in the HTW cleanup program, however, only a few are consistently able to meet the bonding requirements necessary to continually compete for contracts. Some companies stated that they did not even participate in bidding on HTW projects for reasons of liability and the inability to obtain performance surety bonds in the HTW area.[42]

The RAC associations stated to the Corps Study group that the number of contractors bidding on HTW treatment projects is fewer than those bidding on non-hazardous and toxic waste projects, in part due to the bonding problem. One contracting firm pointed out that the HTW program is comparatively small in relation to the entire engineering and construction industry activity in this country. Many firms reported that they have elected not to participate in the HTW cleanup program when they experienced difficulties in securing bonds or anticipated complications in that area. Contractors perceive that the problems in contracting in the HTW area to some extent are due to the Government's use of contracting procedures developed for non-HTW construction and service contracting. HTW work involves a perceived increase in the possibility of liability in excess of traditional construction projects. There is also a strong perception in the surety and insurance industry that the odds of incurring liability given recent asbestos litigation are much greater than before. Contracting firms felt that the laws, regulations, standard Government procurement forms and procedures on HTW contracting efforts were not totally appropriate.[43]

The experience of the Omaha and Kansas City Corps Districts disclosed that there was a small number of bids received on several HTW projects. According to several HTW organizations interviewed, including the Hazardous Waste Action Coalition, Environmental Business Association, Associated General Contractors, National Solid Waste Management Association and the Remedial Contractors Institute, the key factor contributing to lower competition for some HTW projects is the inability of many contractors to secure bonding. Despite a proven history of competence in doing such work, strong finances, assets and profitability and sound leadership and experience in the firm, the Corps Study reports that the resulting shortage of qualified firms that are able to consistently arrange surety bonding may be reflected in higher costs to the government. A restriction on competition, with only four or five final bidders in many cases, may have resulted in higher contract bids than would otherwise be expected. Several contractors stated that they do not have the extensive financial equity necessary to satisfy corporate sureties and secure surety bonds.[44]

The Corps Study group was told, by those surety bond firms that were interviewed, that their concerns are summarized in a document entitled "Hazardous Wastes and the Surety.[45] The sureties believe that design of any sort is not traditionally a surety bond activity. Bonding companies perceive that the risk of bonding design elements of HTW cleanup is even more substantial than what is faced on normal construction projects. This stems from the view that the actual knowledge and experience in the area is limited. Designs may become obsolete very quickly as changes in the HTW processes evolve and generally there is considerable difference of opinion among technical experts on design adequacy. Performance bonds are normally used in construction contracts. In such instances, the design is fixed and technical interpretations are more uniform. However, where design elements and construction are combined in the same contract, bonding problems may arise due to the increased risk to the surety associated with the unknowns on HTW project designs.[45]

Surety firms have stated that the present unfavorable legal environment, with widespread litigation and large awards, has made insurance companies very cautious about insuring HTW projects. Although vocal in their assertions that they not be treated as a substitute for insurance, they fear that by bonding such work they may in the future be sought out based on a legal theory which would treat them as if they were insurance. The cause for liability, such as the appearance of a disease 20 or more years after exposure to toxic substances, leads to a very uncertain situation for sureties. According to the surety firms interviewed, toxic tort litigation features are an important reason for their present reluctance to participate in the HTW cleanup field. In the toxic tort arena a very long time period (10 or 20 years) between exposure and development of injury is typical. Unlike other prototypical injury situations, toxic liability involves long time periods between the alleged exposure and the discovery of damages.[46]

There is a concern by surety firms that they will be targeted by third party liability plaintiffs in the event other parties whose actions may have caused the injury are judgment proof. The lack of sufficient insurance or indemnification for the HTW remedial action contractor leads some bond underwriters to be concerned that the corporate surety based on its providing a surety performance bond may be adjudicated to fill the insurance void so that the third party's injury can be compensated. They worry that, after insurance coverage has lapsed or expired, and perhaps after decades have passed, the corporate surety firm which provided the bond may be looked upon by the courts as the insurer of last resort or a "deep pocket." This unknown risk has led some corporate sureties to forego involvement in the HTW market. Surety bond producers that have made such a decision indicate that they would be more likely to participate in the market if the applicability of SARA indemnification to the surety was clarified. Moreover, that the performance surety bond be clearly represented as being intended by the Government solely as a guarantee of performance by the contractor and not in any way as protection for contractor caused injuries to third parties.[47]

"Indemnification" is an agreement whereby one party agrees to reimburse a second party for losses (in this case liability losses) suffered by the second party. A recent development in the area of Indemnification of Superfund contractors may serve to alleviate some of the concerns that sureties may have in providing performance bonds for Superfund contracts. This development is in the form of an amendment to the Superfund Amendments and Reauthorization Act of 1986 ("SARA"). The amendment adds to the definition of a response action contractor, any surety who after October 16, 1990 and before January 1, 1993 provides a bid, performance, or payment bond to a response action contractor, and begins activities to meet its obligations under such bond.[48] Also contained in the new legislation is the following language:[48]

> (g) Surety Bonds --
>
> (1) If under the Miller Act, 40 U.S.C. sections 270a-270f, surety bonds are required for any direct Federal procurement of any response action contract, they shall be issued in accordance with 40 U.S.C. sections 270a-270d.
>
> (2) If under applicable Federal law surety bonds are required for any direct Federal procurement of any response action contract, no right of action shall accrue on the performance bond issued on such response action

contract to or for the use of any person other than the obligee named in the bond.

(3) If under applicable Federal law surety bonds are required for any direct Federal procurement of any response action contract, unless otherwise provided for by the procuring agency in the bond, in the event of a default, the surety's liability on a performance bond shall be only for the cost of completion of the contract work in accordance with the plans and specifications less the balance of funds remaining to be paid under the contract, up to the penal sum of the bond. The surety shall in no event be liable on bonds to indemnify or compensate the obligee for loss or liability arising from personal injury or property damage whether or not caused by a breach of the bonded contract.

Although the newest version of the indemnification clause does not provide any specific reference to the availability of indemnification for sureties, the term "response action contractor" is being read in some quarters to encompass sureties that begin activities to meet obligations under their bond guarantees.[49]

CONCLUSION

It appears that, in some cases, contractors are having difficulty obtaining surety bonds for Superfund projects. It also appears that surety firms are not overly enthusiastic about issuing bonds for this type of work. On the other hand, sureties have been willing to issue, and contractors have been able to obtain bonds for Superfund work, and as a result there has not been a significant adverse impact on the Corps Superfund contracting program. It may be that part of the problem that some contractors have experienced in obtaining surety bonds is due to their inability to meet the criteria for financial capability and experience which surety firms require for issuance of a surety bond. In other cases the Contractor can meet the surety's financial and experience requirements, but cannot obtain the necessary bonding because the contractor has reached the limit of its bonding capacity with the surety. With respect to the apprehension of the surety industry that issuance of a bond may expose the surety to a type of liability that is not intended, by the surety, to be covered by the bond, the bonding problem discussed herein may, at least in part, be reduced if the surety industry is satisfied that the recent Superfund indemnification amendment will provide the surety with a greater degree of protection against potential liability under the bond.

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DISCLAIMER

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NOTICE:

The remedy-specific schedules are generic in nature and have been developed with the objective of demonstrating management approaches to reducing the overall remedial design duration. They present reasonable approximations of the interrelationships of those activities required to successfully complete a remedial design. The schedules and LOE estimates are intended for training purposes only and should not be used to develop site-specific schedules. The schedules and LOE estimates used by the party contracting for design must reflect their own experience with similar projects.

1.0 INTRODUCTION

The purpose of this paper is to present the results of a study conducted to quantify the Remedial Design (RD) phase of the remediation of a Superfund site.

The purpose of the study is two-fold.

1) Produce remedy-specific generic schedules to be used as tools to assist all parties involved in the development of Remedial Design (RD) schedules;

2) Provide insight, via use of the RD generic schedules, to schedule optimization and schedule maintenance; and resource load the generic schedules to provide additional guidance to those tasked with planning, producing, or managing RDs.

1.1 Background

Successful management of a remedial design depends on the performance of responsible and qualified architectural or engineering (A/E) firms, the maintenance of schedules and budgets, and the rapid resolution of problems. Techniques for establishing good design management include requirements that a schedule be agreed to between the contracting party and the designer, that the schedule be reviewed and updated monthly, and that enforcement of the schedule by the contracting party be maintained. Of course, the schedule must be reasonable, must establish obtainable goals, must contain sufficient detail to permit task control, and must be based upon a complete scope of work.

There are many reasons for maintenance of a schedule. The schedule is a tool used to discuss the design contract between the contracting parties and is also the principal tool for exacting control of contract progress. The schedule also is the basic documentary and analytical tool for negotiation and settlement of requests for equitable adjustments, claims and disputes as well as for contract termination and closeout.

The contracting party has the exclusive responsibility of schedule enforcement, of explicit approval or rejection of the schedule and of imposing sanctions for non-compliance. The control of the schedule is the exclusive responsibility of the designer who also has responsibility for handling unforeseen conditions and interface impacts. Schedule revisions may be requested by either party; however, revisions to the schedule are approved by the contracting party.

The remedy-specific RD schedules discussed herein are generic in nature and have been developed with the objective of reducing the overall remedial design duration. They present reasonable approximations of the durations and interrelations for those activities required to successfully complete a remedial design.

The generic schedules should be used as a guide during development of site-specific schedules.

It is hoped that the judicious use of generic design management schedules will result in a successful project. The hallmark of a successful design project includes a design resulting in a remedy consistent with the Record of Decision (ROD), a design that is completed on time, and a design that is completed within budget. Of course, the ultimate goal of a design project is the initiation and successful completion of Remedial Actions.

2.0 APPROACH

The approach used to develop the generic RD schedules consisted of the following steps:

- Develop a single, generic RD schedule using a commercially available, computer-based, scheduling software package and the Standard RD Tasks as a starting point.

- Canvass the ROD summary documents to identify the universe of technologies being considered for site remediation.

- Develop a series of remedy-specific, generic RD schedules via brainstorming with a multidisciplinary team of scientists and engineers with experience in engineering design and construction, cost and scheduling, and remedial technologies.

- Resource load (Level of Effort only) the generic RD schedules using the RD experience gained in the Superfund program and the RD experience of senior engineers and scientists.

2.1 Scheduling System

Scheduling is the detailed listing of activities that must be performed to reach defined organizational objectives. In any contracting arrangement, scheduling is necessary and may range from a simple agreement to deliver a product on a specified date to an intricate, multi-activity schedule requiring detailed integration of activities and resources.

Scheduling serves several purposes. It provides the framework for discussing any aspect of the contract. It is a principal tool for monitoring progress and is a prime consideration in negotiating a contract. And, as stated earlier, it is the benchmark against which negotiation and settlement of contract adjustments, claims, and disputes are conducted.

Several types of scheduling systems are available. These include milestone charts and bar charts which depict the activities to be scheduled verses time. These schedules do not provide information about the interrelationships of tasks to be performed. To develop this interrelationship requires a network analysis approach such as the Critical Path Method (CPM).

CPM is a network of project activities showing both estimates of time necessary to complete each activity within the project and the sequential relationship between activities that must be followed to complete the project.

The overall duration of the project is controlled by the critical path through the overall schedule. The critical path is the sequence of activities requiring the longest period of time to complete. This path is called the critical path because a delay in the time required to complete this sequence results in a delay for the completion of the entire project.

The computerized scheduling systems selected for this project are OPEN PLAN and PRIMAVERA, both microcomputer-based, commercially available software packages.

2.2 Standard Remedial Design Tasks

Design is a scheme in which means to an end are laid down in an arrangement such that the elements create a work of art, a machine, or other man-made structure. The design for a remedial action must be consistent with the ROD, comply with Superfund program policies and procedures, minimize change orders, and prevent construction contractor claims.

Listed in Table 2-1 are 11 standard tasks that may be used in A/E agreements for RD services. The tasks are intended to provide a consistent method of reporting design work. While some variations are anticipated because of the variety of design projects and differences among the A/E firms providing services for remedial design, the standard tasks should be used and reporting formats should be designed to be consistent with this set of standard RD tasks.

For Federal-lead design, tasks 5, 6, and 7 contain those activities which may be considered properly chargeable to design as set forth in the Federal Acquisition Regulations at 48 CFR 15.903(d)(1)(ii). The regulation limits the total cumulative contract price for design services to 6% of the estimated construction costs.

Some specific comments applicable to all standard RD tasks include:

- All standard tasks need not be used for every A/E agreement. Use only those relevant to a specific design.

- Flexibility is provided for reporting work associated with the design tasks. For some A/E agreements, all of the design work effort may be reported within only two tasks (preliminary and prefinal/final design). In other A/E agreements, the size of the project may be such that the use of two or more sets of design tasks may be appropriate.

For example, if the project involves major construction items such as buildings, and also the design of groundwater collection systems, it may be appropriate to have one set of design tasks for the construction work and one set for the groundwater collection system. In addition, the site may have one or more operable units, which would require the use of several sets of design tasks.

- Services anticipated during the preliminary design (30% complete), intermediate design (60% complete), and prefinal/final design (90% to 100% complete) will depend upon the Work Plan for the A/E agreement.

- Depending on the magnitude of the A/E agreement, the number of documents to be submitted at the designated completion points of design may vary. Also, depending on the size, complexity, and timing of the specific design effort, there may not be a need for all three phases of design. Under these circumstances, communication between the contracting party and the A/E is required to assure acceptable work products.

The Standard Remedial Design Tasks are briefly described below:

TASK 1 - PROJECT PLANNING

This task includes work efforts related to the initiation of a design project after the A/E agreement is executed. The Project Planning Task is complete when the Work Plan is approved by the contracting party. For purposes of transferring necessary data, this task also includes coordination between the firm that conducted the remedial investigation/feasibility study (RI/FS) and the lead design firm. In addition, initial value engineering (VE) screening will be performed on all projects to identify high-cost, non-industry standard items and unusual design criteria.

TASK 2 - FIELD DATA ACQUISITION/SAMPLE ANALYSIS

This task consists of the effort required to obtain field samples and information needed to support the design effort that was not produced during the RI/FS. It also includes the analysis and validation of analytic results. This task begins when any element authorizing field work, as outlined in the Work Plan, is approved and may end when data validation is complete.

TASK 3 - TREATABILITY STUDIES

This task includes efforts related to conducting pilot and bench scale treatability studies during the RD. Specification and procurement of study contractors, sampling, analytical testing, data acquisition and validation, and reporting efforts associated with these tests are included.

TASK 4 - DATA EVALUATION

This task includes efforts related to the organization and evaluation of data that will be used later in the design effort. It is anticipated that this effort will use both existing data and data collected and verified in Tasks 2 and 3. The data evaluation task usually begins on the day when validated data are received by the designer and ends when it is decided that no additional data are required.

TASK 5 - PRELIMINARY DESIGN

This task begins with initial design and ends with the completion of approximately 30 percent of the total design. It incorporates work related to the preparation of plans and specifications, unit process and equipment selections, cost estimating and client review.

TASK 6 - INTERMEDIATE DESIGN

This task begins at the completion of the preliminary design phase and ends with the completion of approximately 60 percent of the total design. Depending on the size, complexity, and timing of the design effort, this task may be omitted at the discretion of the contracting party.

TASK 7 - PREFINAL/FINAL DESIGN

The prefinal/final design phase commences at the completion of the intermediate design effort and is finalized when the entire design effort has been completed and approved. Prefinal/final design documents are submitted in two parts.

The prefinal design documents will be at approximately 90 percent completion of design and will incorporate all work efforts related to the preparation of the plans and specifications, schedule and cost estimates, and the final technical reviews.

The final design effort incorporates all work efforts related to the preparation of 100 percent complete plans and specifications, including the resolution of all client comments.

TASK 8 - DESIGN SUPPORT ACTIVITIES

This task consists of design support effort which is conducted during one or all of the three phases of the design. Specific activities are included on the Activity Listing (Table 2-2). These activities include, Design Analysis, which includes the analytical work (calculations and analyses) required to support the preparation of plans and specifications during design. Also included are the initial and final technical reviews (constructibility, biddability, etc.).

TASK 9 - VALUE ENGINEERING (VE) DURING DESIGN

If the initial VE screening conducted during the project planning task identifies a potential cost savings, a VE study will be initiated under this task. Value engineering is a specialized cost control technique which uses a systematic and creative approach to identify and to focus on unnecessarily high cost in a project in order to arrive at a cost saving without sacrificing the reliability or efficiency of the project. This task also includes the cost of design revisions resulting from the VE study. The VE study is performed during the preliminary design phase.

TASK 10 - COMMUNITY RELATIONS

This task incorporates all work efforts related to the preparation and implementation of the community relations plan during the design phase of the project. This task begins at the onset of project planning and may continue up to the completion of the design.

The present draft of the Standard RD Tasks includes TASK 11 - PROJECT COMPLETION AND CLOSEOUT. This task is not considered on the schedules included in this report. Activities within this task, although necessary, do not contribute to the initiation of the Remedial Action activities.

Several post-RD activities are included within the purview of this study. These activities are listed in the Activity Listing (Table 2-2). They are necessary to provide an estimate of the start of onsite Remedial Action activities and reflect the often accepted statement that design is not complete until construction is complete.

2.3 Technology Categories

ROD summaries were perused to identify the variety of alternative technologies being considered to remediate NPL sites. Broad categories identified include:

- Onsite treatment of soils/sludges and surface water
- Onsite containment
- Offsite treatment and/or disposal
- Pump & treat groundwater
- In-situ treatment of groundwater
- Extending or upgrading existing water supplies or providing alternate water supplies

- Excavation and/or demolition
- Onsite storage/disposal
- No action

Brainstorming sessions were held to determine categories of remediation which could be developed into remedy-specific generic RD schedules. The resulting categories consisted of:

- Pumping, treatment, and discharge of ground and surface water and leachate
- Civil Engineering activities
- Onsite thermal destruction
- Treatment of soils and sludges

These categories were further developed, considering simple and complex cases, into the final generic RD schedules.

3.0 RESULTS

3.1 Schedule Components

The initial step in developing a non-remedy specific, generic RD schedule was to produce a comprehensive list of activities that represent the possible sub-elements of each of the RD Standard Tasks as well as some post-RD tasks which are required to initiate the RA (Remedial Action). The tasks and the respective activities that comprise them are presented in Table 2-2. The scope of the specific activities that comprise each major task are generally apparent from their titles.

3.2 Assumptions

The assumptions used in developing the schedules typically apply to all the schedules regardless of the technology applied to remedy the site. These assumptions include:

- A cost-reimbursement, task order type contract, similar to the EPA's REM and ARCS contracts, is used for the Remedial Design.
- A fixed price type contract for construction will be awarded to the lowest, responsive, responsible bidder after the solicitation of sealed bids.
- The Feasibility Study data are sufficient to specify the Bench and Pilot testing.

- The contracting party design reviews are conducted parallel with the continuing design process rather than in series.

- The individual activity durations, for each of the remedy-specific schedules, were selected based on a review of ongoing RD projects and brainstorming discussions with consultant and regulatory personnel knowledgeable of the various cleanup technologies, design requirements, procurement and planning needs.

- The 60 percent design submittal is not required for the "simple" designs.

- Formal Value Engineering is not required for the "simple" designs.

- The pilot-scale equipment is available i.e., long-lead procurement and/or fabrication is not required.

- Laboratory analysis is conducted similar to EPA's DQO (Data Quality Objectives) Level III i.e., full CLP (Contract Laboratory Program) validation is not required.

- Resource requirements do not restrain the duration of an activity.

3.3 Remedy-Specific Schedules

The ROD review activity described in Section 2.0 resulted in the selection of nine characteristic remedial design categories that typified the universe of remedial actions being considered or implemented at Superfund sites. A general definition of the nature of each of the categories was developed along with appropriate assumptions. The required work activities were selected, integrated with time-phased logic, and given appropriate durations by a team of design engineers. The resulting activities, durations and dependencies were then used to generate nine remedy-specific, generic schedules and associated time-phased logic diagrams. Those nine characteristic remedies for which generic schedules were developed and their durations from RD start to 100 percent design approval are shown in Table 3-1.

In the following discussions each of the nine typical or characteristic remedies is described. It should be noted, as previously discussed, that a site-specific design may have a combination of these remedies as the overall project solution. It is assumed, in that case, that each of the component remedies is worked in parallel and that the more complex, time-consuming remedy controls the overall project duration. The major assumptions that were made in developing the schedules are presented and the results are discussed.

1. Civil Engineering - Simple

This design is for a remedial action that involves principally civil engineering design. This simple category will contain such remedies as fencing, groundwater monitoring, and minor earthwork, demolition or removal activities.

Scheduling Assumptions:

- No treatability studies would be required.

- Data gathering activities would include collection of survey, geotechnical, and chemical analytical data.

- The simplicity of the design activity and magnitude of the design effort would allow elimination of the 60 percent intermediate design submittal.

Figure 3-1 presents this generic schedule in bar chart format.

2. Civil Engineering - Complex

As with the simple case this design activity is principally a civil engineering design activity. The complex case may require more extensive date collection or design effort such as a RCRA (Resource Conservation and Recovery Act) cap, extensive or complicated excavation or demolition activities, or the design of other engineered structures.

Scheduling Assumptions:

o The magnitude of data gathering activities is greater so that the durations of sampling and analysis are greater than the simple case.

- A 60 percent design submittal is required.

- Value Engineering is required.

Figure 3-2 presents this generic schedule in bar chart format.

3. Pump & Treat - Simple

This design category is for groundwater withdrawal, treatment and discharge or disposal and surface water/ leachate treatment. The technology categories include physio-chemical and/or biological treatment of liquids. Specific technologies may include: air stripping, carbon adsorption, metals precipitation, ion exchange, multi-media filtration, aerobic and anaerobic biodegradation, evaporation, and distillation. In this simple case the technologies would be proven for the contaminants of concern and would be available in "off the shelf" package treatment units. In addition, the aquifer characteristics would not be complex, and standard pumping systems would be used.

Scheduling Assumptions:

- Bench scale testing without pilot scale treatability tests would be sufficient for design.
- Extensive aquifer testing and collection of chemical analytical data would not be required.
- A 60 percent design submittal would not be required.

Figure 3-3 presents this generic schedule in bar chart format.

4. Pump & Treat - Complex

This pump & treat design category is as described in the Simple Case; however, the aquifer, contaminants, and the pumping and treatment system design effort is a more complex, time consuming effort. Innovative water treatment technologies may be considered.

Scheduling Assumptions:

- The complexity of the aquifer system requires extensive aquifer testing.
- The contaminants present and processes selected require pilot scale testing in addition to bench scale.
- The complexity of the design effort dictates a 60 percent design submittal.

Figure 3-4 presents this generic schedule in bar chart format.

5. Onsite Thermal Destruction

This design category includes, onsite: incineration, pyrolysis or in-situ vitrification.

Scheduling Assumptions:

- Performance type specifications are produced in the design of the thermal destruction unit.
- Detailed design of auxiliary systems (water supply, electricity, fuel, material handling) is required.

- Bench scale treatability and a pilot scale test burn are required. It is assumed that pilot test burns are conducted at an existing facility.

Figure 3-5 presents this generic schedule in bar chart format.

6. Soils/Sludge Treatment - Simple

This design category includes the physical, chemical or biological treatment or volatilization of soils and sludges. All non-thermal destruction of solids would be treated under this category. In this simple case the process chosen would be a well proven technology for the contaminants of concern and for the existing site conditions.

Scheduling Assumptions:

- Bench and pilot scale testing programs would be required, however, they would be of a relatively short duration.
- The simplicity of design activity and magnitude of the design effort would allow elimination of the 60% intermediate design submittal.
- Formal Value Engineering is not required.

Figure 3-6 presents this generic schedule in bar chart format.

7. Soils/Sludge Treatment - Complex

This design category is similar to the simple case; however, as a result of complex contaminants and site conditions, innovative processes requiring extensive testing and development are required.

Scheduling Assumptions:

- The selected process requires extensive bench and pilot scale testing.
- The design magnitude and complexity dictates the submittal of a 60 percent design package.

Figure 3-7 presents this generic schedule in bar chart format.

8. Pump & Treat - Simple (Expedited) and

9. Civil Engineering - Simple (Expedited)

Both of these categories were developed for those sites where the remedial design is simple and straight-forward and where additional data collection is not required. Sites where the scope is limited to minor removal actions or administrative controls would fall into these categories:

Scheduling Assumptions:

- A single contractor performs the RI/FS, the RD, and construction management.
- Additional data collection to support the RD is not required.
- Following not required:
  - Treatability Studies
  - Value Engineering
  - 60 percent design submittal
- Client agreement at pre-design meeting to initiate some aspects of design before approval of the Work Plan.

Figures 3-8 and 3-9 present these generic schedules in bar chart format.

4.0 APPLICATIONS

Several work applications would find the generic RD schedules a beneficial tool. The generic schedules can be used for multiple-site planning by an entity with responsibility for all sites within a geographic region (for example an EPA Regional Office or the USACE Design Office).

This can be accomplished as follows: for a given suite of sites, peruse the ROD to select the appropriate remedy-specific, generic RD schedule. Where more than a single remedial alternative is contemplated for site remediation, the remedy (and generic schedule) with the longest design duration should be selected.

Then, using the generic schedules selected for each site, a master milestone schedule can be produced. Figure 4-1 is an example of a typical milestone schedule. This schedule is anchored by semi-fixed target dates for a specified event (for example, start of construction) for each site. These target dates are typically set by management during overall program planning. The master milestone schedules are used to track progress, identify problem areas, and allocate resources to meet management goals.

A second use for the remedy-specific, general RD schedules is to develop an initial site-specific schedule by those parties responsible for performing the RD or those responsible for managing or overseeing the RD.

The initial step in the application of the generic RD schedules to actual sites is a thorough review of available site information, including RODs, RI/FS reports, and other available data.

This review of site data will permit the selection of the remedy-specific generic schedule appropriate for the site. Where two or more remedy categories are applicable to the site (for example, groundwater treatment and onsite incineration), a base generic schedule is selected. All other factors being equal, the generic schedule of longest overall duration is selected as the base generic schedule, while the remaining applicable schedules ("subsidiary" schedules) are pooled for incorporation into the base generic schedule. The durations of work activities within each of the "subsidiary" schedules are compared to the durations of equivalent activities within the base generic schedule, and the longest duration for each activity "plugged" into the generic schedule for the site. The manipulation of work activities to achieve a site-specific generic schedule is a straightforward task using the scheduling software currently available.

This series of steps results in a conservative, first-cut RD schedule. This generic schedule can be used as a basis to construct a detailed site-specific RD schedule which must satisfy the interrelationships (predecessor-successor) for each activity which, for the more complex sites, involve many engineering disciplines and individual design efforts.

For the party responsible for overseeing the design, the generic schedule can be used as a basis for negotiations with the A/E performing the design. Also, the schedule can be used as a check-off to ensure that all critical elements to the RD are present.

5.0 SCHEDULE OPTIMIZATION

This section presents a discussion of the optimization assumptions used to develop the generic RD schedules and a discussion of schedule maintenance.

Many of the assumptions discussed herein can be centered around two important areas: communication and the sensitivity of activity durations. The identification of all interested parties for a site and early frequent communication among them should identify potential schedule delays and allow sufficient time to resolve problems.

Task activity durations are sensitive to individual site characteristics, the design complexity, and the needs of the owner. Therefore, it is important that site-specific RD schedules be developed that reflect these sensitivities and emphasize the need for communication throughout the progress of the design.

5.1 Generic Schedule Optimization Assumptions and Discussion

Assumption: RD Work Assignment issued coincident with close of the PRP moratorium period.

Discussion: As a fully optimized approach, the generic schedules show the RD Work Assignment issued, and work commencing, one day after the ROD is signed. This schedule can be modified to allow for a moratorium period for negotiations with Potentially Responsible Parties.

To facilitate this approach requires frequent communication, starting early in the planning process, among the owner, the state agency(s), and others with responsibility for producing, reviewing, or managing work. It is critical that all parties recognize the ultimate goal of the Superfund program (cleaning up contaminated sites, identified as such on the NPL) and that planning must go beyond an intermediate goal (e.g., issuing a ROD). Once the effort is made to identify all concerned parties, data can be distributed and discussions held to bring about early agreement on those issues which will comprise the State Cooperative Agreements, Superfund State Contracts, and Interagency Agreements.

The administrative workload that occurs during the RI/FS - RD turnover can be reduce by using a single A/E contractor to perform both assignments, as proposed under ARCS. This approach should lead to a more efficient design and will instill confidence that the cleanup is proceeding with the best mix of technical quality and cost/schedule efficiencies.

Long delays (up to several years) which have occasionally occurred between ROD signing and initiation of RD activities can present additional problems to rapid execution of designs. These delays may cause problems with the reliability of time sensitive data (e.g., contaminant plume location), the availability of personnel with knowledge of past site activities, and the potential lack of consideration in the FS of recently developed technologies. The resolution of these problems often requires extended durations for several RD activities.

Assumption: Tasks required to procure treatability testing and field investigation services, if needed for the RD, are authorized in the Work Assignment as interim tasks.

Discussion: Considerable schedule savings can be realized by initiating the time-consuming procurement process prior to formal Work Plan approval. The key to pursuing this mode of operation is to develop a thorough understanding of the requirements of the Work

Assignment during early activities and to obtain concurrence regarding the selection approach. Specifically, these exceptions can be realized by a thorough data review, by definition of clear, concise and well thought out design criteria, by a pre-design meeting which presents sufficient detail to permit concurrence with the design approach and the type and quality of data needed to initiate the design, and by early input from the Project Delivery Analysis which may affect the design (e.g., performance vs. prescriptive specification).

Assumption: Review/Approval durations are optimum.

Discussion: The durations presented in the generic schedules require that the reviewers have a thorough knowledge of the ROD and owner requirements and that the reviewers have been kept informed throughout the progress of the project. A necessary corollary to this assumption is that the reviewers give prompt attention to the review package.

The review and approval activities within the generic RD schedules are the responsibility of the owner. These activities may be conducted in parallel with other ongoing activities or in series, whereby subsequent activities do not start until the review is completed, comments are resolved and approval to proceed is provided.

Owner-responsible activities used on the generic RD schedules are classified as follows:

Serial Reviews/Approvals and Parallel Reviews
Review Draft RD Work Plan
Approve Final RD Work Plan30% Design Review
Review Community Relations Plan60% Design Review
Approve Community Relations Plan90% Design Review
Review Draft FSAPTechnical Reviews
Approval Final FSAP
Approve Investigation Contracts
Approve Treatability Contracts
Approve 100% Design

It is desirable that the owner provide the coordination role during the review process. The owner should collect the review comments and provide the design with a concise comment package. This method will also allow the owner to screen and respond to comments which need not be passed on to the designer.

The actual durations for review activities for any particular site are a function of the complexity of the site characteristics and of the design, and also of the administrative requirements of the owner and the reviewers. The specific review/approval activities which are the owners responsibility should be clearly and separately identified on the project schedule. This will reinforce the responsibilities of all parties to the contract and provide early knowledge of the consequence of allowing these activities to move onto the Critical Path.

Assumption: All task durations are considered reasonable. The design is correct.

Discussion: The durations of the activities which comprise the various generic schedules were selected based on experience. However, no time was included to compensate for technical or administrative problems which could arise. This lack of schedule contingency is considered appropriate for the presentation of generic schedules in that one does not plan for technical errors or the lack of proper administrative management. Some potential delays can be anticipated, such as a decrease in production due to inclement weather; however, these are site-specific problems and as such should be considered when developing individual, site-specific design schedules.

An additional item which can affect the overall RD schedule is the use of a design which is extremely complex due either to an innovative approach to the remedy or to a multiplicity of operable units. This also should be considered during the preparation of the site-specific schedule by the designer.

For example, the use of innovative technology (as mandated by SARA, the Superfund Amendment and Reauthorization Act) may obviate a quick RD schedule by requiring time consuming treatability studies, including the potential need for long-lead procurement of equipment. Also, a technology that is new, without a record of performance, may cause a conservative reaction among the interested parties, leading to lengthened activity durations (e.g., increased review time).

It is important that early communication be established with all interested parties concerning the overall site schedule and the planned design approach. This communication should prevent potential schedule delays caused by a "change in direction" during the design sequence or by the need for resolution of comments originated by uninformed reviewers.

Assumptions: Reports are not on the Critical Path.

Discussion: The results of bench and pilot scale testing, field data evaluation, and design analysis are communicated to those requiring the information in a timely manner. There are not planned "comment periods" during which work is suspended while a report is undergoing review. Reports provide formal documentation of data and decisions but are not on the critical path.

Assumption: Work Assignment for A/E support during construction is in place prior to approval of 100 percent design.

Discussion: The concept of working to a "total" remediation schedule for a single site (RI through completion of RA) in an efficient manner necessitates the early identification of an A/E firm to provide engineering support to the owner during construction. This will assure that the RA will not be delayed due to lack of engineering support and also permits timely support to the owner for several pre-award activities including conducting the pre-bid conference and evaluation of the RA bidders.

It is incumbent upon the owner to initiate the activities necessary to procure an A/E firm to support the RA task. It is probably most efficient to use the services of the A/E firm performing the design for this effort.

Assumption: Additional time required to incorporate significant design changes as a result of Value Engineering or other technical reviews (Biddability, Constructibility, etc.) is not represented in the generic schedules.

Discussion: The resolution of technical comments should take place within the design cycle of performance/review for the identified submittal stages (30%-60%-90%/100%) with the stipulation that all comments be resolve prior to submittal of the final design package. The impact to the RD schedule of a Value Engineering change is implicit to the VE decision process.

Assumption: Sufficient planning is performed to avoid schedule delays due to lack of adequate funding.

Discussion: Funding estimates are prepared for each phase of a remediation project. As a project matures, additional site data is collected and the work is more clearly focused on the ultimate remedy. This evolutionary process requires that the budget estimate for a site be modified to reflect the evolution of the project. The milestones where the need for revised funding estimates may occur include submittal of Work Plans for the RI/FS or RD, construction cost estimates that are prepared for the various design stages and the construction bid. A significant increase in required funding and the necessary authorization process at any of these milestones has the potential to delay the project.

Although the reallocation of funds to meet the needs of a single site can be difficult, the suggestion presented in this document of early and frequent communication among the interested parties can reduce as much as possible these potential delays.

Other optimizing assumptions will probably come to light as more experience is gained by the industry. Several, assumptions which were not included in developing the generic schedules are discussed below.

Early RD Start: Although there may be programmatic procedural problems with this assumption it is included to illustrate a major overall schedule reduction potential. In this scenario the RD Work Assignment would be issued at approximately the same time as the finalization of the Feasibility Study (FS), allowing the initiation of planning and data gathering activities prior to the ROD signature. The risk of this course of action is a change in the selected remedial alternative resulting from the ROD process. This approach is most applicable for those sites where the selected remedy is unequivocal. Issuing the RD Work Assignment at FS finalization could accelerate the RA start by months.

Performance Specification: Experience is showing that some RD alternatives (such as onsite thermal destruction) are best handled using a performance type specification that allows the use of alternative processes as long as the performance criteria are met. There are two schedule reductions that can result from a performance-based approach.

- **Bench/Pilot Scale Testing** - In a performance-based approach which allows alternative technologies, extensive testing may have limited additional value to the vendor. The vendor in many cases will have sufficient experience and prior operating data on the process to be able to cost the system as long as good waste characterization data are available, thereby eliminating the need for a testing program.

- **Eliminate 60 Percent Design Submittal** - A performance-based procurement will have fewer design drawings and specifications, thereby making the definition of a logical 60 percent design break difficult to conceive.

Contracting Strategies

- When time is of the essence or when innovative, state of the art designs are to be implemented, a site-specific, fixed price type contract should not be used to conduct the remedial design because of the time required to complete this type of procurement and the inflexibility of such a contract.

- If the project delivery analysis reveals that the circumstances are not appropriate to the solicitation of sealed bids for construction, then competitive proposals should be requested and a fixed-price or cost-reimbursement type contract, or combination thereof, should be emplaced. Appropriate circumstances may include, for example, the construction and operation of a remediation technique for which there is no past experience.

6.0 SCHEDULE MAINTENANCE

Several approaches used to optimize Remedial Design schedules were discussed in Section 5.0. It must be emphasized, however, that preparing a schedule will not "make it happen." In order to be successful the schedule must first be "doable." In essence, the work breakdown structure must be in sufficient detail to identify critical work elements, the logic or precedence of activities must be correct, and the duration of each of the individual activities must be sufficient to accomplish the work with the resources available. Once an optimized schedule is agreed to by the RD contractor and the contracting party, maintenance of the schedule is dependent on a number of key elements that become especially critical because of the optimizing assumptions.

Some of the more important areas that are discussed here include:

- Communications
- Project Delivery Analysis
- Basis of Design Report
- Reviews
- RI/FS-RD-RA Transition Planning
- Cost Estimating/Funding

6.1 Communications

In the optimized RD numerous concurrent activities will be occurring with parallel and concurrent review steps. In this mode of operation, with fewer defined "stop and check" points, the greatest danger to schedule maintenance can be having to redo work that has been completed without the concurrence or understanding of the owner. Regular project communications involving the appropriate decision makers or their representatives are necessary to eliminate false starts or misdirected activities. The communications or reporting plan must however, strike a balance between keeping decision makers informed and imposing a paperwork burden.

6.2 Project Delivery Analysis

The Project Delivery Analysis (PDA) is the development of the contracting strategy for the completion of the remedial action and includes:

1) The number and scope of RA Contracts

2) Contract Types

    - Lump Sum
    - Unit Price
    - Cost Reimbursable

3) Contracting Procedures

    - IFB (Invitation for Bids)
    - RFP (Request for Proposal)
    - Pre-qualification

4) Design Approach

- Detailed Design (prescriptive specification)
- Performance Specification

The decision made in the Project Delivery Analysis must be well conceived and involve the decision makers. PDA must be done as part of RD scoping as the decisions made will dictate the scope and complexity of design. It is possible that the delivery approach can not be finalized without additional data and this must be reflected in the schedule.

6.3 Basis of Design Report

The Standard Tasks for Remedial Design make reference to a Basis of Design Report (BODR). The optimized schedule with parallel review tasks will only succeed if there are no surprises. The objective of the BODR, therefore is to document the criteria for design and clearly establish the design decisions upon which subsequent analyses should be based. If the basis of design is firmly established, subsequent design reviews should not reveal the need for significant changes in the design approach with resultant schedule delays.

6.4 Design Reviews

Optimized schedules are predicated on parallel design reviews while subsequent design steps continue. The inherent risk associated with such an approach is the potential for redesign resulting from review. This risk can be minimized in two ways. First, as was discussed previously, if good communications have been established the review should present no surprises to the reviewing authority and there should be no resultant schedule delays. Second, the review procedure can be enhanced both in its timeliness and its thoroughness by using a panel approach similar to that used for Value Engineering. A detailed format needs to be developed for such an approach but in essence it would involve assembling a panel to accomplish a team review, including a design review presentation and resolution of comments, prior to adjourning the panel.

6.5 RI/FS-RD-RA Transition

This RD schedule optimization exercise has emphasized the importance of not allowing the transition between remedial stages result in work stoppages. Major schedule optimization can be accomplished through total project scheduling and overlap of the remedial stages. Many RD standard tasks can start prior to ROD signing and RA planning can start prior to 100% design approval.

6.6 Cost Estimating

One major impediment to schedule maintenance that frequently results in schedule slippage is the identification of costs in excess of program budgets, requiring reallocation of funds. This can occur both in planning and construction and will be even more important when working to an optimized schedule. This potential schedule maintenance problem underscores the importance of cost control and cost estimate updating.

7.0 OPTIMIZATION IMPACT - EXAMPLE SCHEDULES

As part of the RD Schedule Management assignment seven generic schedules were developed for a range of remedial alternatives. Those schedules contained several optimizing assumptions that have been described in Section 5.0. Two expedited schedules were also prepared for simple design assignments, with little or no additional data gathering requirements.

In order to illustrate additional optimization or schedule reduction alternatives, the onsite thermal destruction generic schedule has been further optimized with assumptions that may have application at a specific site. To further illustrate the impact of schedule optimization we have taken that same generic schedule and eliminated virtually all optimizing assumptions in order to demonstrate the overall duration of the non-optimized schedule.

7.1 Fully Optimized Onsite Thermal Destruction

A fully optimized Onsite Thermal Destruction generic schedule has been developed and is presented as Figure 7-1. In addition to the optimizing assumptions that were built into the original schedule, the following four schedule reduction alternatives have been incorporated into this example schedule:

Early RD Start: Although there may be programmatic procedural problems and limitations due to current policy guidance with this assumption, it was incorporated to illustrate a major overall schedule reduction potential. In this scenario the RD Work Assignment would be issued at approximately the same time as the finalization of the FS, allowing the initiation of planning and data gathering activities prior to ROD signature. The risk of this course of action is a change in the selected remedial alternative resulting from the ROD process. This approach is most applicable for those sites where the selected remedy is unequivocal. Issuing the RD Work Assignment at FS finalization could accelerate the RA start by as much as five months. In the fully optimized schedule appended here it reduces that time by 15 weeks.

Performance Specification: Experience is showing that the onsite thermal destruction alternative is likely to be a performance type specification that would allow alternative processes as long as the performance criteria were met. There are two schedule reductions that can result from a performance-based approach.

- Bench/Pilot Scale Testing - In a performance-based approach which allows alternative technologies, extensive testing may have limited additional value to the vendor. The vendor in many cases will have sufficient experience and prior operating data on the process to be able to cost the system with good waste characterization data. Therefore the pilot scale activities have been eliminated from the program. This schedule reduction reduces the bench/pilot scale program by eight weeks and takes this program off the critical path.

- Eliminate 60 percent Design Submittal - A performance-based procurement will have fewer design drawings and specifications, thereby making the definition of a logical 60 percent design break difficult to conceive. Therefore, the 60 percent design submittal is eliminated. In so doing, the overall design time has been reduced without entirely eliminating the time that was included in the 60 percent design step. This schedule reduction reduces the overall schedule by four weeks.

Mobile Laboratory Data: The generic schedule includes laboratory turnaround time as well as Level III validation time. The fully optimized schedule has been reduced by two weeks by placing a mobile laboratory onsite and utilizing Level II data for design purposes.

Summary: The three schedule reduction alternatives described above have reduced the overall schedule (RD start to RA start) by 12 weeks. Assuming that RD can start prior to ROD signing, the ROD to RA start could be reduced by an additional 15 weeks.

7.2 Non-Optimized Schedule

In order to illustrate the schedule impact of eliminating virtually all schedule reduction/optimization approaches incorporated into the generic schedule, a non-optimized schedule has been prepared (Figure 7-2) with the following deviations from the generic schedule:

No Interim Authorization: Only Project Planning and Community Relations Planning is authorized in the RD Work Assignment. No other work proceeds until these plans are approved. This extends the schedule by 11 weeks.

Review Schedule:

- Draft Work Plan Review has been extended to four weeks.
- 30% Design Review is a four-week Serial Review.
- 60% Design Review is a four-week Serial Review.
- 90% Design Review is a six-week Serial Review.
- 100% design approval has been extended to three weeks.

All of these review considerations extend the schedule a total of 17 weeks.

Value Engineering: In the non-optimized schedule VE-driven redesign activity is included, increasing the 60 percent design activity by two weeks.

Summary: The non-optimized Onsite Thermal Destruction Schedule takes 97 weeks from ROD signing to RA start as compared to 67 weeks for the generic schedule and 40 weeks for the fully optimized schedule.

8.0 RESOURCE LOADING OF THE GENERIC RD SCHEDULES

The contractors working on the Superfund Program have considerable experience planning and conducting Remedial Designs for hazardous waste sites. This experience was used to resource load the generic schedules. Two approaches were used. Firstly, a data base was assembled of RDs conducted under the USEPA's REM III Program. These data were categorized by technology. Secondly, a group of engineers, scientists, and managers were assembled to brainstorm specific Level of Effort ranges for each activity in each of the nine generic schedules. These personnel had experience in technical areas pertinent to remedial design, including planning, treatability studies, field data collection, basic engineering design, technologies available to remedy hazardous waste sites, and contracting mechanisms.

8.1 Assumptions

The resource-loading activity was accomplished within pre-defined boundaries so that some reasonable quantification could be achieved. The general assumptions are discussed in this section. Assumptions specific to a particular schedule are discussed in Section 8.2 (Results).

The generic RD schedules previously developed (see Table 3-1) were not modified during the resource-loading exercise. Activity inter-relationships and durations were fixed.

The typical RD assignment was a turnover (intra-company) from an RI/FS work assignment. A cost-reimbursement, task order contract is used for the remedial design.

All review comments will be consolidated by the lead agency (contracting party) and transmitted to the RD contractor in a single package and within the allotted schedule.

A range of job hours is selected for each scheduled activity. A typical RD assignment is expected to fall within this range.

The resource-loading activity is limited to LOE i.e., job hour estimates. No attempt was made to estimate other direct costs or subcontractor costs. These costs however, are identified by category in the summary tables. Also, the program management activity LOE is not included in these estimates. This activity includes cost/schedule control, progress reporting, problem solving, contractual modification justification, subcontractor control, invoicing, and other general management functions required to run task-order contracts. These costs can be estimated as a percent of the total task LOE and may vary depending on factors such as work complexity, the total number of active tasks in the contract and the RD contractors corporate management structure.

8.2 Results

The results of this resource-loading activity are presented in the following subsections.

8.2.1 Remedial Design Experience Matrix

Data were collected from within the USEPA REM III Program to summarize current remedial design experience. Data sources included monthly progress reports, individual RD work assignment work plans, and interviews with site managers.

Many of the RDs were not conducted within the template of the Standard RD Tasks; therefore, a subjective evaluation of each project was completed to correlate the actual project task structure with the Standard RD Tasks. This evaluation relied heavily on the site manager interviews. Project RD LOE experience was used as one source of data during the brainstorming session.

8.2.2 Resource Loading the RD Schedules

The nine remedy-specific generic Remedial Design schedules were resource loaded using a brainstorming technique. Drawing from the REM III Program, corporate, and personal experiences and the activity durations within the generic schedules, the team assigned a range of LOE to each activity in each of the nine schedules. The first schedule addressed was Pump and Treat - Complex as the team experience was greatest in this technology. The LOE ranges for this schedule were used as a template to select appropriate levels of effort for activities in the other eight schedules. Therefore, modifications to an activity LOE among the several schedules was, of necessity, supported by sound technical reasoning. This approach also resulted in some activities having the same LOE range for all generic schedules.

The following paragraphs discuss loading of each of the 9 generic schedules.

<u>Pump and Treat - Complex</u>

Assumptions used to load the activities are presented for each standard task in the following paragraphs.

<u>Task 1 - Project Planning</u>

Three technical experts (civil engineering, hydrogeology, and chemical process engineering) are needed to support the work plan preparations. The contracting party will consolidate comments to maximize efficiency of review and comment resolution efforts.

Task 2 - Field Data Acquisition/Data Analysis

Four technical specifications are required (drilling/well installation, laboratory analytical services, surveying, waste disposal). The field data collection effort is 6 weeks in duration and includes a 2-week pumping test. Twenty samples are analyzed and DQO Level III validation is used.

Task 3 - Treatability Studies

For contracting and evaluation purposes assume three separate innovative technologies are potentially viable treatment options. One contract modification is issued. One person is needed at the site periodically to oversee the pilot test programs.

Task 4 - Data Evaluation and

Task 8 - Design Support Activities

One of the early deliverables from these tasks is the Basis of Design Report. It is estimated that five criteria categories are addressed in this report. They are: site elements (civil) criteria, hydrogeologic criteria, process design criteria, health and safety criteria, and environmental criteria.

It was assumed that six permits would be required including NPDES (National Pollution Discharge Elimination System), air, wetlands, erosion and sedimentation control, and local municipality. The RA contractor will acquire the building and construction permits.

The final technical design reviews (constructibility, biddability, operability, environmental, and claims prevention) are included under this task.

The Operations and Maintenance Manual is, at this stage, a detailed "specification" to guide the contractor. The manual is completed by the RA contractor during start-up operations.

Tasks 5, 6, and 7 - Design

It was determined that ESSENTIALLY there should be no difference in LOE between prescriptive and performance specifications. Most site designs will require both using prescriptive specifications for site-specific requirements such as earthwork, and using performance specifications for many of the innovative technologies which have limited performance histories.

Three design packages are delivered for review: preliminary, intermediate, and pre-final/final.

Task 9 - Value Engineering

The level of effort for VE during design is taken from the USEPA guidance document for performance of VE during remedial design.

Task 10 - Community Relations

This task is essentially an extension of community relations (CR) activities conducted during the pre-design (RI/FS) phase. LOE is typically a function of schedule duration. Activities include revision of an existing CR plan, one public meeting, and continued CR support through the start of construction.

Task 11 - Project Completion and Closeout

Activities and associated LOE required for this task were assumed to be included in "Program Management".

Summary

The total estimated LOE for the Pump and Treat - Complex generic RD schedule is 8,350 to 11,149. With a schedule of 13 months (to approved of 100% design), this loading is equivalent to 4-1/3 - 5-1/2 people full-time.

Pump and Treat - Simple

The Task 2 field data acquisition is set at 6 weeks with 10 samples collected and analyzed. Also, it is assumed that a pumping test is not required. The design tasks LOE is estimated at one-third of the complex design. An intermediate design submitted and formal value engineering are not included in this design. The LOE required to obtain permits and site access is held constant for all cases. Permit requirements are typically tied to very specific data acquisition and reporting formats irrespective of the complexity of the design.

Summary

The total estimated LOE for the Pump and Treat - Simple generic RD schedule is 3372 to 4691. With a schedule of 10 months (to approval of 100 percent design), this loading is equivalent to 2 to 3 people full-time.

Pump and Treat - Simple (Expedited)

The expedited schedule assumes no additional field data collection is required to complete the design. A portable, "off-the-shelf" treatment system will be selected. The treatment system vendor will supply much of the design analysis.

The product of the design tasks will be a package consisting of twenty specifications (civil, chemical, and mechanical) and five drawings (site plan, general arrangement, P&ID (piping & instrumentation diagram), electrical, and a process diagram).

Summary

The total estimated LOE for the Pump and Treat - Simple (Expedited) generic RD schedule is 1,641 to 2,225. With a 4 month schedule (to approval of 100% design), this loading is equivalent to 2-1/2 to 3-1/2 people full-time.

Treatment of Soils and Sludge - Complex

The field data acquisition activities require five specifications. In addition to those identified previously, the services of a geotechnical laboratory are also required.

The average NPL site is 10 acres in area. Assume the field data collection requires 5 weeks and includes the collection of 300 samples, all but 30 are analyzed using an on-site laboratory. Assume that one technology of a very complex nature will be studied under the treatability task.

The design criteria to be considered include civil, process engineering, health and safety, and environmental. The design components were estimated using a large, east coast Superfund project as a template. This project design package included 50 specifications and 33 drawings.

Summary

The total estimated LOE for the Treatment of Soils and Sludge - Complex generic RD schedule is 10,570 to 13,823. With a 17 month schedule (to approval of 100% design), this loading is equivalent to 4 to 5 people full-time.

Treatment of Soils and Sludge - Simple

The site for which this category is considered appropriate is assumed to be one acre in area. Fifty samples are taken during the field investigation of which 10 are sent to an off-site analytical laboratory. Design criteria and design activities are similar to the complex category; however, LOE is considerably reduced due to the reduction in complexity. As with the other "simple" categories, the intermediate design submittal and value engineering are not required.

Summary

The total estimated LOE for the Treatment of Soils and Sludge - Simple generic RD schedule is 4,406 to 5860. With a 9 month schedule (to approval of 100% design), this loading is equivalent to 3 to 4 people full-time.

Civil Engineering - Complex

The model used for this design category was a large, east coast Superfund site which included several activities: soil excavation, water treatment, a slurry wall, and building decontamination. The actual LOE for this site was reduced to "remove" the Pump and Treat aspect from consideration.

Field data collection activities are assumed to be similar to those required in the Soils/Sludge - Complex category. Similar design criteria are also considered. An intermediate design submittal and formal value engineering are included in this category.

Summary

The total estimated LOE for the Civil Engineering - Complex generic RD schedule is 10,420 to 13,605. With a 12 month schedule (to approval of 100% design), this loading is equivalent to 5-3/4 - 7-1/4 people full-time.

Civil Engineering - Simple

The field data acquisition consists of installing 3 shallow monitoring wells and excavating several test pits. Ten samples are analyzed at an off-site laboratory. Four design criteria are considered in developing the Basis of Design (civil, hydrogeologic, environmental, and health and safety).

The design is straight forward with 20 specifications and 5 drawings required for the procurement package. The design reviews are performed by a single person (rather than a team) and the operability review is not performed.

Summary

The total estimated LOE for the Civil Engineering - Simple generic RD schedule is 3,146 to 4,227. With a 9 month schedule (to approval of 100% design), this loading is equivalent to 2-1/4 - 3 people full-time.

Civil Engineering - Simple (Expedited)

In this generic category there are no field data collection activities and no laboratory analysis. The Basis of Design Report is issued during activity 0103 (Define Design Criteria). The design activities are simple and uncomplicated with minimal institutional concerns.

Summary

The total estimated LOE for the Civil Engineering - Simple (Expedited) generic RD schedule is 1,641 to 2210. With a 4 month schedule (to approval of 100% design), this loading is equivalent to 2-1/2 to 3-1/2 people full-time.

On-Site Thermal Destruction

The LOE for a generic design for on-site thermal destruction was estimated by first determining the limiting size of a site which could be remediated under ARCS. A typical unit cost of $750 per cubic yard for incineration is assumed and a programmatic limitation exists of $15 million for Construction under ARCS. Therefore, the maximum excavation permitted is 20,000 cubic yards using ARCS as the contracting mechanism.

An existing Superfund incineration project with a required quantity of excavation reasonably close to this limit was selected as the template for the generic design.

Some water treatment will be necessary for incineration of sludges (treating effluent of the dewatering effort). Treatability studies are required at the bench-scale for the water treatment and at bench and pilot-scales for the material to be incinerated. Five specifications are needed to conduct field data collection activities.

The LOE to support the field data collection activities is assumed to be similar to that required for the Treatment of Soils/Sludge - Simple category. A typical site one Acre in extent and with a required depth of excavation of 10 feet satisfies the area and volume assumptions presented here and under the Soils/Sludge - Simple category.

Four design criteria are considered: civil, process (including also the electro-mechanical criteria), environmental, and health and safety.

The design activities are similar to the complex categories previously described and include formal VE and an intermediate design submittal.

Summary

The total estimated LOE for the On-Site Thermal Destruction generic RD schedule is 9,851 to 12,939. With a 12 month schedule (to approval of 100% design), this loading is equivalent to 5-1/2 - 7 people full-time.

9.0 COST CONSIDERATIONS

The preceeding sections of this report present estimates of level of effort (job hour) requirements for the nine remedy-specific, generic remedial design schedules. An estimate of cost can be developed by determining the distribution of the various professional/technical classifications required and applying the appropriate salary value to calculate the cost of services. However, this is incomplete because the LOE estimates presented herein are for technical production and did not include LOE required for program management services (including cost/schedule control and management reporting). Also, some RDs require a significant expenditure of funds for other direct cost (including subcontracting for field and laboratory data collection). Other direct costs (ODCs) are very site-specific and are not presented in this document.

10.0 CONCLUSIONS (RESOURCE LOADING ACTIVITY)

1. The resource data presented in this report, when combined with the remedy-specific, generic RD schedules, are an excellent tool for:

   - initiating planning for RD work assignments; and

   - use as an aid to review and provide constructive criticism by RPMs to those producing site-specific RD schedules.

2. The user must be aware that the resource reports and graphs, like the generic RD schedules they compliment, are not substitutes for site-specific schedules and budgets developed by individual task managers.

3. All resource estimates presented in this document are based on actual work assignment data and the personal experience of individual engineers, scientists, and managers.

4. All resource estimates are presented within the format of the Standard Remedial Design Tasks.

5. Table 10-1 presents a comparison of LOE for each standard Task for each of the nine generic RD schedules.

11.0 RECOMMENDATIONS FOR USERS

The following recommendations are offered for consideration by users to further enhance the usefulness of the concept of a generic RD schedule.

- The approach presented in this manual should be used by all parties to an RD work assignment. They will then have a common starting point from which project-specific discussions and eventually a site-specific schedule and budget can be developed.

- Develop and implement a schedule tracking system to monitor progress on Remedial Designs at all sites. This system will provide the contracting party with a real-time measure of predicted vs. actual activity relative to the baseline schedule.

- To maximize cost and technical efficiencies and to become aware of and correct possible deficiencies, initiate the technical reviews (biddability, constructibility, environmental, claims prevention, operability) during intermediate design. For similar reasons, a VE screening should be initiated early in the project schedule and a formal VE review, if deemed appropriate, should be conducted during intermediate design.

- For those sites whose RD will be conducted outside the limits of the assumptions presented in this manual, obtain specific information about duration requirements and current practice for procurement, interagency agreements, owner reviews, etc., which may effect the start or overall duration of a Remedial Design.

- For those sites where early RA starts are required to protect the health and safety of the public or for other reasons, the RD/RA schedule can be organized to allow for early RD completion and RA implementation on the simplest operable units first. This would allow earlier RA starts while simultaneously proceeding with design on the more complex operable units.

- For any site, the same A/E firm should be used to conduct the RI/FS, the RD, and the construction management. This project management concept reduces procurement delays, reduces time required for internal quality control, and improves contractor accountability.

- The standard tasks for remedial design services are intended to provide a consistent method of reporting design work. They should be used to the maximum extent possible within the constraints of site-specific or other criteria.

12.0 REFERENCES

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U.S. Environmental Protection Agency, June 19, 1987. Draft Standard Remedial Design Tasks.

U.S. Environmental Protection Agency, September 1986. Superfund Treatment Technologies: A Vendor Inventory, EPA Report No. 540/2-86/004(f).

OPEN PLAN software package, WST Corporation, Houston, Texas.

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TABLE 2-1
STANDARD TASKS FOR REMEDIAL DESIGN (RD)

1. PROJECT PLANNING
2. FIELD DATA ACQUISITION/SAMPLE ANALYSIS
3. TREATABILITY STUDIES
4. DATA EVALUATION
5. PRELIMINARY DESIGN (30% COMPLETE)
6. INTERMEDIATE DESIGN (60% COMPLETE)
7. PREFINAL/FINAL DESIGN (90%/100% COMPLETE)
8. DESIGN SUPPORT ACTIVITIES
9. VALUE ENGINEERING (VE) DURING DESIGN
10. COMMUNITY RELATIONS
11. PROJECT COMPLETION CLOSEOUT

TABLE 2-2
GENERIC SCHEDULE TASKS/ACTIVITIES

TASK 1
<u>PROJECT PLANNING</u>
OBTAIN SITE ACCESS DATA REVIEWS DEFINE DESIGN CRITERIA INITIAL SITE VISIT PRE-DESIGN MEETING PREPARE DRAFT RD WORK PLAN REVIEW DRAFT RD WORK PLAN FINALIZE RD WORK PLAN APPROVE FINAL RD WORK PLAN PREPARE HEALTH & SAFETY PLAN PREPARE DRAFT FIELD SAMPLING & ANALYSIS PLAN REVIEW DRAFT FIELD SAMPLING & ANALYSIS PLAN FINALIZE FIELD SAMPLING & ANALYSIS PLAN APPROVE FINAL FIELD SAMPLING & ANALYSIS PLAN

TASK 2
<u>DATA COLLECTION/SAMPLE ANALYSIS</u>
PREPARE FIELD SAMPLING & ANALYSIS SPECIFICATION REVIEW AND APPROVE SPECIFICATION ISSUE INQUIRY RECEIVE FIELD SAMPLING & ANALYSIS BIDS EVALUATE FIELD SAMPLING & ANALYSIS BIDS APPROVAL/ISSUE CONTRACT FIELD SAMPLING/SURVEYS LAB ANALYSIS DATA VALIDATION

TASK 3
<u>TREATABILITY STUDIES</u>
PREPARE TREATABILITY SPECIFICATION REVIEW & APPROVE TREATABILITY SPECIFICATION ISSUE INQUIRY TREATABILITY SPECIFICATION RECEIVE TREATABILITY BIDS EVALUATE TREATABILITY BIDS APPROVAL/ISSUE TREATABILITY CONTRACT BENCH-SCALE PROGRAM BENCH-SCALE REPORT PILOT-SCALE PROGRAM PILOT-SCALE REPORT

TASK 4
<u>DATA EVALUATION</u>
INITIATE DESIGN CRITERIA EVALUATION

TABLE 2-2 (Cont'd)
GENERIC SCHEDULE TASKS/ACTIVITIES

TASK 5
<u>PRELIMINARY DESIGN</u> PROCESS/EQUIPMENT SELECTION PRELIMINARY DRAWINGS & SPECIFICATION - 30% DESIGN PRELIMINARY SCHEDULE/ESTIMATE - 30% DESIGN PARALLEL REVIEW - 30% DESIGN SERIAL REVIEW - 30% DESIGN

TASK 6
<u>INTERMEDIATE DESIGN</u> PRELIMINARY EQUIPMENT SELECTION DRAWINGS & SPECIFICATION - 60% DESIGN SCHEDULE/ESTIMATE - 60% DESIGN PARALLEL REVIEW - 60% DESIGN SERIAL REVIEW - 60% DESIGN

TASK 7
<u>PRE-FINAL/FINAL DESIGN</u> FINAL EQUIPMENT SELECTION DRAWINGS & SPECIFICATIONS - 90% DESIGN FINAL SCHEDULE/ESTIMATE 90% DESIGN SERIAL REVIEW - 90% DESIGN FINALIZE DRAWINGS & SPECIFICATIONS APPROVAL 100% DESIGN

TASK 8
<u>DESIGN SUPPORT</u> FINALIZE DESIGN CRITERIA PERMITS, APPROVALS & SITE ACCESS SITE SAFETY PLAN SPECIFICATION QUALITY ASSURANCE PROJECT OUTLINE OPERATION & MAINTENANCE MANUAL DESIGN ANALYSIS INITIATE PROJECT DELIVERY ANALYSIS FINAL PROJECT DELIVERY ANALYSIS INITIAL TECHNICAL REVIEWS - 60% DESIGN FINAL TECHNICAL REVIEWS - 60% DESIGN

TASK 9
<u>VALUE ENGINEERING</u> VALUE ENGINEERING STUDY

TABLE 2-2 (Cont'd)
GENERIC SCHEDULE TASKS/ACTIVITIES

TASK 10
COMMUNITY RELATIONS
REVISE COMMUNITY RELATIONS PLAN REVIEW COMMUNITY RELATIONS PLAN FINALIZE COMMUNITY RELATIONS PLAN PUBLIC MEETING RD COMMUNITY RELATIONS PLAN APPROVE COMMUNITY RELATIONS PLAN COMMUNITY RELATIONS SUPPORT

PRE-BID
ROD SIGNING
ROD SIGNED

POST-BID
POST RD ACTIVITIES
PREPARATION OF ARCHITECT/ENGINEER SCOPE ISSUE ARCHITECT/ENGINEER WORK ASSIGNMENT ARCHITECT/ENGINEER SERVICES DURING CONSTRUCTION PRE-SOLICITATION NOTICE ISSUE/RECEIVE BIDS EVALUATE BIDS/AWARD CONTRACT NOTICE TO PROCEED/MOBILIZATION START SITE CLEANUP

TABLE 3-1
DURATIONS: REMEDY-SPECIFIC
GENERIC REMEDIAL DESIGN SCHEDULES

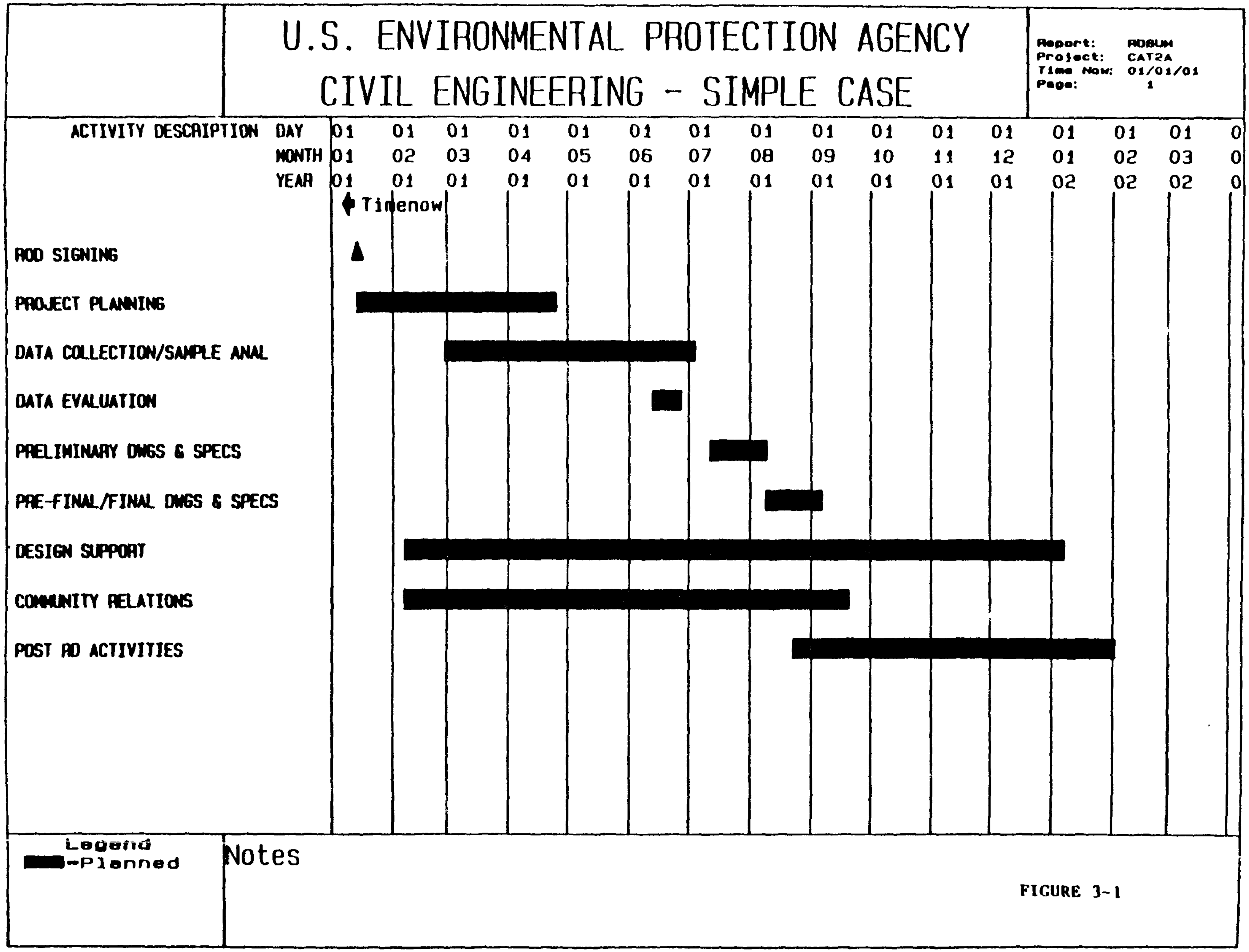
REMEDY	TOTAL DURATION
1. CIVIL ENGINEERING - SIMPLE	9 MONTHS
2. CIVIL ENGINEERING - COMPLEX	12 MONTHS
3. PUMP AND TREAT - SIMPLE	10 MONTHS
4. PUMP AND TREAT - COMPLEX	13 MONTHS
5. ON-SITE THERMAL DESTRUCTION	12 MONTHS
6. SOILS/SLUDGE - SIMPLE	9 MONTHS
7. SOILS/SLUDGE - COMPLEX	17 MONTHS
8. PUMP AND TREAT - SIMPLE (EXPEDITED)	4 MONTHS
9. CIVIL ENGINEERING - SIMPLE (EXPEDITED)	4 MONTHS

TABLE 10-1
LEVEL OF EFFORT VS. STANDARD RD TASKS

TASK	DESCRIPTION	PUMP AND TREAT			CIVIL ENGINEERING			TREATMENT OF SOILS AND SLUDGE		ON-SITE THERMAL DESTRUCTION
		COMPLEX	SIMPLE	EXPEDITED	COMPLEX	SIMPLE	EXPEDITED	COMPLEX	SIMPLE	
1	PROJECT PLANNING	712	592	226	712	592	196	712	592	712
2	FIELD DATA ACQUISITION/ SAMPLE ANALYSIS	1360	492	N/A	1244	585	N/A	1260	710	710
3	TREATABILITY STUDIES	544	176	N/A	N/A	N/A	N/A	404	200	660
4	DATA EVALUATION	240	100	N/A	300	60	N/A	300	176	344
5	PRELIMINARY DESIGN	606	202	456	1028	218	520	1006	320	1038
6	INTERMEDIATE DESIGN	1206	30	N/A	2018	40	8	1908	30	1683
7	PREFINAL/FINAL DESIGN	1716	712	392	2868	811	366	2616	1102	2536
8	DESIGN/SUPPORT ACTIVITIES	1512	834	400	1802	606	382	1712	1042	1768
9	VALUE ENGINEERING	200	N/A	N/A	200	N/A	N/A	200	N/A	200
10	COMMUNITY RELATIONS	250	234	167	250	234	167	250	234	200
11	PROJECT COMPLETION AND CLOSEOUT	A	A	A	A	A	A	A	A	A
	TOTALS	8350	3372	1641	10420	3146	1641	10570	4406	9851

NOTE: A = This task was not evaluated for cost. These activities would normally be included in program management.

1009



U.S. ENVIRONMENTAL PROTECTION AGENCY
CIVIL ENGINEERING - SIMPLE CASE
Report: RDBUM
Project: CAT2A
Time Now: 01/01/01
Page: 1
ACTIVITY DESCRIPTION
DAY 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 0
MONTH 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03 0
YEAR 01 01 01 01 01 01 01 01 01 01 01 01 02 02 02 0
Timenow
ROD SIGNING
PROJECT PLANNING
DATA COLLECTION/SAMPLE ANAL
DATA EVALUATION
PRELIMINARY DWGS & SPECS
PRE-FINAL/FINAL DWGS & SPECS
DESIGN SUPPORT
COMMUNITY RELATIONS
POST RD ACTIVITIES
Legend
-Planned
Notes

FIGURE 3-1

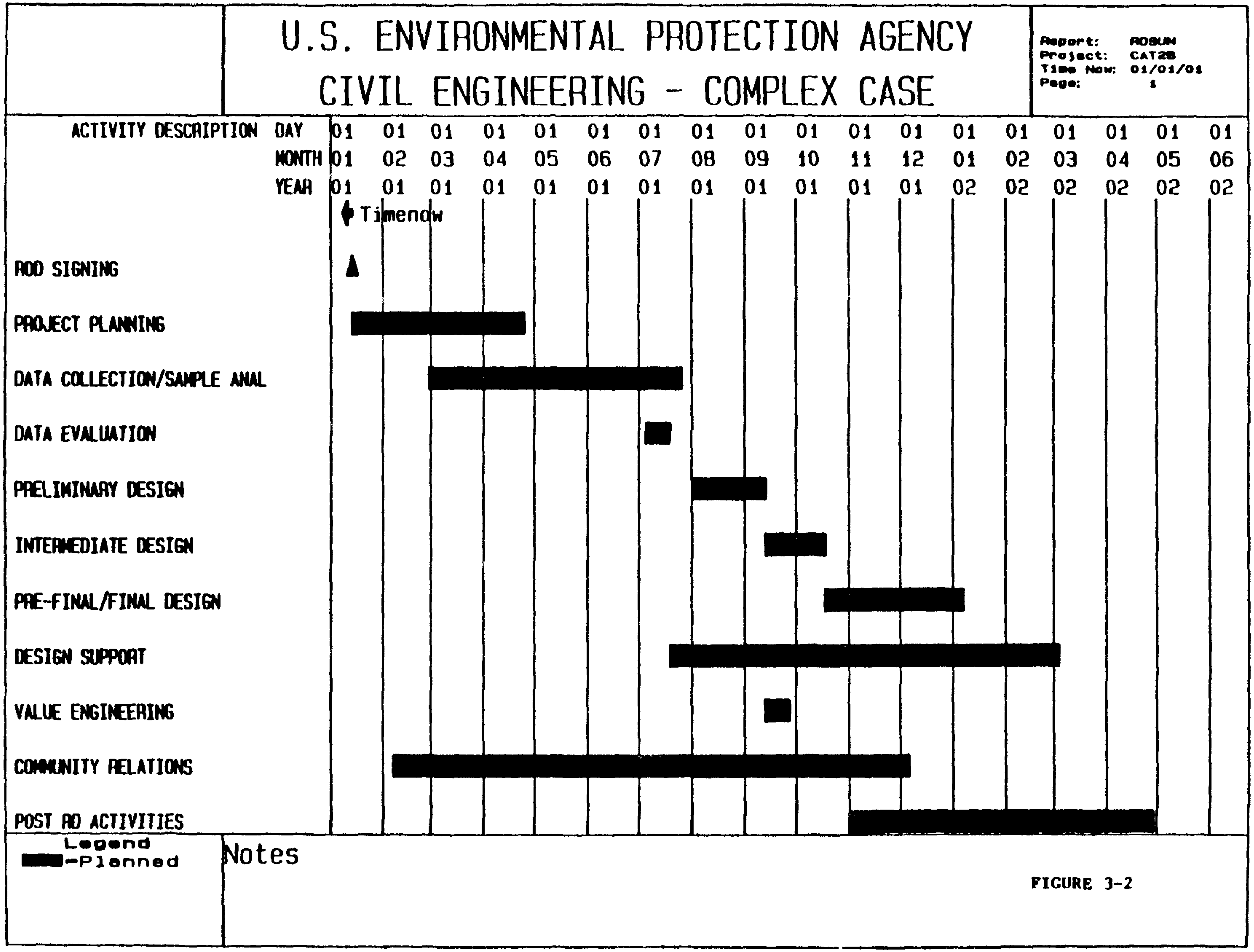

U.S. ENVIRONMENTAL PROTECTION AGENCY
CIVIL ENGINEERING - COMPLEX CASE
Report: RODSUM
Project: CAT2B
Time Now: 01/01/01
Page: 1
ACTIVITY DESCRIPTION
DAY 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
MONTH 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03 04 05 06
YEAR 01 01 01 01 01 01 01 01 01 01 01 01 02 02 02 02 02 02
Timenow
ROD SIGNING
PROJECT PLANNING
DATA COLLECTION/SAMPLE ANAL
DATA EVALUATION
PRELIMINARY DESIGN
INTERMEDIATE DESIGN
PRE-FINAL/FINAL DESIGN
DESIGN SUPPORT
VALUE ENGINEERING
COMMUNITY RELATIONS
POST RD ACTIVITIES
Legend
-Planned
Notes

FIGURE 3-2

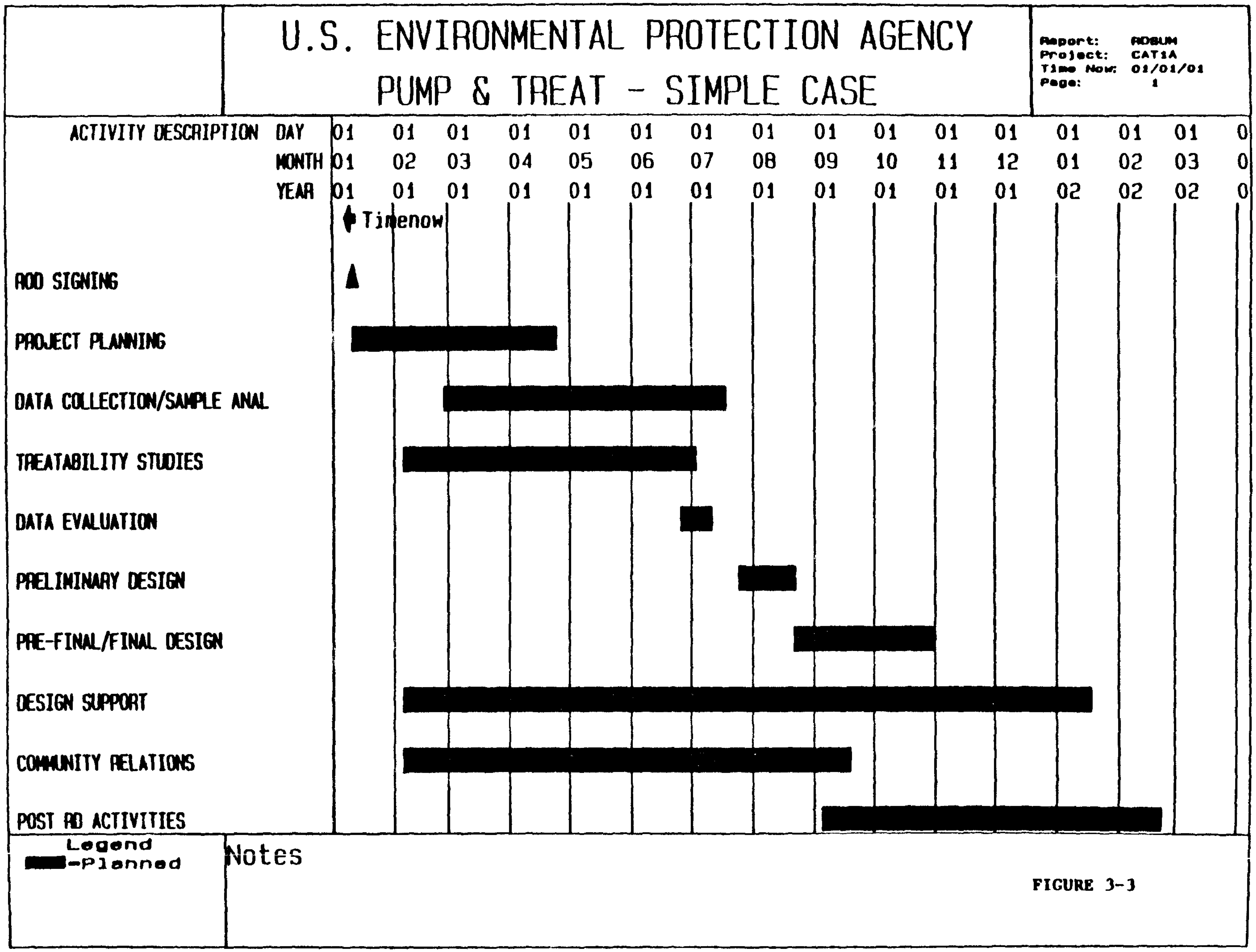
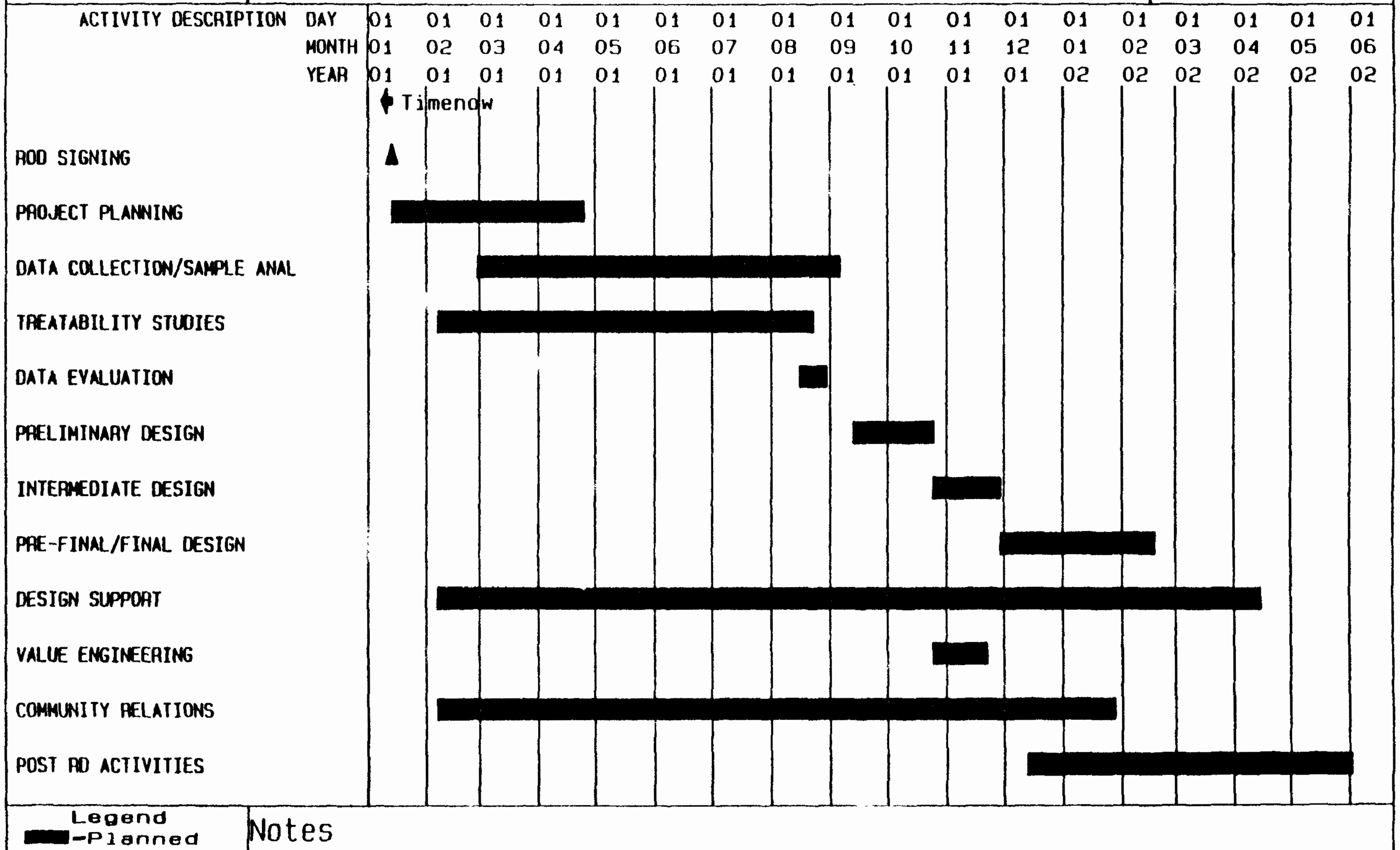


FIGURE 3-3

1012

U.S. ENVIRONMENTAL PROTECTION AGENCY
PUMP & TREAT - COMPLEX CASE

Report: RDSUM
Project: CAT1B
Time Now: 01/01/01
Page: 1



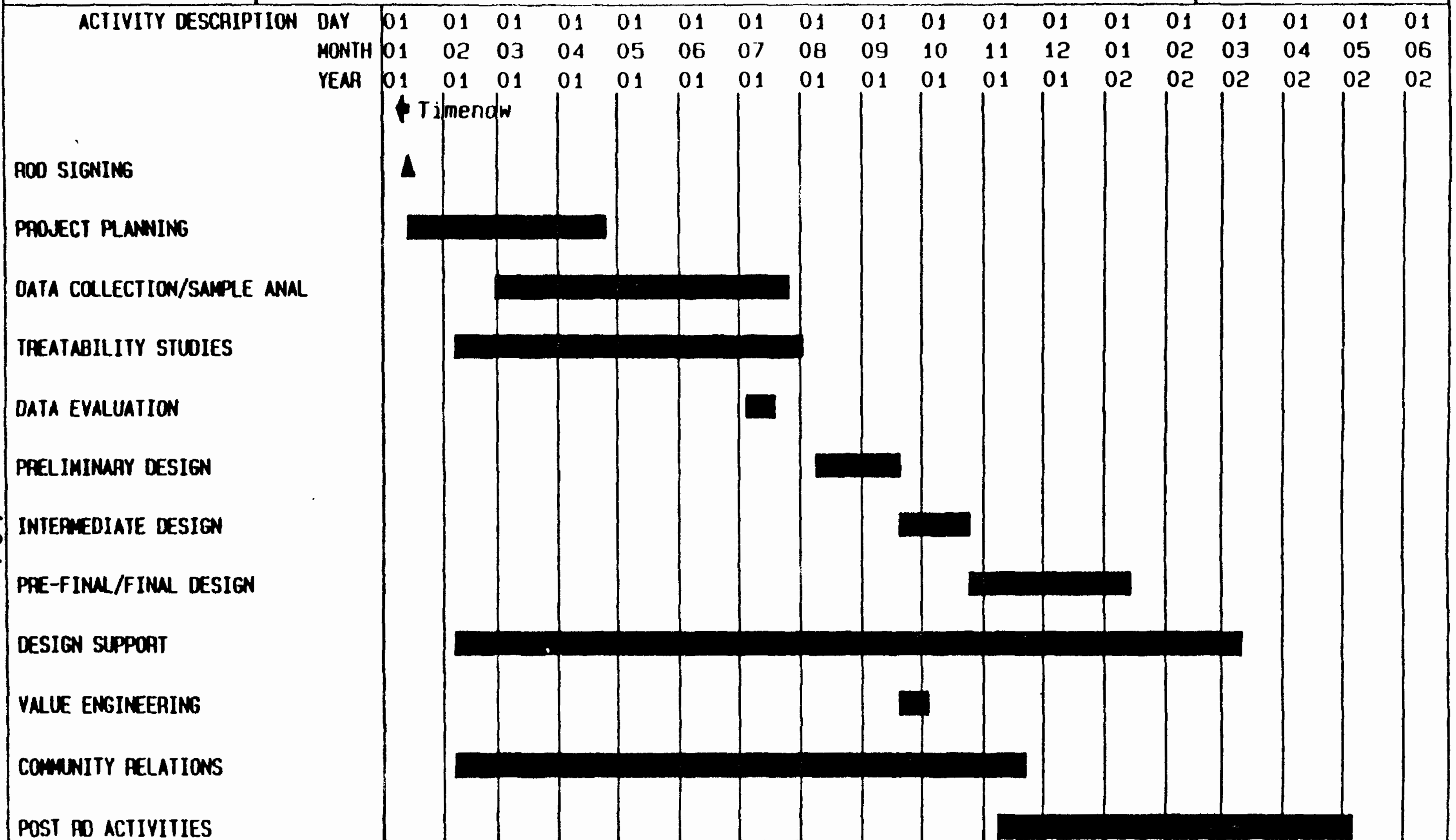
Notes

FIGURE 3-4

1013

U.S. ENVIRONMENTAL PROTECTION AGENCY
ON-SITE THERMAL DESTRUCTION

Report: RDSUM
Project: CAT3
Time Now: 01/01/01
Page: 1



Legend
—Planned

Notes

FIGURE 3-5

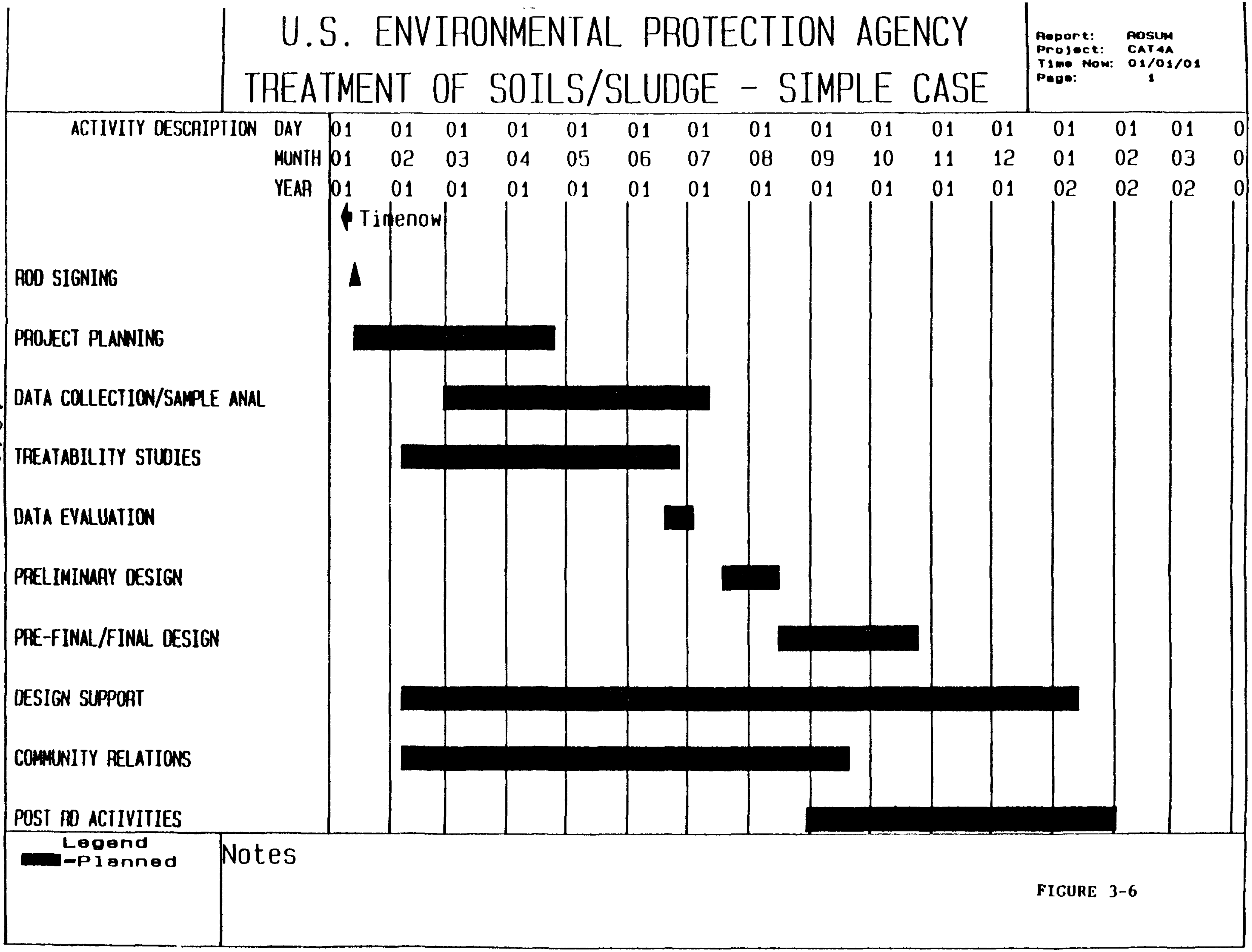

U.S. ENVIRONMENTAL PROTECTION AGENCY
TREATMENT OF SOILS/SLUDGE - SIMPLE CASE
Report: ADSUM
Project: CAT4A
Time Now: 01/01/01
Page: 1
ACTIVITY DESCRIPTION
DAY 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
MONTH 01 02 03 04 05 06 07 08 09 10 11 12 01 02 03
YEAR 01 01 01 01 01 01 01 01 01 01 01 01 02 02 02
Timenow
ROD SIGNING
PROJECT PLANNING
DATA COLLECTION/SAMPLE ANAL
TREATABILITY STUDIES
DATA EVALUATION
PRELIMINARY DESIGN
PRE-FINAL/FINAL DESIGN
DESIGN SUPPORT
COMMUNITY RELATIONS
POST RD ACTIVITIES
Legend
-Planned
Notes

FIGURE 3-6

1016

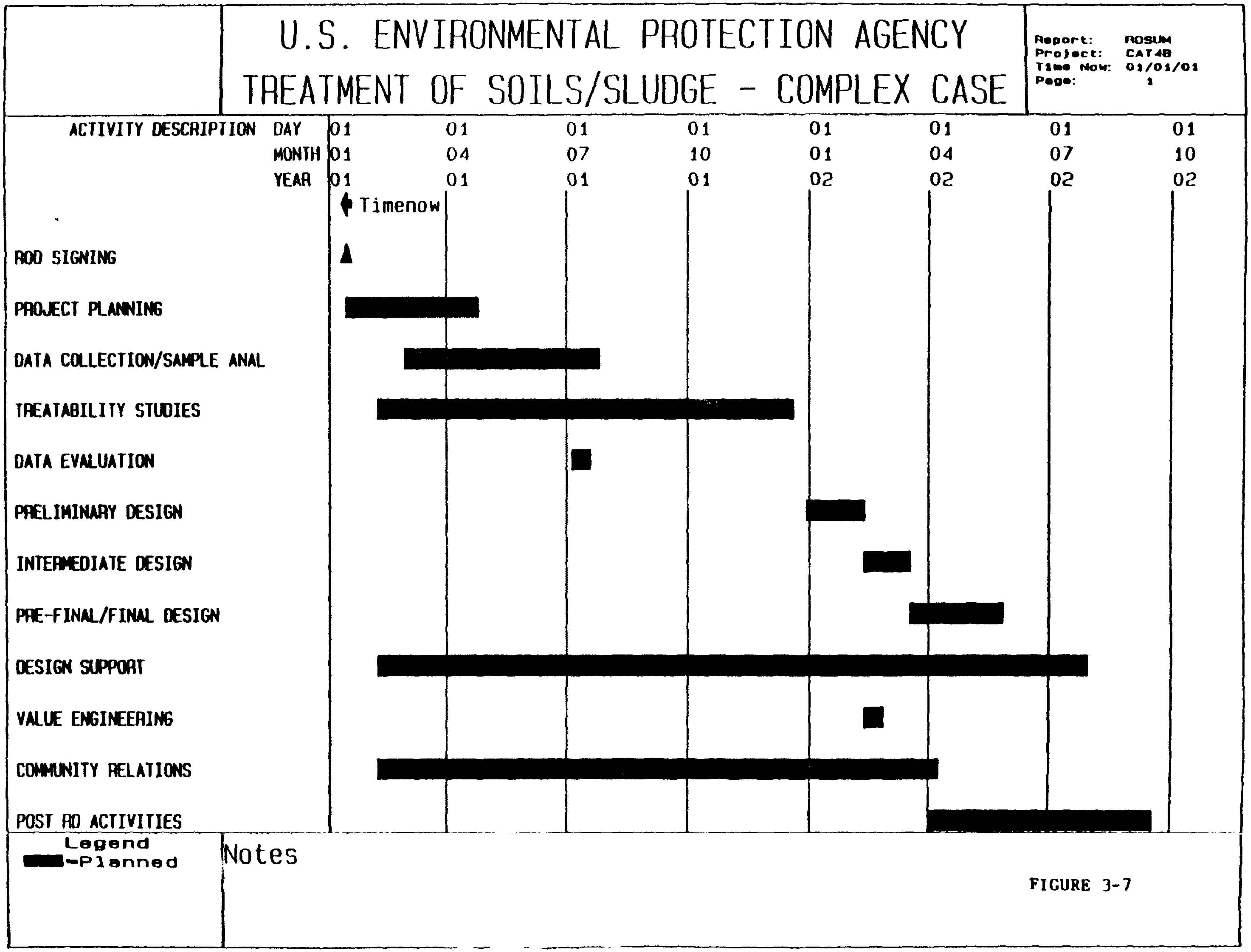


FIGURE 3-7

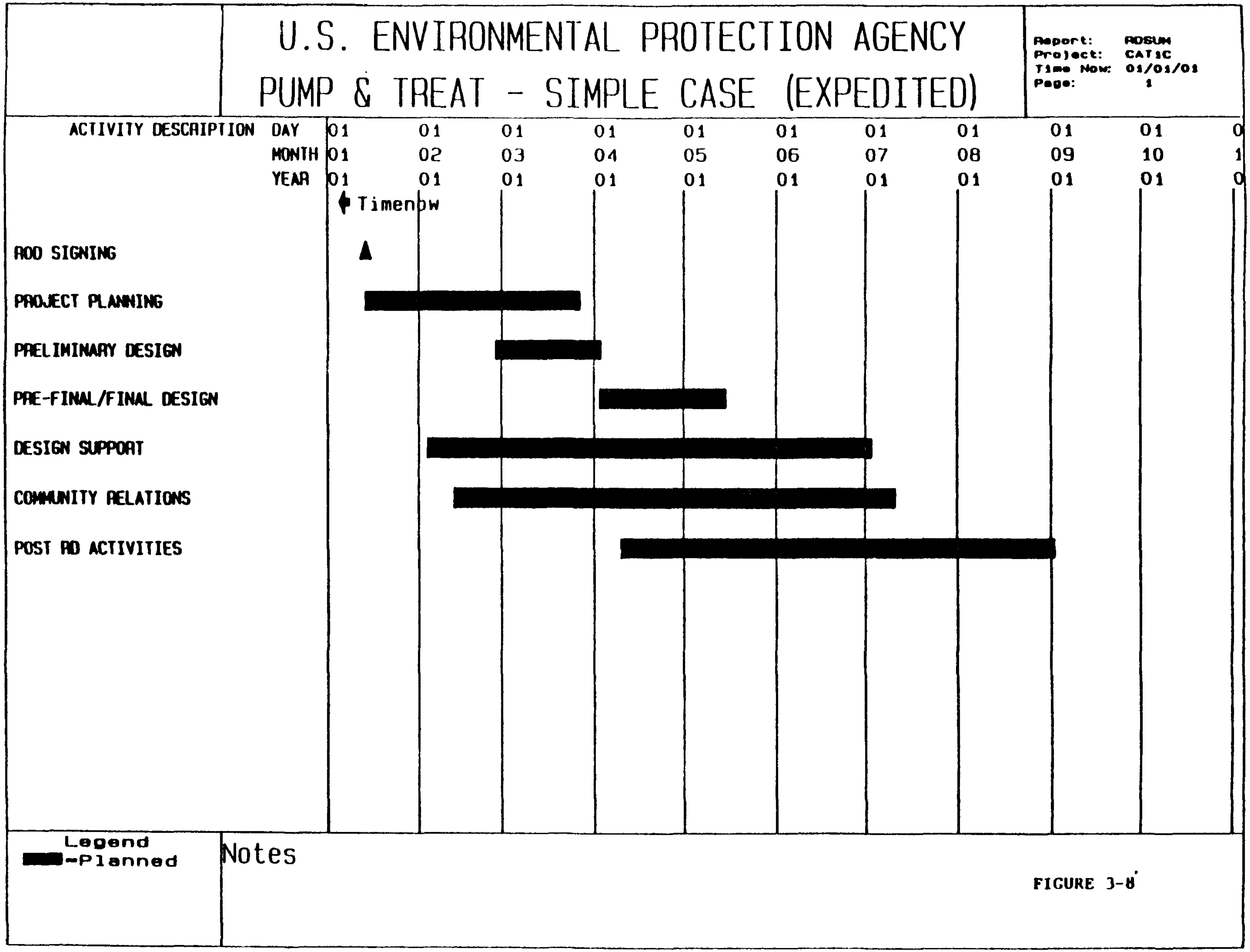
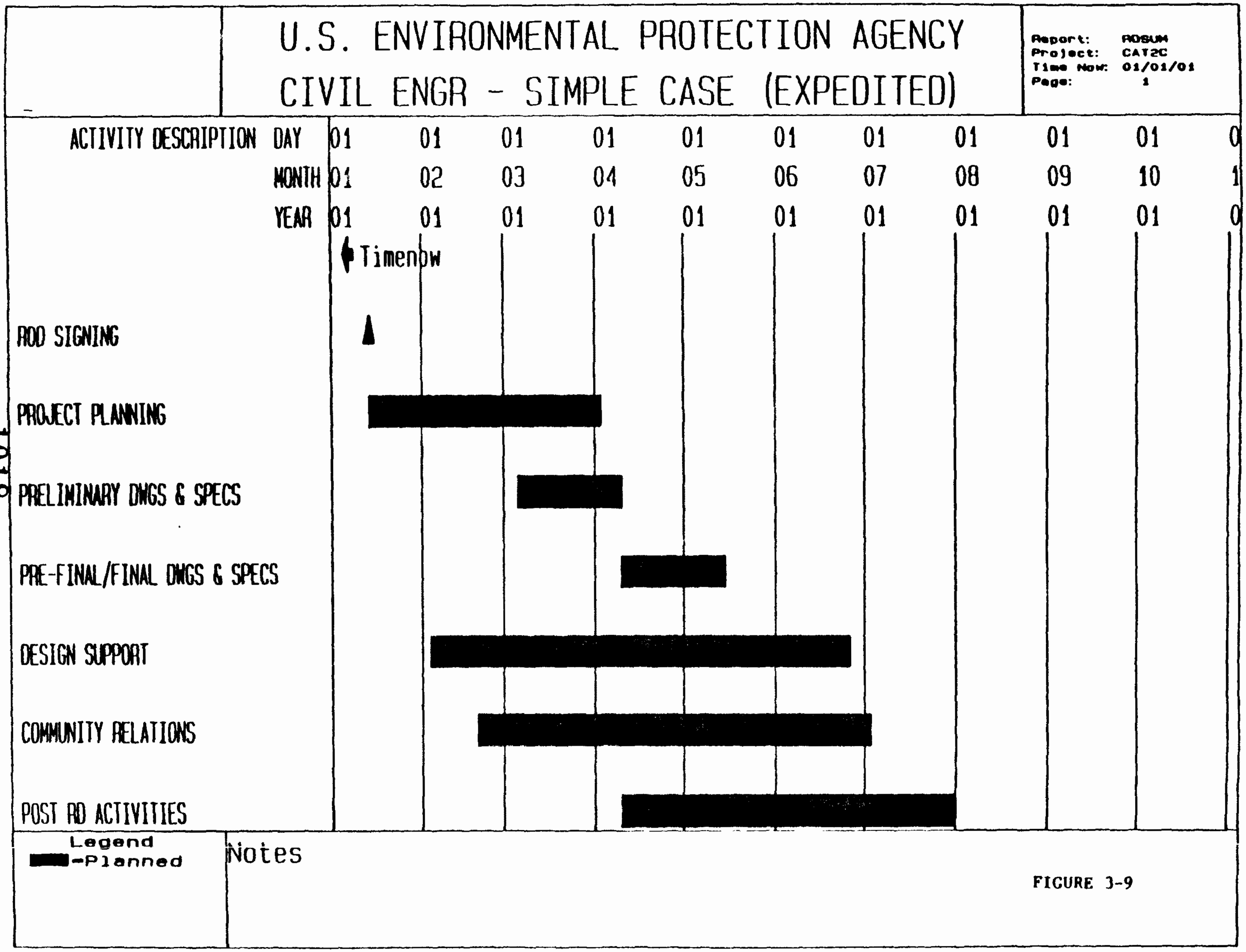
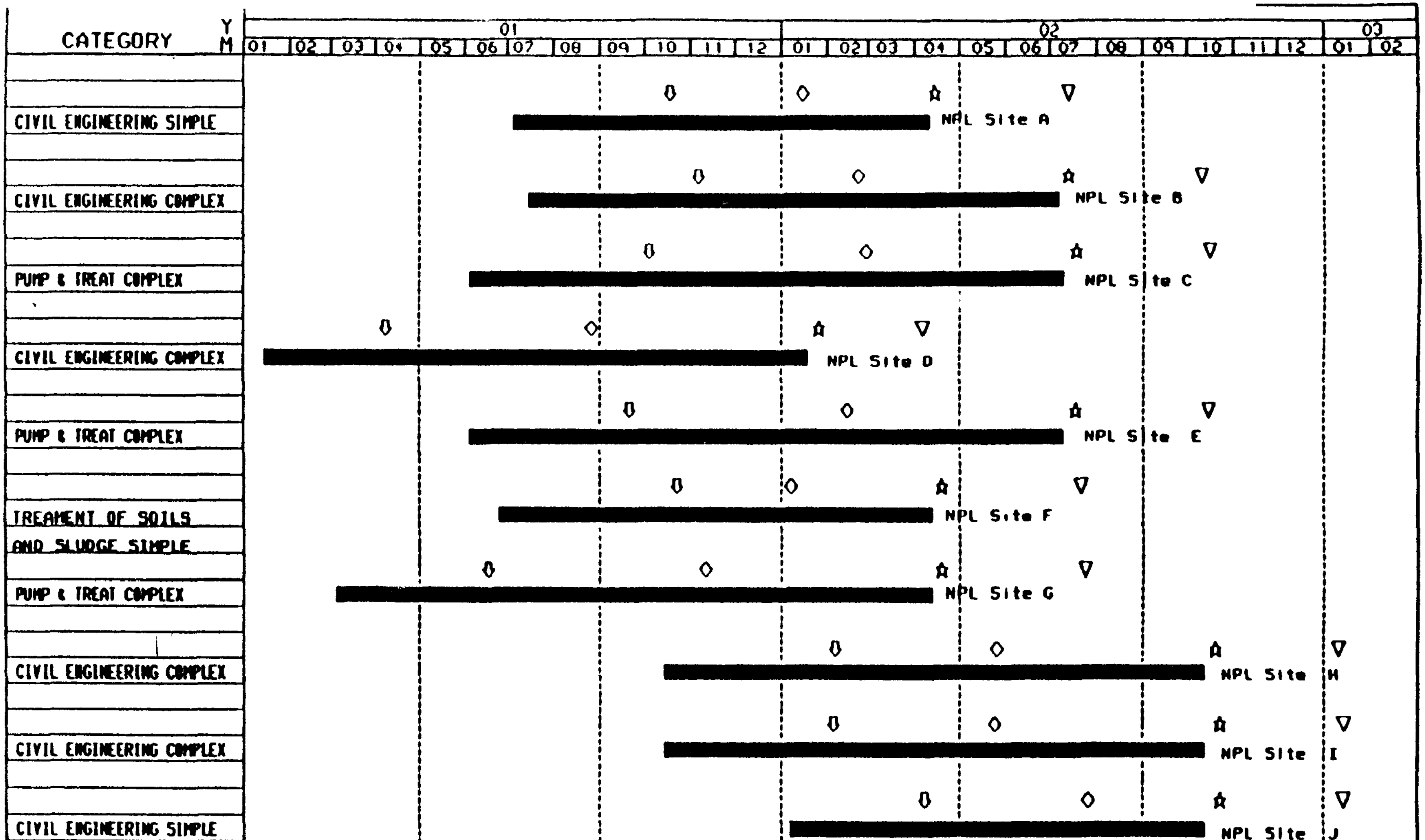

U.S. ENVIRONMENTAL PROTECTION AGENCY
PUMP & TREAT - SIMPLE CASE (EXPEDITED)
Report: ROSUM
Project: CAT1C
Time Now: 01/01/01
Page: 1
ACTIVITY DESCRIPTION
DAY 01 01 01 01 01 01 01 01 01 01
MONTH 01 02 03 04 05 06 07 08 09 10
YEAR 01 01 01 01 01 01 01 01 01 01
Timenow
ROD SIGNING
PROJECT PLANNING
PRELIMINARY DESIGN
PRE-FINAL/FINAL DESIGN
DESIGN SUPPORT
COMMUNITY RELATIONS
POST RD ACTIVITIES
Legend
-Planned
Notes

FIGURE 3-8



1018

FIGURE 3-9



GENERAL NOTE:

THIS REMEDY SPECIFIC SCHEDULE IS GENERIC IN NATURE AND HAS BEEN DEVELOPED WITH THE OBJECTIVE OF REDUCING THE OVERALL REMEDIAL DESIGN DURATION. IT PRESENTS REASONABLE APPROXIMATION OF THE DURATIONS AND INTERRELATIONSHIPS OF THOSE ACTIVITIES REQUIRED TO SUCCESSFULLY COMPLETE A REMEDIAL DESIGN. THE SCHEDULE SHOULD BE USED AS A GUIDE DURING DEVELOPMENT OF SITE-SPECIFIC SCHEDULES

BAR CHART KEY:
- St Treat/Data Coll
- St Prel Des
- Awd RA Contract
- Fin 100% Des
- Planned

Sheet 1 of 1

GENERIC RD MILESTONE SCHEDULE
US EPA REM III PROGRAM

FIGURE 4-1

1019

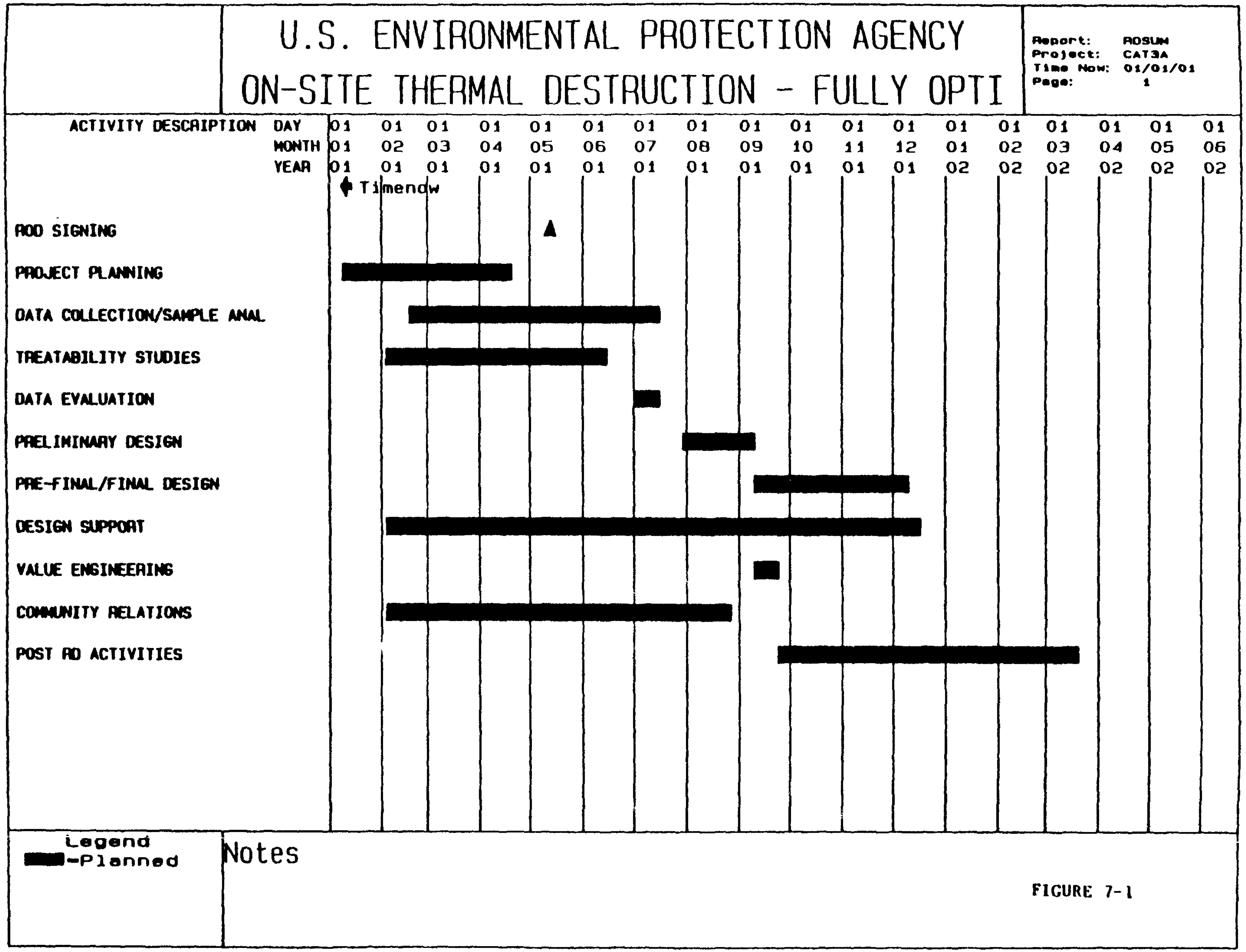


FIGURE 7-1

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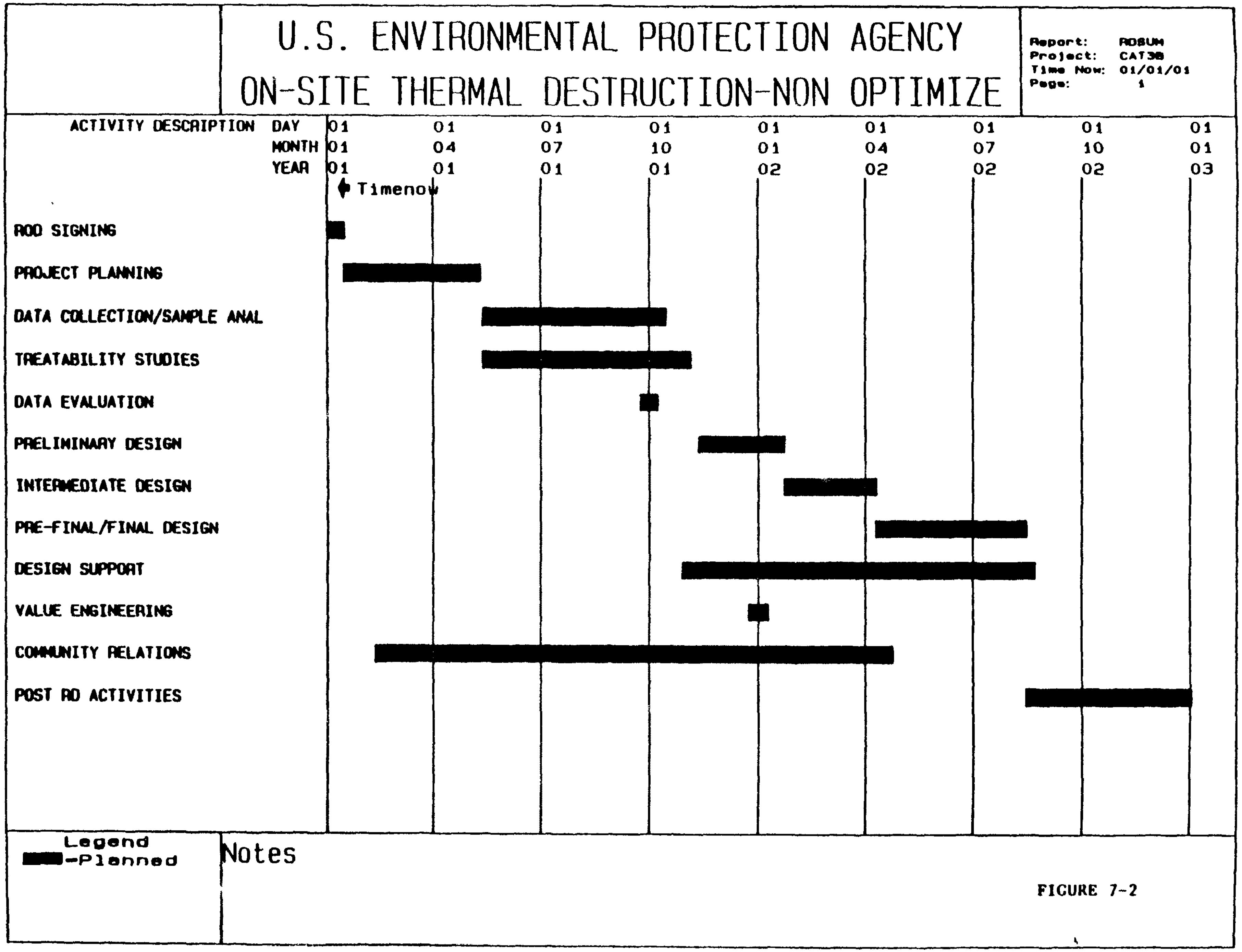
U.S. ENVIRONMENTAL PROTECTION AGENCY
ON-SITE THERMAL DESTRUCTION-NON OPTIMIZE
Report: RDSUM
Project: CAT3B
Time Now: 01/01/01
Page: 1
ACTIVITY DESCRIPTION
DAY 01 01 01 01 01 01 01 01 01
MONTH 01 04 07 10 01 04 07 10 01
YEAR 01 01 01 01 02 02 02 02 03
Timenow
ROD SIGNING
PROJECT PLANNING
DATA COLLECTION/SAMPLE ANAL
TREATABILITY STUDIES
DATA EVALUATION
PRELIMINARY DESIGN
INTERMEDIATE DESIGN
PRE-FINAL/FINAL DESIGN
DESIGN SUPPORT
VALUE ENGINEERING
COMMUNITY RELATIONS
POST RD ACTIVITIES
Legend
-Planned
Notes

FIGURE 7-2

Remedial Management Strategy

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PRE-DESIGN PLANNING

There is a fascination to watching a scientific proposal to reduce, control, or eliminate risks to human health and the environment contained in the Record of Decision (ROD) emerge through the aid of engineering to a remedial design on paper. And indeed it is, for the conception of the remedy can involve as much a leap of the imagination, and as much a synthesis of experience and knowledge as any scientist is required to formulate a hypothesis. And once that remedy is chosen in the ROD, by the RPM, as scientist, it must be analyzed by the engineer, as designer, in a rigorous practical application of the knowledge of pure science.

It is, however, impossible to go directly from the ROD into remedial design (RD). Unfortunately, a phase prior to design has often been overlooked. That is, "The Preliminary or Design Report Phase" between planning and design which is described in ASCE's Manual No. 45, "Consulting Engineering; a guide for the Engagement of Engineering Services." In the Superfund program this phase is called the pre-design planning phase. During this phase the ROD and supporting documents should be converted to a scope for RD and remedial action (RA) by expressing EPA's technical and managerial requirements.

The Pre-Design Technical Summary (PDTS) and Remedial Management Strategy (RMS), completed during the pre-design planning phase, form the link between the scientific site assessment and the engineered solution. The PDTS expresses EPA's technical requirements; the RMS contains the managerial requirements. Therefore, the PDTS and RMS should constitute the complete project definition, including realistic objectives. The objectives must be quantified; the requirements must be clearly stated.

The PDTS is a comprehensive compilation of technical information to ensure that the designer fully understands the technical objectives of the RA. A separate guidance document explains the preparation and content of the PDTS. The RMS contains an analysis of the major management considerations required to achieve the goals of the ROD in a timely manner. Preparation of the PDTS and RMS are essential for the smooth progression of a project through remedial design and remedial action.

The PDTS should be completed prior to negotiations with the PRPs whereas the RMS should be completed after the negotiations. It is recommended that the initial RMS be completed by the RPM if the project is fund lead. (The RMS would also be a useful analysis for the PRP). The RMS should be considered an iterative document to be finalized by the party that contracts for design prior to preparing the scope of work for the design.

PROJECT REQUIREMENTS

Innovation is a mandate in the Superfund program. Innovation and project complexity involve cost, time, and performance risks because of the lack of precedent. The RMS should consider the allocation of these risks as well as in what degree and where there shall be compromises before the design is initiated. The terms of the compromises - including inexperience, overly restrictive technical or managerial requirements, pressures of deadlines and economy in cost - vary the shape of the project to be designed. The PDTS and RMS must, therefore, contain wise and carefully selected technical and managerial requirements.

Unfortunately, compromise implies a degree of failure. It is then the responsibility of the designer to obviate failure within the context of the technical and managerial requirements articulated in the PDTS and RMS. It is, however, impossible for any design to be "the logical outcome of the requirements" simply because, the requirements being in conflict, their logical outcome is an impossibility.

The content of the RMS should, of course, be modified depending on the complexity of the RD and RA. For simple projects many of the requirements need not be addressed the content and level of detail are left to be the discretion of the analyst.

DISCUSSION

The managerial requirements stated in the RMS should encourage efficiency and cost-effectiveness in remedial design, remedial action, operation and maintenance. The requirements should also control and manage RA risks within reasonable limits. As a minimum, the RMS should contain an analysis of the project's managerial goals and constraints as stated in the ROD and a critical strategy for RD and RA as well as EPA policy and guidance.

I. Develop a plan for communications, co-ordination, and organization of all the parties involved in the project, including procedures for rapidly resolving conflicts.

   A. Contracting Party. The RMS should state which organization will contract for RD (PRP, State, EPA, USACE or USBR) and the RA (PRP, State, ARCS, USACE or USBR).

   B. Communications. The best way to assure a rapid response to conflicts is with a communication matrix. This matrix should show the procedural flow of information such as submittals, memoranda, documents, and approvals. These communications procedures should be agreed to by all parties before the RD begins.

II. Provide a reasonable estimate of the duration and resources needed for design; schedule and budget projections for remedial action; and cost and schedule control procedures.

   A. Funding. Funding considerations are of particular concern in the development of a management strategy, particularly if the project is a multi-year effort. The strategy must address the availability of funds including the State cost share and obligations during future years. The RMS should include budget planning projections based on the proposed project schedule, contract packages, and the contingent liability for increased cost during RA.

B. Resources. An analysis must be made to determine the special technical qualifications required for the work, the workload and availability of the resources required, and the level of interest of qualified designers and RA contractors.

C. Schedules. Successful management of the project depends on the performance of responsible and qualified managers and contractors, the maintenance of schedules and budgets, and the rapid resolution of problems. Techniques for good management include requirements that a schedule be agreed to between the contracting party and the contractor, that the schedule be reviewed and updated monthly, and that enforcement of the schedule by the contracting party be maintained. Of course, the schedule must be reasonable, must establish obtainable goals, must contain sufficient detail to permit task control, and must be based upon a complete scope of work.

There are many reasons for development and maintenance of a schedule. The schedule is a tool used to discuss the RD or RA contract between the parties to the contract and is also the principal tool for exacting control of contract progress. The schedule also is the basic documentary and analytical tool for negotiation and settlement of requests for equitable adjustments, claims, and disputes as well as for contract termination and closeout.

The party that contracts for RD or RA has the exclusive responsibility of schedule enforcement, of explicit approval or rejection of the schedule and of imposing sanctions for non-compliance. The control of the schedule is the exclusive responsibility of the RD or RA contractor who also has responsibility for handling unforeseen conditions and interface impacts. Schedule revisions may be requested by either party; however, revisions to the schedule must be approved by the contracting party.

III. Develop a Remedial Delivery Analysis.

The Remedial Delivery Analysis (RDA) is the development of the contracting strategy for the completion of the RD and RA. The decisions made in the Remedial Delivery Analysis must be well conceived and involve the decision makers. The initial RDA should be done as part of the RMS as the decisions made will dictate the scope and complexity of the design. It is most likely that the RA contracting strategy can not be finalized without additional data, obtained during the early design tasks, and this should be reflected in the design schedule.

Although the party contracting for RA will have its own objectives and priorities as to cost, time, and quality, it may often look to the designer as an advisor to recommend the RA contracting strategy deemed most suited to the project. If the party contracting for RA relies on the designer and later encounters problems in the selected contracting strategy, it may blame the designer. In those situations where the party contracting for RA takes the initiative and mandates a given delivery strategy, the party contracting for RD and RA should explicitly set forth recommendations for the role of the designer during RD and RA.

A. Design Approach

B. The number and scope of RD and RA Contracts

C. RA Procurement Methods

D. RD and RA Contract types

IV. Determine the number of remedial design and remedial action contracts.

A. Phasing and fast-tracking. Since EPA has a preference for quick action, an important item to be evaluated in an RMS is the potential for phasing or fast-tracking the project. These approaches will allow the RA to be implemented sooner than if all of the steps were treated as a single design and remedial action.

B. Equipment. The ROD may specify a process or remedy that requires special or proprietary material and equipment, particularly if a new or innovative technology is recommended. In these instances, it is important to evaluate the delivery schedule for such material and equipment. This would include the time necessary to review shop drawings, do performance testing, and for shipping requirements. If these processes are anticipated to take a long time, consideration should be given to purchasing the material and equipment under a separate contract to ensure its timely delivery to the site.

C. Use of or Rights in Patents. There are at least two occasions when the contracting party may be obligated to pay a royalty for the use of or for rights in patents:

1. The remedial design includes a patented product, apparatus, or process, or

2. A patented product, apparatus or process may be necessary for the proper performance of a contract.

Royalties for the use of or for rights in patents, are generally allowable costs within the limits of the principles and procedures contained in the Federal Acquisition Regulations and EPA's Regulations Governing Cooperative Agreements.

D. Advertising. When considering when to award the RA contract, especially small projects, the best time to advertise the RA must be evaluated including the seasons of year when the work will occur, the geographic location, and other contractors working at the site.

E. Remedy classification. The remedy should be classified into one or more of EPA's characteristic remedies. Each remedy may be a separate design or a comprehensive design may contain a combination of these remedies. In that case, each of the component remedies is worked in parallel and the more complex, time-consuming remedy will control the overall project duration.

1. Civil Engineering.

2. Pump & Treat.

3. On-site Thermal Destruction.

4. Soils and Sludge Treatment.

F. Noncompetitive Procurement. The Competition in Contracting Act of 1984 (CICA) provides for the use of "other than full and open competition" for some acquisitions. The term "noncompetitive" is often used to mean other than full and open competition.

This means not only sole source acquisitions, but also those situations where an agency is permitted to limit the number of sources solicited.

G. RA Procurement Methods. Two primary competitive methods procedures may be used for the procurement of supplies, services, and RA. These are the solicitation of sealed bids (formal advertising method) and the request for competitive proposals (competitive negotiation method).

In determining the appropriate competitive procedures to be used, a public agency should determine:

1. The time available for the solicitation, submission, and evaluation of offers;

2. If the award will be made on the basis of price, other factors or a combination;

3. If it is necessary to conduct discussions with the responding source about their offers; and

4. If there is a reasonable expectation of receiving more than one offer.

H. RD and RA Contract Types. The enormous scale and complexity of public acquisition has necessitated the development of a wide variety of contract types. The term "contract type" has several different connotations. Often it is used to indicate the various methods of pricing arrangements, of which there are two basic types: fixed-price contracts and cost-reimbursement contracts.

V. Assure a quality design which anticipates potential problems, is in sufficient detail to solicit reasonable offers for remedial action and ensures function, efficiency and economy.

A. Responsibility of the Contracting Party. It is the responsibility of the party that contracts for design to:

1. Prepare a complete, detailed scope of work for design.

2. Communicate project objectives and critical need dates.

3. Select qualified professionals, identify special expertise needed and authorize formation of multidiscipline design teams.

4. Establish design criteria and requirements.

5. Provide adequate schedule and budget for design.

6. Require the designer to implement quality assurance, quality control, and peer review programs.

7. Provide timely reviews and approvals.

8. Stress completeness, timeliness, and professional presentation of submittals.

9. Assure that value engineering, biddability, constructibility, operability, claims prevention, and environmental reviews of the design are conducted.

10. Be prepared to coordinate, negotiate, and resolve conflicts in a timely manner.

B. Designer Responsibility. Design is a professional service, as defined by State law, which is required to be performed or approved by a person licensed, registered, or certified to provide such a service. Because the A-E, as the designer, offers professional services on the basis of its fitness to act in the line of work for which it is employed, the A-E has a duty to avoid negligence; provide an implied warranty for the design; and fulfill specified contractual requirements. The A-E is responsible for providing professional quality work that meets the standard of care, skill, and diligence that one in the profession would ordinarily exercise under similar circumstances.

When a modification to a RA contract is required because of an error or deficiency in the design, the party that contracted for the design must consider the extent to which the A-E may be reasonably liable.

C. Risk Management. The RMS should contain an analysis of the potential risks associated with the project including financial, schedule and technical risks. This evaluation should include a review of the degree of certainty regarding the estimates of the types and quantity of work that needs to be done as well as cost estimates.

While the party contracting for RA may wish to shift a significant amount of risk to the RA contractor, an inordinate or inequitable transfer of risk may impact the project in terms of increased cost. These increased costs may result from less competition among RA contractors who may be unwilling or unable to provide an offer, increased contract modifications because of unknown or unanticipated subsurface conditions, claims based on conduct of the party contracting for RA, or schedule delays.

The RMS should contain an analysis of the basis for the method of managing the risks associated with the project. This includes decisions regarding the method of procurement, type of contract, availability, types, and amounts of insurance required by contractors, the availability and amount of bonding required, indemnification and liquidated damages.

D. Design versus Performance Specifications. Frequently an RA contractor will encounter difficulties in performing under the specifications or drawings. Generally, defective specifications are defined as those specifications which contain errors, conflicts, or omissions which prevent performance completely or in the manner contemplated by the parties to the contract. The most common defective specifications are clear errors in the contract documents or conflicts between provisions. Other common deficiencies include: errors or omissions of important facts or dates, and conflicts between the specifications and drawings. Many of these problems may be the pecuniary liability of the designer.

The party contracting for RA impliedly warrants that the RA contractor will be able to fulfill its responsibilities, as set out in the specifications, if "design" specifications are provided which precisely states how the contract is to be performed. If the RA contractor makes a good faith effort to follow the design specifications, but is unable to comply because the contract documents are inadequate or do not contain the required or necessary details to complete the item specified, the contracting party bears the risk of loss.

In contrast, if the party contracting for RA allows the contractor discretion in how to meet the contract obligations by providing "performance" specifications and no explicit statement of how to design or build the item is offered by the contracting party, the inability to complete the contract is borne by the RA contractor. If the RA contractor has undertaken an impossible task, meets technological problems, or cannot complete performance because of its lack of experience, the contractor and not the contracting party, bears the risk of loss.

E. Project Quality. Quality is conformance to the requirements that meet the project's needs and expectations. Of course, to achieve those needs and expectations, they must be clearly stated at the beginning of the task as they cannot be misunderstood. Quality neither depends on, nor is achieved through, multiple reviews.

VI. Develop a well defined scope of work for RD.

It is expected that the RD will be consistent with the Record of Decision (ROD), will comply with Superfund program policies and procedures, will minimize RA contract modifications, and will prevent RA contractor claims.

EPA's 11 standard tasks that should be used in architectural or engineering (A-E) agreements for RD. The tasks are intended to provide a consistent method of reporting design work. While some variations are anticipated because of the variety of design projects and differences among the A-E firms, the standard tasks should be used and reporting formats should be amended to be consistent with this set of standard RD tasks.

The standard tasks for RD are:

1. Project Planning. This task includes work efforts related to the initiation of a design project after the A-E agreement is executed.

2. Field Data Acquisition and Sample Analysis. This task consists of the effort required to obtain specific field samples and information needed during the design effort that was not produced during the RI and FS.

3. Treatability Studies. This task includes work efforts related to conducting pilot and bench scale treatability studies during remedial design.

4. Data Evaluation. This task includes efforts related to the organization and evaluation of data that will be used later in the design effort.

5. Preliminary Design. This task begins with initial design and ends with the completion of approximately 30 percent of the total design.

6. Intermediate Design. This task begins at the completion of the preliminary design phase and ends with the completion of approximately 60 percent of the total design. Depending on the size, complexity, and timing of the design effort, this task may be omitted at the discretion of the contracting party.

7. Prefinal/Final Design. The prefinal/final design phase commences at the completion of the intermediate design effort and is finished when the entire design effort has been completed.

8. Design Support Activities. This task consists of design support effort which is conducted during one or all of the three phases of design.

9. VE During Design. If the initial VE screening conducted during the project planning task identifies a potential cost savings, a VE study will be initiated under this task. Value engineering is a specialized cost control technique which uses a systematic and creative approach to identify and to focus on unnecessarily high cost in a project in order to arrive at a cost saving without sacrificing the reliability or efficiency of the project.

10. Community Relations. This task incorporates all work efforts related to the preparation and implementation of the community relations plan during the design phase of the project.

11. Project Completion and Closeout. This task includes efforts related to the support of project completion and closeout activities in both the technical and financial area as well as in the file maintenance and record indexing area.

VII. Expect that the RA contract documents be free of potential errors, conflicts, omissions, ambiguities, and misrepresentations and establish a system to administer, interpret and manage those contracts.

A. Design Reviews. It is the responsibility of the party that contracts for design to assure that the design reviews and approvals are conducted. These activities may be conducted in parallel with other ongoing design activities or in series, whereby subsequent activities do not start until the review is completed, comments are resolved, and approval to proceed is provided.

The designer has a professional responsibility regarding the impact and liability of the comments on the design and must communicate this to the contracting party. The review of the plans and specifications, by the party that contracted for design, generally is for administrative purposes only. That is, the review is to assess the likelihood that the project will achieve its remediation purposes and that its performance and operations requirements have been identified. The structural, mechanical, and electric aspects of the plans and specifications need not to be reviewed in detail by the party that contracted for design. The acceptance of plans and specifications by the party that contracted for design does not relieve the designer of its professional liability for the adequacy of the design.

B. Principal Purpose of the RA Contracts. RA means those actions consistent with the permanent remedy taken instead of, or in addition to, removal action in the event of a release or threatened release of hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future health or welfare or the environment. It should be noted that not all of the activities contemplated as "Remedial Actions" are in the nature of "construction". Some can be considered to be the performance of "services."

The distinction between construction contracts and service contracts for remedial action can be quite difficult when determining whether DBA applies. Instances may arise in which, for the convenience of the contracting party, instead of awarding separate RA contracts for construction work subject to DBA and for services of a different type to be performed by service employees, the contract may include separate specifications for each type of work in a single contract calling for the performance of both types of work. For example, offers may be solicited for a pump and treat system or an incinerator, as well as their operation and maintenance. The installation as well as associated excavation, hauling and landscaping may be considered to be construction covered by DBA; whereas, operation and maintenance is a service and not covered by DBA.

VIII. Provide for the inspection of the implementation and completion of the remedial action by qualified persons to ascertain compliance of the remedy with the ROD and its project performance requirements.

A. Engineering Support during RA. The contract for A-E support during RA should be in place prior to approval of 100 percent design. The concept of working to a "total" remediation schedule for a single site (RI through completion of RA) in an efficient manner necessitates the early identification of an A-E to provide engineering support during RA. This will assure that the RA will not be delayed due to lack of engineering support and also permits timely support to the party contracting for RA for several pre-award activities including the pre-offer conference and evaluation of the RA offerors.

It is incumbent upon the party that will contract for RA to initiate the activities necessary to identify the A-E to support the RA task early. It usually is most efficient to use the services of the A-E firm performing the design for this effort.

B. Remedial action quality assurance requirements. A requirement for an RA contractor developed quality assurance plan should be included in the statement of work or specifications for each RA. The development and application of a site-specific quality assurance plan will help to ensure that all the components of the completed project or RA have been completed to meet or exceed design criteria, plans, and specifications. Quality assurance includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of the project.

C. Project Performance. Project performance includes project start-up, systems testing under the various possible operating conditions, acceptance or rejection, warranties, operation and maintenance manuals, and organizational responsibilities. The project must conform to its applicable performance and operations requirements.

ACQUISITION SELECTION FOR HAZARDOUS WASTE REMEDIATION

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INTRODUCTION

Engineers, by the nature of their education, strive for precision and accuracy in their work. The engineer typically selects building materials through design calculations that point to a specific amount of a specific item. This process often leads the engineer to the preparation of detailed specifications and drawings suitable for fixed priced type contracts. There are times when it is not advantageous to the client to obtain the specificity needed to develop such a contract. Additional field investigations may be cost-prohibitive or time constraints placed on the client may require expeditious action. In these cases the engineer needs to develop an acquisition strategy based on the amount of information available for their design. The engineer would then select the appropriate type of specification and contract to meet the needs of the project.

The intent of this paper is to discuss the various options available to the engineer in selecting an acquisition strategy for hazardous waste remediation. Most hazardous waste remediations will use well defined specifications and a fixed price contract. Hazardous waste remediations provide more design uncertainty than other civil engineering projects. For this reason the engineer should consider various acquisition methods early in their design.

BACKGROUND

Traditional Government Construction Contracts

The construction of buildings, roads and dams come to mind when thinking of traditional Government construction. These projects are usually well-defined. They use a sealed bid procurement process with design specifications and a fixed price (lump sum or unit price) contract for construction. These contracts allocate a substantial amount of risk for increased costs, delays and non-performance on the contractor.(1) In return the contractor adds a contingency for unexpected work into their offer. A well defined project gives the contractor a better means to define the possible risk. The amount of contingency a contractor includes in the offer relates directly to the perceived risk.

Procurement Procedures

The Invitation for Bid (IFB) procedure is the Government's common procurement method for most civil engineering projects. This procedure is the easiest for the Government to administer and insures a competitive process. The IFB procedures tie both the Government's and the bidder's hands at the time of bid opening. Bids opened in public limit both the Government's and the contractor's options after the opening. The Government determines that the bids are responsive and responsible. (Responsiveness is a determination that the contractor has met the requirements of the IFB while responsibility is the determination that the contractor can perform the specified work.)(2) After this determination, the Government's only option is to award the contract to the bidder with the lowest responsive and responsible bid. The procedure also limits the bidders' options. A bidder has no chance to adjust, clarify or correct the bid after the opening. Essentially the Invitation for Bid procedure is a one shot deal. The prospective bidder must consider the potential risk and include in the bid price(s) a contingency for that risk.

The Two-Step Sealed Bidding process provides a mechanism for negotiation on the technical aspects of a project while retaining the competitive nature of the sealed bid. In the first step of this process the Government issues a Request for Technical Proposals (RFTP) describing the project requirements. Bidders in turn respond to the Government with a technical proposal explaining their approach to the project. The Government then reviews the proposals, determines if they satisfy the minimum RFTP requirements, and possibly clarifies the proposals with the bidders. The second step is the submission of sealed bids by the bidders whose technical proposals meet the Government's minimum requirements. The Government opens the bids publicly and awards the contract to the lowest responsive and responsible bidder.

The two-step sealed bid offers several advantages. First the two-step seal bid accords the Government a method to review proposals that, under the strict specification adherence of the sealed bid method, would not be considered equal. The process assures the Government that the procurement is competitive through the submission of sealed bids during the second step of the process. The two-step sealed bid permits the Government a means to collect technical information without the use of research and development contracts. The Government can use this information to help in future solicitations using the sealed bid method.(2)

The two-step sealed bid has disadvantages as well. Preparation and review of technical proposals is time-consuming and costly to both the bidders and the Government. Final submissions are based on the least costly design to assure bidders that they remain competitive. The Government does not have the flexibility the select other than the lowest bid although another package may be technically superior. The flexibility and latitude allowed the contracting officer opens ground for bid protests and contract disputes.(2)

The Request for Proposal (RFP) procedures are similar to the two-step sealed bidding process in that they permit the Government and the offeror a means to discuss the project during the procurement process. Unlike the two-step sealed bidding procedure, price can be discussed during negotiations using a request for proposal. The offeror typically submits a technical proposal including a price. The Government then evaluates the technical proposal, and discusses the proposal with the offeror. Through these discussions the Government determines if the technical proposal meets the minimum requirements of the specifications. Offerors who meet the minimum requirements are deemed technically acceptable. The Government requests a best and final offer from those proposers. Typically the Government selects the offer with the lowest price judged to be technically acceptable.

One advantage in using the negotiated procurement procedure is that it allows the Government discretion in selecting a successful offeror. The Government, through a source selection plan, determines evaluation factors, the relative importance of the factors and the importance of the cost differentials of the offers. Government evaluators use weighted evaluation factors to help in selecting the best offer. Inclusion of the factors in relative order in the RFP informs potential offerors of the areas considered critical by the Government.

The Government also has the prerogative to use a tradeoff analysis rather than select the low price or highest rated proposal. Using the tradeoff analysis the Government can select a proposal with the best balance of technical merit and cost. Cost consideration usually occurs in one of two methods: total points or dollar per point. The total point method includes cost as an evaluation criterion. The lowest price receives all the points available as determined in the criterion. The other offered costs receive points proportionally to their costs as compared to the lowest cost. The dollar per point method divides the offered cost by the point score of the other criteria in the evaluation.(3)

A strict adherence to either method may lead to a selection that is not in the best interest of the Government. A point score leads to the belief that the evaluation is a precise operation when in fact the scores show only a relative relationship between the offers. Offers with similar point scores can vary significantly in technical merit and price. When the Government performs a tradeoff analysis, the contracting officer reviews the point scores to determine whether a point differential represents a signficant difference in technical merit. This review may lead the Government to select the proposal with the "greatest value" (FAR 15.605) rather than cost alone. The application of the tradeoff analysis to the final scores before award allows the Government to select the best overall offer.(3)

The Request for Proposal process allows the offeror the opportunity to limit their risk by further defining their proposed actions within the technical specifications of the project. The Government has the option under the RFP process to negotiate with the offerors on the technical and financial aspects of the project if it chooses, allowing offerors to seek clarification on the technical aspects of the project that could reduce their risk and subsequent offer.

Specification Type

Contract specifications can be classified into three types: design, performance and functional. While specifications can be classified into these types, few if any specifications are purely one type. Most often a specification is primarily one type with components of the others included. Traditional Government construction contracts are a combination of design and performance specification.

A design specification provides specific detail/instruction on the methods and/or materials to be used to accomplish a task of work. Design specifications set out materials, tolerances, measurements, quality control, inspection requirements and other specific information. The use of design specifications for a specific process or product is desirable. Design specifications are advantageous in that they provide the Government assurance that it gets exactly what it wants. The disadvantage of the design specification is that the Government accepts all responsibility for a product that does not function as desired provided the contractor performed within the design specification.

Performance specifications describe the desired result and general approach rather than a specific process or design characteristic(s). Performance specifications require contractors to select the method they feel will best meet the Government's requirements. The construction contractor is generally responsible for the detailed design, construction and final achievement of the product. By using performance specifications the contractor will share in the risk and responsibility for final project performance. The contractor generally controls the detailed design and construction process while the Government inspects and approves the final project. The contractor is responsible for meeting the requirements of the Government's performance specifications.

Performance specifications generally allow more than one approach in meeting the required end result, suggesting that this type of specification is not appropriate for sealed bidding. The variation of approaches selected by potential bidders cannot be assessed in a sealed bidding process. When prepared to restrict the bidder's options to only those methods that will meet the Government's needs, performance specifications can be used with the sealed bid.(2) When writing performance specifications for use with a sealed bid, the engineer must provide a set of criteria that limits prospective bidders' procedurial options such that all offers are equal.
Functional specifications state only the final or ultimate objective of the desired product. Functional specifications can be considered a performance specification that does not address any approach or

process in meeting the product. A functional specification describes the minimum characteristics needed to achieve the objective. The use of a functional specification assumes an attainable objective. Because of the variety of approaches that can be offered under this type of specification, the Government must be prepared for the possibility of a lengthy and costly evaluation process.

Risk or responsibility for meeting the project goals varys significantly depending upon the type of specification. The Government, as author of the project specification, can delegate the risk involved. By calling for specific materials, equipment or methods in a design specification, the Government assures itself that the desired work occurs. The Government bears a large portion of the responsibility and risk for performance since it provides detailed instruction to the contractor. Performance and functional specifications require the contractors to select methods they feel will meet the needs of the Government while staying within their cost constriants. Methods used are not a concern of the Government provided the results meet the requirements of the contract. Performance and functional specifications tranfer control and risk from the Government to the contractor.(5)

Contract Types Available to U.S. Government

The Federal Acquisition Regulations (FAR) define the system that the United States Government must use to obtain contractual services. There are four general contract types available under the FAR: Fixed Price, Indefinite Quantity, Time and Material and Cost Reimbursement. Fixed price contracts can be divided into four sub-types:

Firm Fixed Price - FAR 16.202 Firm fixed price may be sealed bid or negotiated. This type of fixed priced contract can be used when defined design or performance specifications are available. The contract price is not subject to change despite contractor performance costs. This type of contract places all the financial risk on the contractor while it places the least amount of administrative burden on the contracting officer.

Unit Price - FAR 16.2 & 12.403 (c). Unit price may be sealed bid or negotiated. This type is for construction only. The required quantity of a specific unit can be undetermined, but a reasonable estimate is known and reasonably definite design or performance specifications are available for the units. The contract includes a "variation in estimated quantities" clause to allow equitable adjustment between target quantity and actual quantity delivered. This provision reduces the contractor's fixed price per unit due to equitable adjustment based upon actual performance. It places the burden of providing for accurate recording of quantities delivered on the contracting officer.

Fixed Price Incentive - FAR 16.204 & 16.403. Fixed price incentive can only be used with negotiated procurement. It is selected when cost uncertainties exist, but there is potential for cost reduction and/or performance improvement by giving the contractor a degree of cost responsibility and a positive profit incentive. Profit is earned, or lost, based upon the relationship of the contractor's final negotiated cost to total target cost. The incentives are placed on cost.

Fixed Price with Award Fee - FAR 16.402-2. Fixed price with award fee is for sealed bids only. The contract is firm fixed price at the start based on definitive specifications, but the contract allows payment of an additional fee or portions thereof for exceptional performance. The performance must be objectively measurable (ie, "exceptional" versus minimum requirements of contract). The contract must provide clear and unambiguous evaluation criteria. The deletion of a work item requires a compensating deletion in award fee.

Indefinite quantity is the second type of contract allowed in the FAR. It may be used with a sealed bid or negotiated procurement. The Government would select an indefinite quantity contract where it is impossible to determine in advance the precise quantities of supplies or services that will be needed by designated activities during a definite contract period. The method of ordering work must be stated as well as minimum/maximum orders allowable during a specified period. Regulations require the development of a fixed unit price schedule (Schedule of Work) before award that provides a basis of cost for items to be ordered. The contract contains estimated quantities used for bid evaluation. There are two sub-types of indefinite quantity contracts.

> Requirements - FAR 16.503. In a requirements type contract the Government is not obligated to place any minimum orders. The contract obligates the Government to order from successful contractor and no other source for all supplies and services described in the contract. The contractor has the legal right and duty to provide the supplies or services determined by the Government's need and not by a fixed quantity.

> Indefinite Quantity - FAR 16.504. In an indefinite quantity type contract a stated minimum shall be ordered by the Government during the contract period. The contract also must specify a maximum amount to be ordered. The regulations limit the use of this type of contract to commercial or commercial type items that the Government needs on a recurring basis.

Time and Materials type contracts are defined in FAR 16.601. Time and materials contracts may be sealed bid or negotiated procurements. The Government selects this type of contract when it is not possible at time of contract preparation to estimate the scope (extent or duration) of work required with high degree of accuracy. The contract calls for provision of direct labor hours at an hourly rate and provision of materials at a designated cost. The contract contains estimated quantities used for bid evaluation purposes. Time and materials contracts require the use of time and cost standards applicable to particular work items and appropriate surveillance by government personnel. Funding is obligated to each work order prepared under the contract.

Cost Reimbursement contracts can be used for negotiated procurement only. The total award fee plus base fee cannot exceed the statutory limits as indicated in FAR 15.903(d). This type of contract is very costly to administer and requires the contractor to have an adequate accounting system. This type of contract can be used only when the nature of the work or the unreliability of the cost estimate makes it impossible to use another contract type. Two sub-types of cost reimbursement contracts are:

> Cost Plus Incentive Fee, FAR 16.404-1. Cost plus incentive fee is utilized when development has a high probability that it is feasible and positive profit incentives for contractor management can be negotiated. The performance incentives must be clearly spelled out and objectively measurable. The contract must contain target cost, target fee, minimum and maximum fees, and fee adjustment formula. The fee adjustment is made upon completion of the contract and based on the end results, not their cause. Cost plus incentive fee contracts are suitable for research and development projects.

> Cost Plus Award Fee, FAR 16.404-2. Cost plus award fee contracts are very effective in cases where it is impossible to write a contract specification containing a precise description of the work expected to be performed. The Government uses a cost plus award fee contract when contract completion is feasible, incentives are desired but contractor performance is not susceptible to finite measurement. This contract sub-type provides for subjective evaluation of contractor performance. The Government determines the fee to be paid and the determination is not subject to dispute. A cost plus award fee contract must contain clear and unambiguous evaluation criteria to determine award fee. The Federal Acquisition Regulations

permit the Government a variety of choices in selection of contract type. The Government must decide where it wishes to place its resources and risk in the completion of a project. The fixed price contracts force the Government to do a thorough investigation and design prior to solicitation. The benefit of this work is a contract that minimizes risk allocation to the Government and has the lowest price at the time of solicitation. The other types of contracting allow an expedited solicitation while placing greater demands on the Government in contract administration, risk allocation and potential cost.

Hazardous Waste Categories

The Design and Construction Management Branch, Hazardous Site Control Division, U.S. Environmental Protection Agency, has developed categories for Superfund remediations for discussion purposes. These categories are used in subsequent discussions of remediations and possible acquisition strategies.

Civil Engineering: The simple civil engineering projects contain such remedies as fencing, groundwater monitoring, and minor earthwork, demolition or removal activities. The complex civil engineering projects may require more extensive construction effort such as a Resource Conservation and Recovery Act (RCRA) cap, extensive or complicated excavation or demolition activities, or the construction of other engineered structures.

Pump & Treat: This category is for groundwater withdrawal, treatment and discharge or disposal and surface water or leachate treatment. The technology categories include physio-chemical and biological treatment of liquids. Specific technologies include: air stripping, carbon adsorption, metals precipitation, ion exchange, multi-media filtration, aerobic and anaerobic biodegradation, evaporation, and distillation. In the simple projects the technologies would be proven for the contaminants of concern and would be available in "off the shelf" package treatment units. In addition, the aquifer characteristics would not be complex, and standard pumping systems would be used. In a complex pump and treat project, the aquifer, contaminants, and the pumping and treatment system design effort is a more difficult, time consuming effort such as innovative water treatment technologies.

Soils and Sludge Treatment: This category includes the physical, chemical or biological treatment or volatilization of soils and sludge. All non-thermal destruction of solids would be treated under this category. In the simple project the process chosen would be a well proven technology for the contaminants of concern and for the existing site conditions. A complex project would include innovative processes requiring extensive testing and development.

On-site Thermal Destruction: This category includes on-site incineration, pyrolysis and in-situ vitrification.

DISCUSSION

Hazardous waste remediation does not fit the mold of the typical Government construction project. The Government spends considerable effort to define a project in its solicitation package. Hazardous waste sites consist primarily of abandoned buried waste with little or no record of the location. Sampling during the remedial investigation and feasibility study is directed toward remedy selection, not design. Many sites require additional sampling and engineering investigation activities so that the Government can prepare a detailed solicitation package. This effort often conflicts with the neighboring community's desire for action at the site.

Several design options are available to the Government and its engineer. Most engineers prefer to devote the time and effort to define a project to the best of their ability. Solicitation packages generated because of this process place a substantial amount of risk on the contractor. The engineer ultimately must make the decision regarding adequate design information. The engineer's goal is to minimize risk to the Government. The engineer must consider the costs for additional investigation activities versus the potential construction cost savings resulting from better project definition. This decision is further complicated in hazardous waste remediations by pressure applied from the project manager and community.

Acceptance of risk by the Government permits the engineer to produce a less-defined package and use a non-conventional acquisition strategy. This acceptance by the Government often results in expediting the start of construction activities. It does not guarantee the early completion of a project. Circumstances at hazardous waste sites often make it uneconomical to investigate the site that would allow the engineer to produce a well-defined project. In these cases the engineer must recognize this limitation and modify the acquisition strategy accordingly. Assessing the potential Government risk is key to these efforts.

Prior to issuing a remedial design assignment, the U.S. Environmental Protection Agency recommends that the project manager develop predesign technical and remedial management summaries.(4) These summaries are more thought process than formal documents. The summaries focuses the project manager to address major components of the remedial design and remedial action. The predesign technical summary deals with site information including availability of data, selected remedy, technical approach, applicable or relevant and appropriate requirements (ARARs), health and safety concerns, and any unresolved issues. The remedial management strategy focuses on the implementation of remedial design and remedial action activities. This includes consideration of phasing and/or expediting portions of the remedy. An acquisition strategy is an end product of the remedial management strategy.

Discussion of the manner in which a project manager or engineer selects the various components will begin by addressing the simplest type of hazardous waste remediation, the simple civil engineering project. These projects differ little from any other Government civil engineering project. The simplest remedies do not deal with hazardous waste. Examples might be alternate water supply systems or installation of cap material over a site without disturbing the existing soils. Additional field investigation is minimal and the project can be well-defined. Design work can commence with the goal of developing a design specification for a fixed price contract procured through an invitation for bid.

Complex civil engineering projects are actions such as contaminated soils excavation, slurry wall construction, and building decontamination or dismantling. These project require additional field investigations prior to commencement of design activities. Health and safety and quality control and assurance plans become part of the contractor's required submittals. If the project can be well-defined, the use of design specifications, fixed price contract and an invitation for bid is preferred. Alternatives should be considered when the engineer cannot adequately define the project due to unknowns or time constraints. These alternatives include performance specifications, indefinite delivery or time and materials contracts, and negotiated procurements. Examples where these may be appropriate would be: 1) expediting building decontamination or dismantling because of potential risk or interest from the community, 2) expediting soils excavation where contaminants are known but additional sampling would be required to determine the amount of material involved, 3) wanting to obtain recommendations from private industry for approaches to slurry wall construction, 4) wanting to discuss proposed construction plan with offerors prior to contract award when working in residential areas requiring good community coordination.

RECOMMENDED ACQUISITION STRATEGIES FOR HAZARDOUS WASTE REMEDIATION

REMEDIATION CATEGORY		
Specification	Procurement	Contract
SIMPLE CIVIL ENGINEERING		
Design	Invitation for Bid	Fixed Price
COMPLEX CIVIL ENGINEERING		
Design Performance	Two-Step Bid Request for Proposal	Fixed Price Indefinite Quantity Time and Materials
SIMPLE PUMP AND TREAT		
Design	Invitation for Bid	Fixed Price
COMPLEX PUMP AND TREAT		
Design Performance	Two-Step Bid Request for Proposal	Fixed Price Indefinite Quantity Time and Materials Cost Reimbursement
SIMPLE SOILS AND SLUDGE TREATMENT		
Design	Invitation for Bid	Fixed Price
COMPLEX SOILS AND SLUDGE TREATMENT		
Design Performance Functional	Two-Step Bid Request for Proposal	Fixed Price Indefinite Quantity Time and Materials Cost Reimbursement
ON-SITE THERMAL DESTRUCTION		
Performance Functional	Request for Proposal	Fixed Price Indefinite Quantity Time and Materials Cost Reimbursement

Simple pump and treat remediations are those where the movement of the plume has been restricted or the waste is easily treated. This permits the development of a solicitation package with minimal additional field investigation and treatment technology is readily available. A package treatment plant may be a viable option for this remedy. Specifications can be design-based and a fixed price contract can be procured with a sealed bid. The use of alternative strategies would have minimal impact in expediting this type of project.

More complex pump and treat remedies require greater flexibility. Additional well drilling may be necessary to define the plume. To avoid the need for contract modification, renegotiation, or resolicitation, an indefinite delivery on time and materials contract may be favored over a fixed price contract.

Some ground water contaminants may require innovative technologies and treatabililty studies. This work can be conducted by a research and development contract followed by design and construction contracts. The alternative is to enter into a negotiated procurement and request that offerors demonstrate that their proposals meet the project requirements. Specification used in the solicitation would be performance- or perhaps functional-based. Considering treatment alternatives does not preclude the use of a fixed price contract. A fixed price incentive contract provides the Government a method to select a technology with cost uncertainties. If the contractor can improve the treatment performance the cost savings are shared.

Simple soils and sludge treatment projects are those in which the extent of contamination has been defined and the treatment technology is proven. Minimal additional field work is needed prior to commencing design. Remediation activities can be easily defined in design- and performance-based specifications. An indefinite delivery or time and materials contract can be used in lieu of a fixed price contract if quantity definition is a problem.

Complex soils and sludge treatments and on-site thermal destruction require extensive design and construction activities. These projects involve substantial risk to both the contractor and the Government. A negotiated procurement gives the Government the opportunity to evaluate each offeror's approach to the project. Factors the Government might consider include the technology, work health and safety plan, involvement and protection of the community, quality control and assurance measures, and previous experience in similar type work. This process allows the selection of a contractor that best fits the Government's needs. Specifications for these remedies are performance- and functional-based allowing the Government to consider a range of approaches to the remediation. Quantity definition is often a problem. The amount of data collection needed for design is dependent on the Government's willingness to share in the risk allocation. With known contaminants and technologies, remediation can be expedited through the use of an indefinite delivery or time and materials contract. When considering new and innovative technologies, the Government may wish to further share in the risk and use a cost reimbursement contract. Cost reimbursement contracts require substantial Government contract management. The advantage of their use in new and innovative technologies is that they provide a means for the Government to enhance its knowledge base. Costs involved are actual, not those determined by a contractor trying to consider all possible contingencies during the solicitation. Modification to the technology during the contract is easier to accomplish with a cost reimbursement contract.

CONCLUSION

All hazardous waste remediations do not fit the traditional Government construction project mold. It is often difficult to adequately determine quantities or inappropriate to provide a detailed design. The Government has many options available within the limits of the Federal Acquisition Regulations to select an acquisition strategy for hazardous waste remediations. The key to success is the early selection of a strategy based on the amount of risk the Government wishes to accept. Risk transferred to the contractor impacts directly on the addition of contingency to the offered price.

The fixed price, invitation for bid, design specification approach is acceptable for simple hazardous waste projects . As complexity increases, however, this approach becomes undesirable. Procurement of a complex hazardous waste project must be flexible. The Government and the contractor must have a clear understanding of their responsibilities at a complex remediation if the project is to be successful.

A better approach is the evaluation of each hazardous waste project early in its development and the selection of the proper contract, procurement and specification type. The goal of this procedure should be to select the method that best balances the needs of the Government with the risk of the contractor. There is no reason the Government and the contractors cannot be partners rather than adversaries. Contractor contingency can be reduced by making them feel they are partners in the project, by reducing the risk through negotiation of complex projects, and by sharing risk.

DISCLAIMER

This report has undergone a relatively broad initial, but not formal, U.S. Environmental Protection Agency peer review. Therefore it does not necessarily reflect the views or policies of the Agency. It does not constitute any rulemaking, policy or guidance by the Agency, and cannot be relied upon to create a substantive or procedural right enforceable by any party. Neither the United States Government nor any of its employees, contractors, subcontractors or their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use or the results of such use of any information or procedure disclosed in this report, or represents that its use by such third party would not infringe on privately owned rights.

We encourage your comments on the utility of this paper and how it might be improved to better serve the Superfund program's needs. Comments may be forwarded to the attention of Kenneth W. Ayers, Design and Construction Management Branch, U.S. Environmental Protection Agency, Mailcode OS-220 W, Washington, D.C., 20460.

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VII. PRE DESIGN ISSUES

The Importance of Pre-Design Studies
In Superfund Remediation

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INTRODUCTION

Prior to initiation of the remedial design for the Marathon Battery Superfund Project, a number of complex design and construction issues had to be resolved. This paper focuses on the importance of studies performed after the RI/FS and the ROD were finalized to resolve issues vital to completion of the final remedial design. These included:

- A supplemental sampling program to better define and delineate areas of contamination
- Application of geostatistical analysis methods to evaluate the accuracy and significance of the sampling data and provide a rational, scientific basis for delineating areas for remediation
- Evaluation of the technical feasibility and development of specifications for solidification/fixation of dredged materials
- Archeological investigations to determine the historical significance of areas to be impacted during construction and identify those areas requiring mitigation, and
- Comparison of transport options for movement of construction materials and stabilized waste.

The results of these pre-design efforts substantially affected final design by reducing the proposed remediation zones, developing a balanced transportation plan which will reduce both project costs and local impacts of construction, cataloguing methods and areas for mitigating the impact of construction on potentially significant archeological sites, and identifying areas requiring only partial mitigation.

The effectiveness of these studies in achieving their stated goals at the Marathon site point up the need to assess the adequacy of existing data and evaluating practical alternatives to achieving ROD objectives. Since many of these issues often can not be resolved within the relatively short time frames and limited budgets characteristic of the RI/FS Process, design engineers and regulatory officials must be aware of the critical role additional pre-design studies can play in developing a cost-effective remedial design for a hazardous waste site.

BACKGROUND

Project Location and Description - The Marathon Battery Superfund Site lies on the east bank of the Hudson River, across from West Point and approximately 40 miles north of New York City in Putnam County. The portion of the site addressed in this paper includes part of the river near Cold Spring, NY, and the three wetland areas of East and West Foundry Coves and East Foundry Cove Marsh. Water flows from the Hudson River through a 70-foot passage under a railroad trestle into the 30-acre East Foundry Cove, which is an active fisheries spawning area. Flow then proceeds through a channel and dike system that connects Foundry Cove to Constitution Marsh, a sensitive 281-acre wildlife sanctuary operated by the Audubon Society. The residential and business districts of the town of Cold Spring lie close by to the north, and the site also includes a portion of a significant national historic site, the Old Foundry, to the east. *(Figure 1)*

Between 1952 and 1979, when the facility became inactive, the Marathon Battery plant produced nickel-cadmium batteries, and released treated and untreated production wastewater into East Foundry Cove Marsh and the Hudson River. Concentrations of cadmium, nickel and cobalt in the marsh sediment at the outfall reached levels as high as 171,000 ppm, 156,000 and 6000 ppm, respectively, with concentrations gradually decreasing in East Foundry Cove and Constitution Marsh. Heavy metal wastes are concentrated primarily in surface sediments from 0 to 14 inches deep. The contaminated areas at the site, both exposed and submerged, are affected by 0 to 40 feet of tidally-influenced water. The amount of sediment-bound cadmium was estimated in the RI/FS at 50 metric tons.

To allow for widely varying environmental features and pollutant levels, the site was subdivided into three operable units: Area I consists of East Foundry Cove Marsh and Constitution Marsh, Area II encompasses the former manufacturing site and surrounding grounds, and Area III includes East and West Foundry Coves and the Hudson River near the Cold Spring pier. East Foundry Cove Marsh in Area I is partially isolated from West Foundry Cove and the Hudson River (Area III) by a railroad bed to the west. Remediation of the adjacent Areas I and III will be implemented concurrently.

In-depth (Stages 1A, 1B and 2) archaeological studies were also conducted near proposed staging and treatment areas. The project's environmental and archaeological concerns, along with the impacts of engineering alternatives and the cost of remediation dictated the application of value engineering (VE) studies. In what is believed to be the first application of VE to a Superfund site, the Area I remedial site design was optimized for a potential multi-million dollar savings in construction costs. A comparable value engineering review of Area III will also be implemented.

Project Responsibility - Remediation overview of the site is being directed by the U.S. Environmental Protection Agency (Region II), with project management delegated to the Kansas City District of the Corps of Engineers under an interagency agreement. After completion of the RI/FS by others and issuance of the Record Of Decision (ROD), Malcolm Pirnie, Inc., a consulting environmental engineering firm based in White Plains, NY, was contracted by the Corps to complete pre-design investigations and remedial designs for Areas I and III, along with the Area II plant site.

Pre-Design Recommendations - The ROD recommended that in Area I earthen dikes be constructed around East Foundry Cove Marsh to isolate it from the tidal flushing of the Hudson River. The diked marsh would then be flooded and hydraulically dredged, with contaminated sediment pumped to large settling tanks for mechanical thickening. The VE evaluation of the project subsequently produced a recommendation which eliminated the need for flooding the marsh and mechanical thickening, and included diking, dewatering and mechanically excavating the marsh, and stockpiling and treating the excavated sediment.

The remediation outlined in the ROD for Area III included dredging one foot of contaminated sediment from East Foundry Cove and the Cold Spring Pier area, constructing a series of lagoons for dewatering the dredged materials, solidification/stabilization so heavy metals could not leach to the environment and final disposal of the fixated product in an off-site landfill. Initial pre-design studies, along with the post-ROD decision by the sponsoring agencies to remediate Areas I and III concurrently, led to serious consideration of a revised plan for Area III which included hydraulically isolating East Foundry Cove from the river and Constitution Marsh, hydraulically dredging contaminated sediment from the cove and pond to the diked East Foundry Cove Marsh (in effect, using these diked marsh areas as dewatering and sedimentation basins), excavating the cove and pond dredge spoils from the diked area, treating contaminated sediments and water from the dewatering area, and off-site landfilling of the fixated product. Contaminated sediments in the pier area would be handled similarly.

DISCUSSION

To prepare for the RD phase, several predesign investigations were initiated which had dramatic effects on the ultimate remedial design of the site.

- **Sampling -** At a site the size of Marathon Battery, the soil and sediment sampling program is vital for assessing the specific area and depth of contamination, as well as for defining the volume of contaminated material to be removed, treated and transported. In previous studies, sampling was used to delineate broad areas of contamination. However, these efforts produced only general levels of contamination in generalized areas and lacked clarity in terms of the exact depth and lateral extent of required remediation. Also, these data could not be verified because sampling sites were not accurately located. A comprehensive sampling program was developed to augment the RI/FS, which included soil and sediment for Areas I and III, vegetation in Area I and soil in Area II.

To insure accuracy and allow for replicable results, sampling points were located on gridded site maps and either staked or located electronically, depending on the nature of the site. All samples were analyzed by a Corps-validated independent lab for cadmium, nickel and cobalt, which were used in the battery plant, and lead, which had been found in previous sediments samples and was thought to originate from remnants of the Civil War-era foundry within the site. Cadmium was selected as the key indicator for development of cleanup plans since that was the most toxic metal, as well as the metal present in the consistently highest concentrations.

In Area I, 324 sediment samples were collected from 61 staked sampling points located on a 100-foot grid of the 14-acre marsh. *(Figure 2)* Since the area's dense vegetation – including roots ranging from very fibrous to large and yam-like – precluded obtaining continuous samples, six-inch samples were retrieved from depths up to three feet using a custom-made stainless steel hand-operated corer. Cadmium contamination levels ranged as high as 91,700 mg/kg, with most of the marsh in the hundreds of ppm range. Using these sampling data, excavation plans were initially developed requiring removal of from one to four feet of sediment, depending on the proximity to the tidal channel and outfall, with the deepest excavation to be adjacent to the tidal channel.

In Area III, near the Cold Spring pier, the river area with the highest suspected level of contamination, gridded sampling points were located through electronic positioning to a tenth of a foot. A total of 111 samples were taken initially from 49 river locations (on a 150-foot grid within 300 feet from shore) at depths from 0 to 24 inches around the pier, as well as grab samples from six locations beneath the pier, with four additional samples taken at the adjacent beach. The 150-foot grid was expanded to a 300-foot grid away from the pier.

In East Foundry Cove and Pond, 67 samples were taken from the 0 to 24 inch depth at 39 staked positions, including 30 sampling locations in East Foundry Cove and 9 locations in East Foundry Pond. These were located with an electronic positioning system based on a 250-foot grid. In West Foundry Cove, 26 samples were taken.

Two-phased depositional studies were also implemented for West Foundry Cove to assess the ROD's findings regarding the depositional nature of the Cove. In the first phase, samples from West Foundry Cove were analyzed for cesium as well as cadmium and lead to date the sediment and confirm the depositional characteristics of certain key sub-areas. This was critical in determining whether any remaining contamination would migrate or remain stationary. [A by-product of aboveground testing of nuclear devices, cesium concentrations can be correlated with post-1953 testing activities to date materials.] The second phase of the study, scheduled to begin shortly, involves contaminant flux studies to determine if contamination from West Foundry Cove might be transferred to East Foundry Cove after remediation. While observations determined that some mixing does occur, the net effect was confirmed as depositional.

Cadmium contamination was concentrated primarily in the top four inches of sediment in East Foundry Cove and East Foundry Pond, with cadmium levels in the upper sediment layer of the pond reaching 3520 ppm. Of the locations tested below 12 inch depth in East Foundry Cove, only one in the southern part of the Cove had a detectable amount of cadmium (875 ppm), compared with 145 ppm in the overlying (0 to 4 inch) interval at this location. In East Foundry Pond, only two locations tested below 12 inch depth had detectable amounts of cadmium, which correspond with the highest measured concentrations from 0 to 4 inch depth. *(Figure 3)*

Except for two locations adjacent to the Pier and within the boat club marina where concentrations increased with depth, the Cold Spring pier area also revealed decreasing trends of cadmium with depth. In addition, 21 sampling locations near the Cold Spring pier area from 0 to 4 inch depth and 35 locations from 12 to 24 inch depth had undetectable cadmium concentrations. The highest levels of contamination was found in quiescent zones adjacent to the pier, although the pier structure itself had low to medium concentrations of cadmium. While only low (38.8 ppm) levels of contamination were found on the beach at from 0 to 12 inch depth, the high degree of direct human exposure does warrant excavation of contaminated material in this area.

- **Geostatistical Analysis** - Since the goal of the sampling effort at the Marathon Battery site was to determine the concentration and distribution of heavy metals on the site, geostatistical analysis, a technique originally developed to evaluate concentrations and distribution of ore deposits for the mining industry, was implemented. Geostatistical analysis used the sampling data to model the spatial relationships of the levels and extent of cadmium contamination. It was also expected to offset the variation in sampling data expected from non-static areas such as East Foundry Cove and the Hudson River in the vicinity of the Cold Spring Pier, where tidal flows may alter sampling results.

This type of statistical modeling of contamination concentrations is relatively new to the environmental field. The model used for the Marathon Battery project, the INSITE System Version 4.0. by Geostat Systems International, Inc., is recognized by regulatory agencies and health departments across the country. It provides a broader overview of sampling results than similar programs by producing concentration contours as well as statistical confidence levels, providing more control over the statistical parameters that are applied.

Accurate geostatistical modeling has several important requirements and stages. It is vital to use known accurate sampling coordinates, and samples must undergo stringent quality assurance to insure the accuracy and viability of data. After meeting these two requirements, a basic data analysis of the sampling results from the Marathon site was performed to preview general results and trends. The complete data base was then used to produce a variogram or graphic display of the level of error of the spatial properties and qualities of data. The variogram was used to fine tune the modeling program by graphing the expected variance in error of a projected value over distance and direction, and exploring, checking and validating assumptions regarding site hydrology and contaminant transport mechanisms. The results of the variogram analysis were first compared and contrasted to those of the exploratory data analysis and to baseline data, and then directly incorporated into the geostatistical estimation process of "kriging," which employs geostatistical computation methods to determine the variance of a group of data points as a function of distance from those points.

Used for parameters exhibiting spatial correlation, kriging incorporates the quantification of the correlation structure by the variogram to estimate the values of parameters at unsampled locations and to calculate the corresponding estimation variance for the interpolated values. The variance is a quantification of the lack of data supplying the unknown parameter values. Simply put, kriging uses a search ellipse drawn between three to six samples to create 'working averages' for locations between those sampling locations and to develop levels of confidence for these estimates. To orient results to the physical characteristics of the site, the extrapolated data is then plotted as blocks or contours. *(Figure 4)* As output, each block in the representational model contains a kriged estimate of contaminant concentration and a measure of the kriging error of estimation. Using this graphic display along with the known level of error, one can determine those areas with relatively high concentrations of contamination, and can evaluate the cost impacts of removing different levels of contamination.

From the sampling data collected at the Marathon site, the geostatistical model kriged concentrations of cadmium (in ppm) between the actual sampling points for every 50 feet in five levels of concentration: 0 - 5 ppm, 5-10 ppm, 10-50 ppm, 50-100 ppm, and 100-1000 ppm, graphing each level in a different color as well as determining estimated levels of error for these calculations.

In the kriging process, an estimate with a relatively high level of error not consistent with other sampling findings could drive the model falsely. As a result, it would require clarification either from existing data or through additional sampling to determine whether the high reading was a true hot spot of contamination or an anomaly. (This potential requirement for additional data also points up the importance of strict locational control of all sampling to verify or deny the data necessary to redirect the geostatistical model.)

After the first kriging, additional sampling was conducted to explain isolated high values (with an error of greater than 2.0) which were an order of magnitude higher than adjacent points. Since these sampling data could be driving the statistical model to indicate a larger than necessary area of contamination, the cost of remediating the larger areas far outweighed the expense of additional sampling.

The supplemental sampling was extremely effective: 10 additional samples produced 27 new blocks of estimated concentrations. More importantly, the new data and estimates showed drastically reduced concentrations of blocks registering above 100 ppm in the pier area (which subsequently increased the number of blocks in the 50-100 ppm category). *(Figure 5)*

By using the kriging methodology it was possible to employ a larger, 'coarser', sampling grid in the initial sampling effort. 'Questionable' or 'problem' areas could then be identified via kriging, and resolved via limited, focused additional sampling. The net result was a program that saved significant time and expense for field and analytical efforts and developed critical contamination data far more efficiently.

Determining the level of remediation to be accomplished in Area III (cove and river sediments) was complicated by the fact that the ROD gave no specific numerical contaminant thresholds to be remediated, but, rather, specified that the site be remediated to a depth of 12 inches which would expect to remove "up to 95 percent" of the existing contamination. With no absolute definition of cleanup levels, the geostatistical analysis provided additional guidance in determining the areas and amounts of remediation. As a result, the design team had a rational, logical and replicable data base that provided a firm scientific basis for establishing cleanup standards.

According to the ROD, one foot of sediment was to be dredged from East Foundry Cove. Interpretation of the krig contours indicated cadmium concentrations generally decreased as one nears the water channels in the East Foundry Cove, with measured values of cadmium virtually undetectable in these channels.

These data suggested that cadmium is concentrated in the central depositional area of the Cove and scoured from areas subject to erosion during rising and falling tides. This depositional theory was confirmed by separately kriging the bathymetric data for specific locations in Area III (performed along tracklines spaced at 50 foot intervals) and the sampling data, and then overlaying the two. Kriging the sampling data showed that the increased depth of the subsurface depressions corresponded to lower cadmium levels. The correlation of the two krigs confirmed the scouring action of tidal flow and water movement, and the concentration of contamination in the delta. As a result of these studies, it now appears feasible to limit sediment removal activities to those specific portions of East Foundry Cove with the highest measured levels of contamination as opposed to the recommendation in the ROD of remediating the entire Cove. *This will result in cost savings of up to $10-million by eliminating 16,000 cubic yards of sediment from the remediation process.* Thus, a small investment in additional studies yielded very large returns.

- **Archaeology** - Since the Marathon Battery site includes the West Point Foundry, a national historical site dating from the Civil War, extensive Stage 1A and 1B cultural resource surveys and a Stage 2 archeological field investigation were conducted at areas which could be impacted by remedial activities.

The hazardous nature of the site coupled with tight schedule requirements necessitated alteration of standard archeological practices. Temporary protective enclosures were erected so the archeological work could continue through severe Northeastern winter weather. *(Figure 6)* And because the archeological investigations were being performed at a hazardous waste site, all on-site project personnel people were required to complete health and safety training. Handling methods also needed to be modified.

To minimize exposure of the archaeologists to the hazardous environment and to the winter elements, advanced Rolliometric photographic techniques were used to document excavated areas. *(Figure 7)* This customized highly calibrated, computer coordinated photographic method accurately documents physical features to scale, and eliminates the traditional method of scale drawings by hand and physical measurements of strata and subsurface structures typically completed at the archeological site. Instead, this specialized photographic method produces photos and maps showing the sizes and locations of subsurface archeological sites that can be evaluated off-site with a scale ruler to determine their relative relationships, size and locations.

Three areas of archeological importance have been investigated to date. Initial field studies were completed under the aegis of the Corps of Engineers, and more detailed investigations were subsequently funded under the U.S. EPA's Alternative Remedial Contract Strategy (ARCS) program. These investigations have added significant new information to the history and development of the National Historic foundry site, including valuable data on metallurgy in the later 1800's, and provided new insights into the industrial and technological makeup of the foundry as a critical Civil War defense establishment.

The results of investigations in the foundry worker housing area, which overlaps the site of the proposed haul road, radically changed the existing perception of the ethno/economic status of workers at the old foundry. Based on artifacts and toys found at the site, archaeologists concluded that educated upper class European skilled workers were present among the work force along with the unskilled English and Irish workers previously known to have been employed. The foundry proofing area, the site of the proposed equipment staging and waste stabilization areas, was discovered to be the site of a unique gun testing platform. Covered by four feet of post-Civil War/20th century industrial fill, the platform is the only known testing area in existence that was used for proofing the famous "Parrott Cannon" used during the Civil War. This site will require some degree of avoidance or protection during remediation. Additional studies used remote sensing surveys with electronic instrumentation as well as a historic records search to investigate the cove and river near the pier. Early records as well as the on-site survey and magnetic anomalies revealed evidence of what may be sunken ships or barges.

The result of these archeological studies could have wide-ranging impacts on the remedial design. While no remedial action is expected in West Foundry Cove and remediation in the pier area is not expected to impact historical resources, historical sites in East Foundry Cove may impact the schedule for remediation and require action prior to dredging, with further measures such as avoidance or unearthing the site currently under investigation.

- **Solidification/Stabilization** - The ROD specified stabilizing/fixating the treated material to tie up heavy metals to allow safe disposal of the material. Separate studies were conducted in Areas I and III to determine the technical feasibility of solidification/stabilization on sediments from zthe site. *(Figure 8)*

In Area I, bench-scale and pilot plant treatability studies, with the latter organized as demonstrations by five pre-qualified vendors, tested two types of fixation/solidification processes on representative Area I samples of contaminated marsh sediment with known cadmium concentrations. The vendors used between four and six cubic feet of highly contaminated marsh sediment (average concentrations: 4,700 mg/kg) in the on-site demonstrations to produce either a solid concrete product or a soil-like soft product. After both 7- and 28-day curing periods, samples were sent to a Corps-certified laboratory for Toxicity Characteristic Leaching Procedure (TCLP) toxicity testing. After a total 60-day curing period, additional samples underwent toxicity and long-term biodegradation testing to evaluate the long-term stability of the treated material and its potential for heavy metals leaching from the formed matrix in light of the substantial quantities of large organic material in the marsh sediment, including yam-sized roots from cattails. All five vendors were able to produce a non-hazardous substance after the initial 7-day curing, although the 'soft' product failed the criteria for classification as a non-hazardous substance after the 28-day curing period.

After it was determined that solidification could be successfully achieved to adequately bind heavy metals for treated material from Area I to pass TCLP testing, additional studies were initiated using sediment from Area III to develop an optimum generic solidification/fixation process that would be incorporated into bid specifications to stipulate the required weight and volume of the end product, and to help develop basic design parameters for other parts of the remedial design. This generic formula would provide essential design data on the amount of dewatering required, the ability of the stabilization process to solidify a wide range of sediments, the volume of resulting solidified material expected, and the optimum fixating agents.

Since cadmium exhibits varying degrees of adsorption based on particle size which would affect the solidification formulations, the two distinct types of sediment from Area III were utilized: "coarse" (with more than 90 percent sand), and "fine," which constituted the majority of the sediment (90 percent or more silt and clay). The laboratory experiments used five gallon sediment samples from three site areas – the pier area, East Foundry Cove and East Foundry Pond. Prior to initiating laboratory work to develop the generic solidification formula and determining the total volume of solidified material, questions were raised as to whether all the sediment would require solidification as hazardous waste. As a result, untreated samples were analyzed for total cadmium and lead, and were also subjected to TCLP analysis. After graphing in-situ cadmium concentration against TCLP leachate values from the samples, it was determined that the fine sediments tended to "hold" cadmium and lead and exhibited much lower TCLP results than coarse sediments. As a result, *it is likely that substantial amounts of sediment from the pier area, pond and cove will not be classified as hazardous waste and will require only dewatering and landfilling instead of the more costly solidification/fixation.* Actual amounts will depend on the mixing and dilution that occurs, and can only be determined during actual dredging.

In East Foundry Cove and Pond, various ratios of sediment were tested with six fixation additives using different levels of water contents to develop optimum generic formula. Findings from this study are currently being expanded using one cubic yard of a blended mix of sediment from the three areas to test the selected formula on a larger scale. This fixation formula will then be used on all dredged stockpiled sediment materials which fail to meet TCLP restrictions.

An additional study is currently evaluating the potential for thermal reduction of marsh sediment, which is characterized by heavily contaminated organic peat moss. The economic and technical feasibility of mobile on-site incineration is being evaluated for its potential to reduce the peat content and ultimately the volume of material to be treated and disposed. This testing is extremely site-specific and could also have major impacts of remedial design and final project cost.

- **Transport Options** - With approximately 150,000 cubic yards of dredged material to be transported, materials handling is a major issue that must be addressed during design. Remediation will require transport of quantities of clean sand and gravel as well as heavy equipment into the site, and the transport of fixated dredged material to an ultimate disposal site. In an initial pre-design transportation study, several alternatives were evaluated to determine the most efficient method of transporting large quantities of materials, personnel and equipment to and from the site.

Truck transport along local roads and/or a haul road, water and rail transport were evaluated for cost, efficiency and impact on the local population and infrastructure. The Marathon site has no easy public access. The narrow local roads built in the early 1800's pass through the Village of Cold Spring's Historic District, known for its 150-year old buildings, antique shops and tourist attractions. Since prolonged truck traffic could affect the structural integrity of these buildings, and would severely restrict local traffic throughout the work day along with raising sensitive public concerns and giving the project unwanted visibility, the local road option was eliminated.

Water traffic via barges was eliminated since barge entry to the cove was restricted by the railroad crossing and this alternative would limit options for ultimate disposal of the fixated material or mandate double handling for transport to the final disposal site.

The rail spur option, the easiest to construct from an engineering aspect, could link to a commuter/freight line which runs adjacent to the site. Built directly on an old rail bed used in the 1800's, the spur could be used for transport of fixated material. *(Figure 9)* However, further study determined that rail transport alone would greatly restrict site access since equipment shipments would merit only "secondary" scheduling priority, and could not be delivered on an as-needed basis. In addition, rail transport of new construction materials (i.e., earth, gravel, etc.) was found to require specialized facilities for unloading. This construction was determined to be difficult and costly due to the constricted site and numerous archeological concerns.

The use of a separate haul road would remove truck traffic from the center of town but may also require additional archeological mitigation since it passes through a portion of the Old Foundry historical site. In addition to these archeological concerns, the local geography of steep embankments would require terracing and switchbacks to reduce the grade and improve stability. Despite these requirements, extensive economic analysis points to the haul road as the favored option. Construction priorities are now being evaluated to determine the measures necessary to mitigate impacts on archeological areas; an archeological data recovery program appears likely.

CONCLUSION

The final remedial design for the Marathon Battery Site is expected to be completed during the summer of 1991. In completing the design for this complex site, pre-design studies have been vital in redefining the area and type of remediation as well as in identifying other steps critical to successful completion of the project.

In undertaking future remedial designs, it is important to remember that the process of developing an RI/FS and ROD for a site deals with "big picture" issues. It cannot be expected to answer all of the questions which must be addressed before a detailed remedial design can be completed. The experience we have discussed in this paper makes a strong case for planning adequate time and budget for performance of additional site investigations in preparation for the remedial design. These additional investigations can pay big dividends by defining the actual contamination in a way that the RI/FS typically does not, and by exploring viable alternatives for achieving the intent of the ROD. The result is a more complete, practical and cost effective remediation.

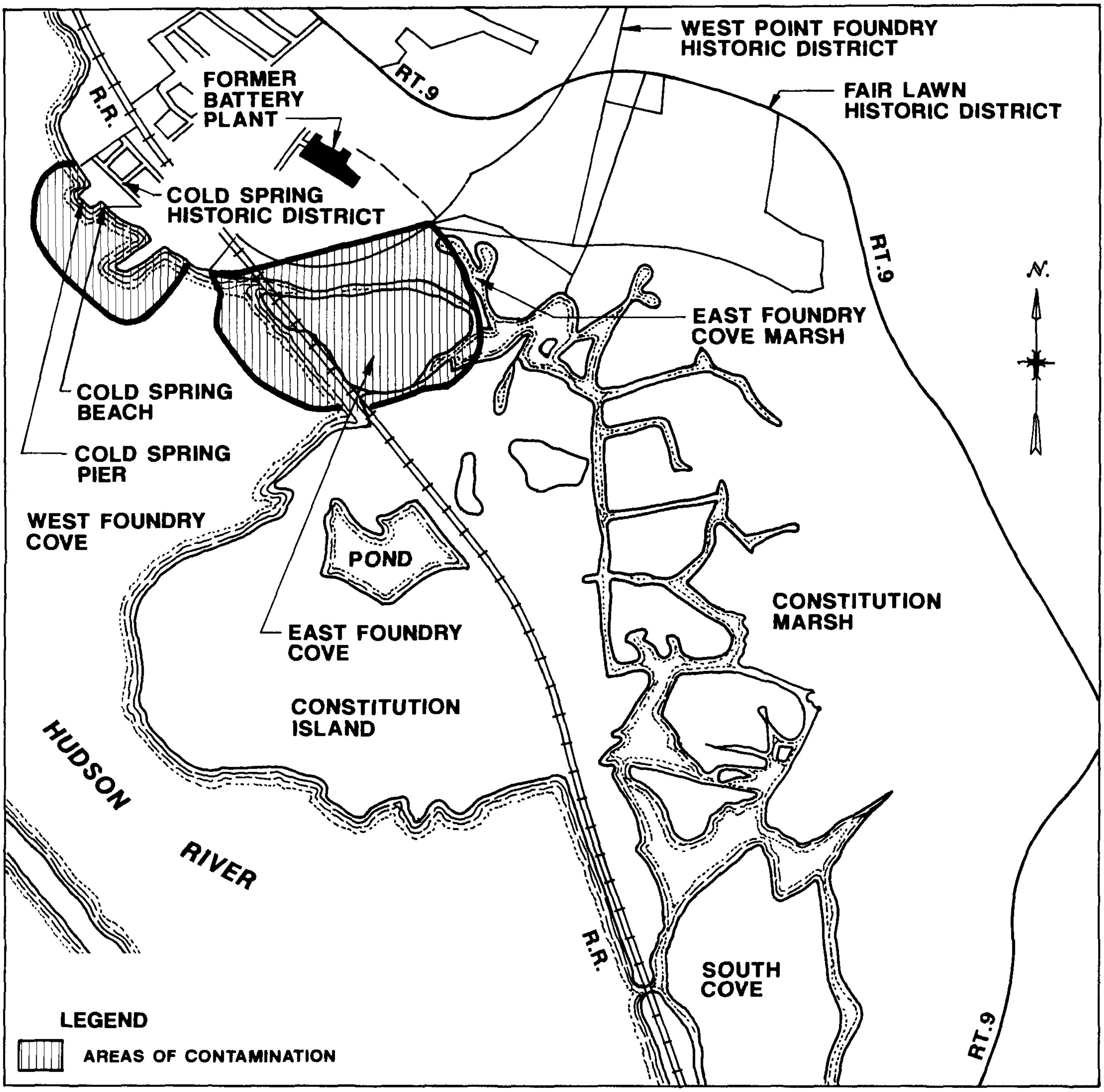


FIGURE 1

The Marathon Battery site lies on the Hudson River adjacent to Cold Spring, New York. Contaminated areas are shaded.

FIGURE 2

Supplemental pre-design sampling points in East Foundry Cove Marsh were located on a 100 foot grid.

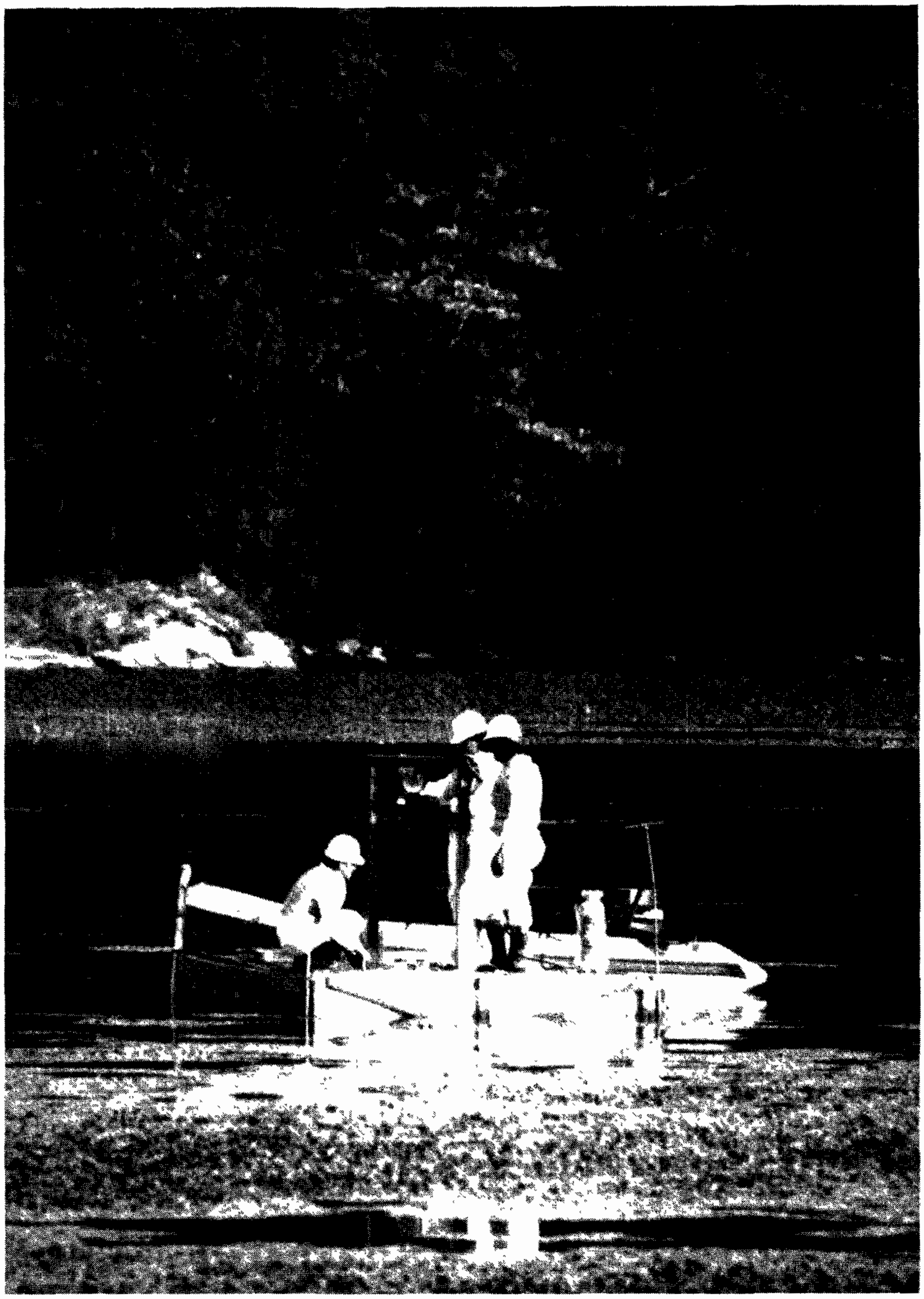


FIGURE 3

Targeted sediment sampling better defined contaminated areas and significantly reduced remediation in East Foundry Cove.

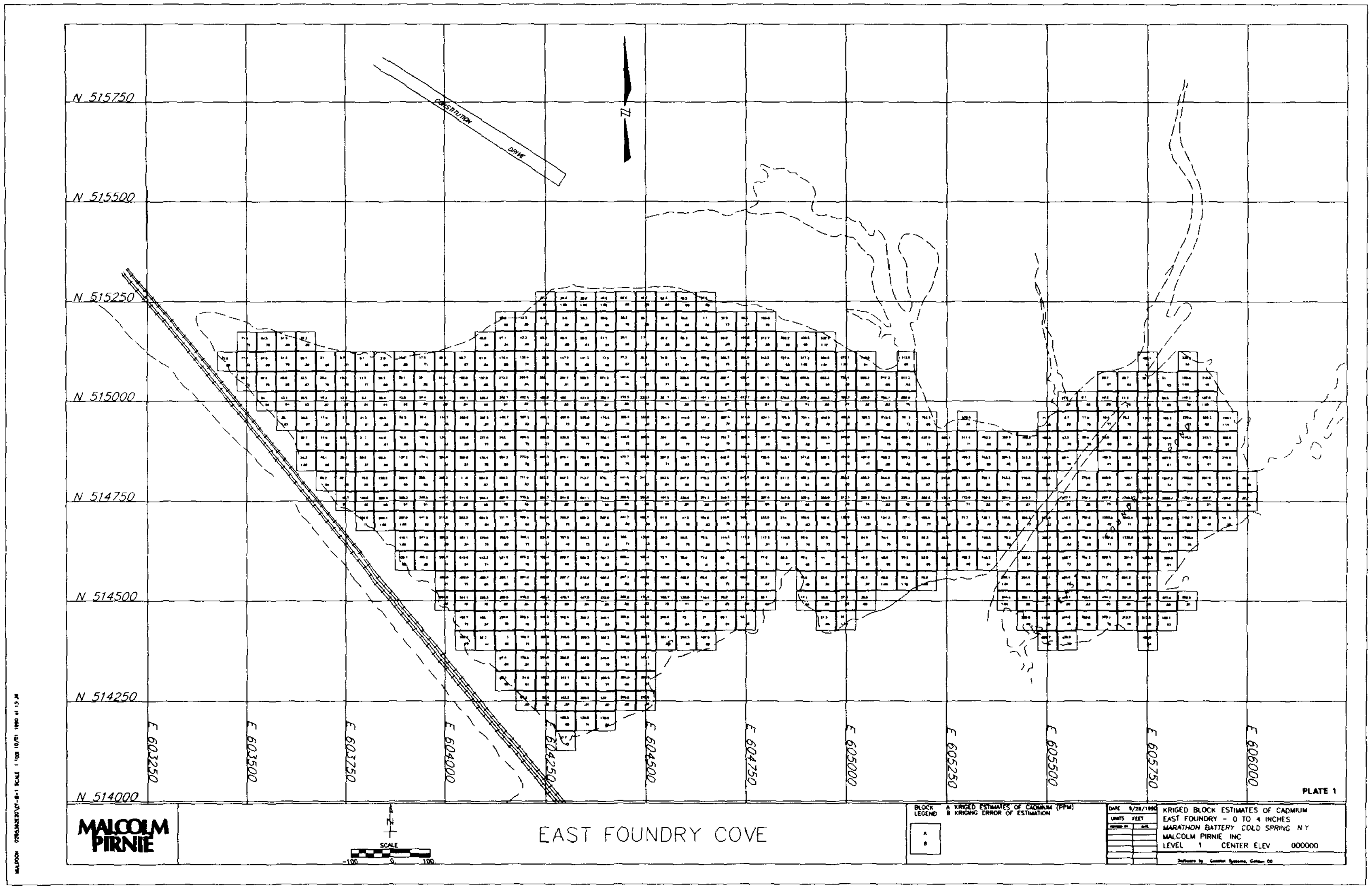
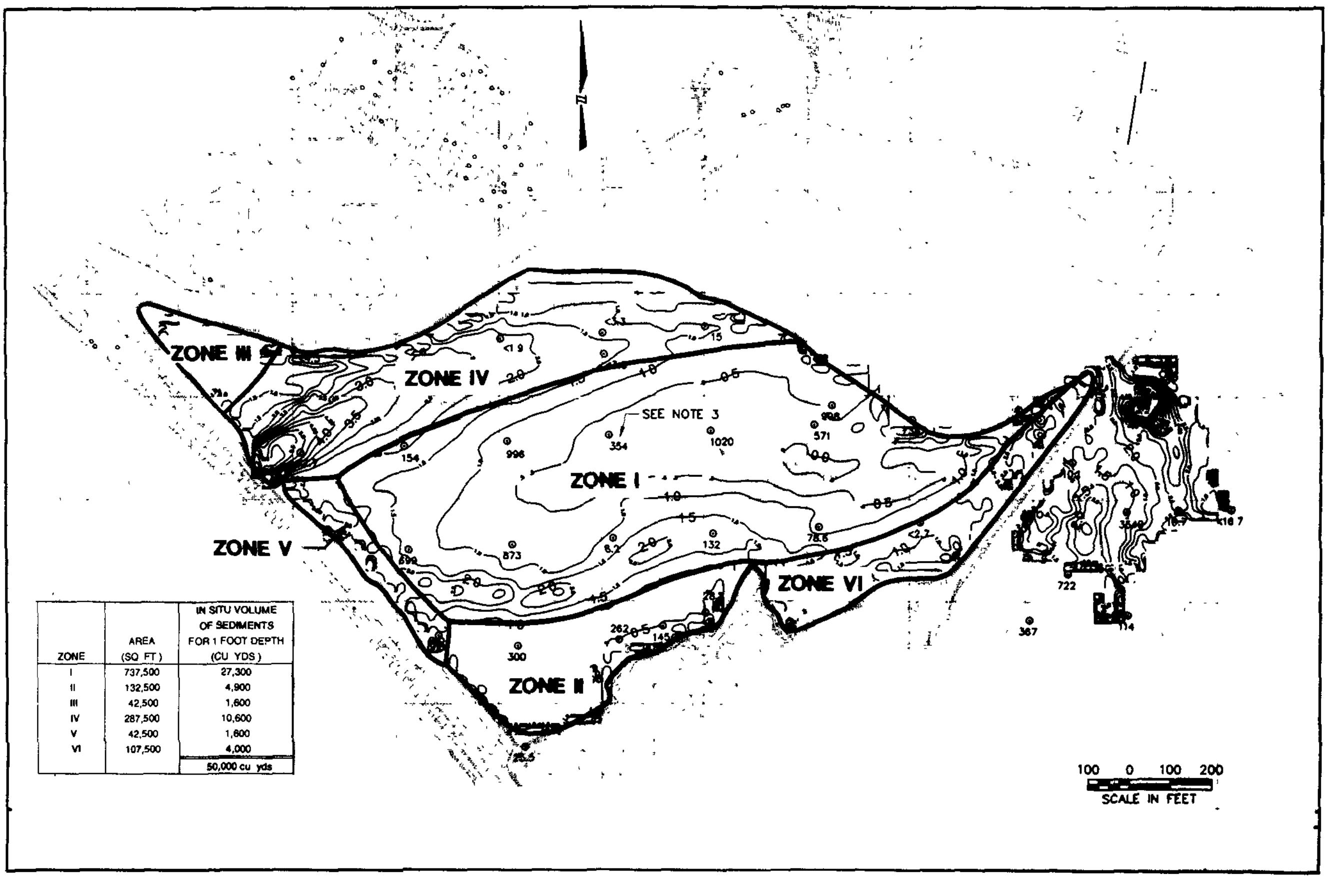


FIGURE 4

"Kriging" was used to evaluate field data and determine additional sampling needs.



ZONE	AREA (SQ FT)	IN SITU VOLUME OF SEDIMENTS FOR 1 FOOT DEPTH (CU YDS)
I	737,500	27,300
II	132,500	4,900
III	42,500	1,600
IV	287,500	10,600
V	42,500	1,600
VI	107,500	4,000
		50,000 cu yds

FIGURE 5

The supplemental sampling program revealed distinct zones of contamination in East Foundry Cove.

FIGURE 6

Temporary protective enclosures allowed archeologists to work in severe winter weather.

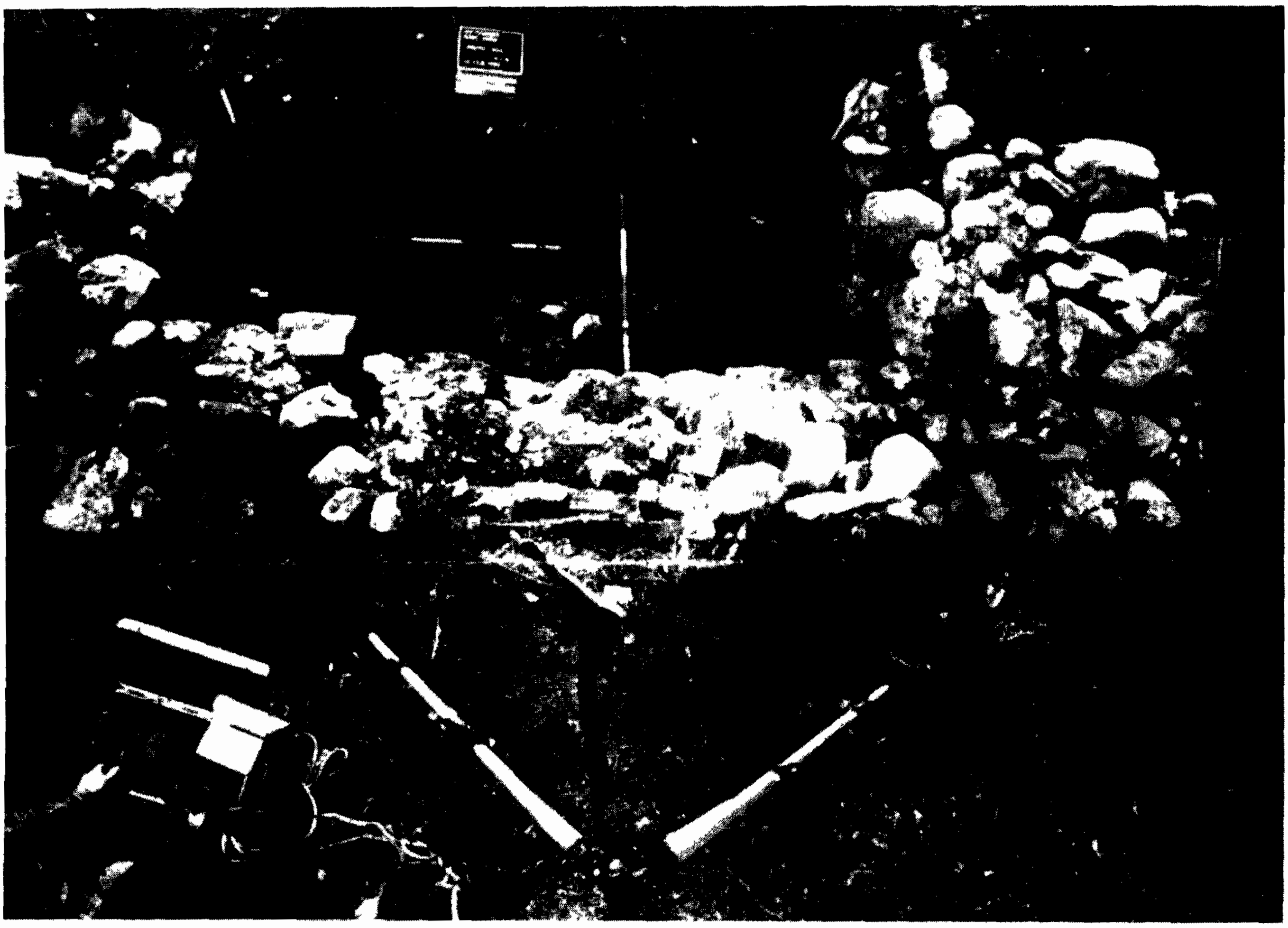


FIGURE 7

Advanced Rolliometric photography methods were used at the site to document excavated areas.

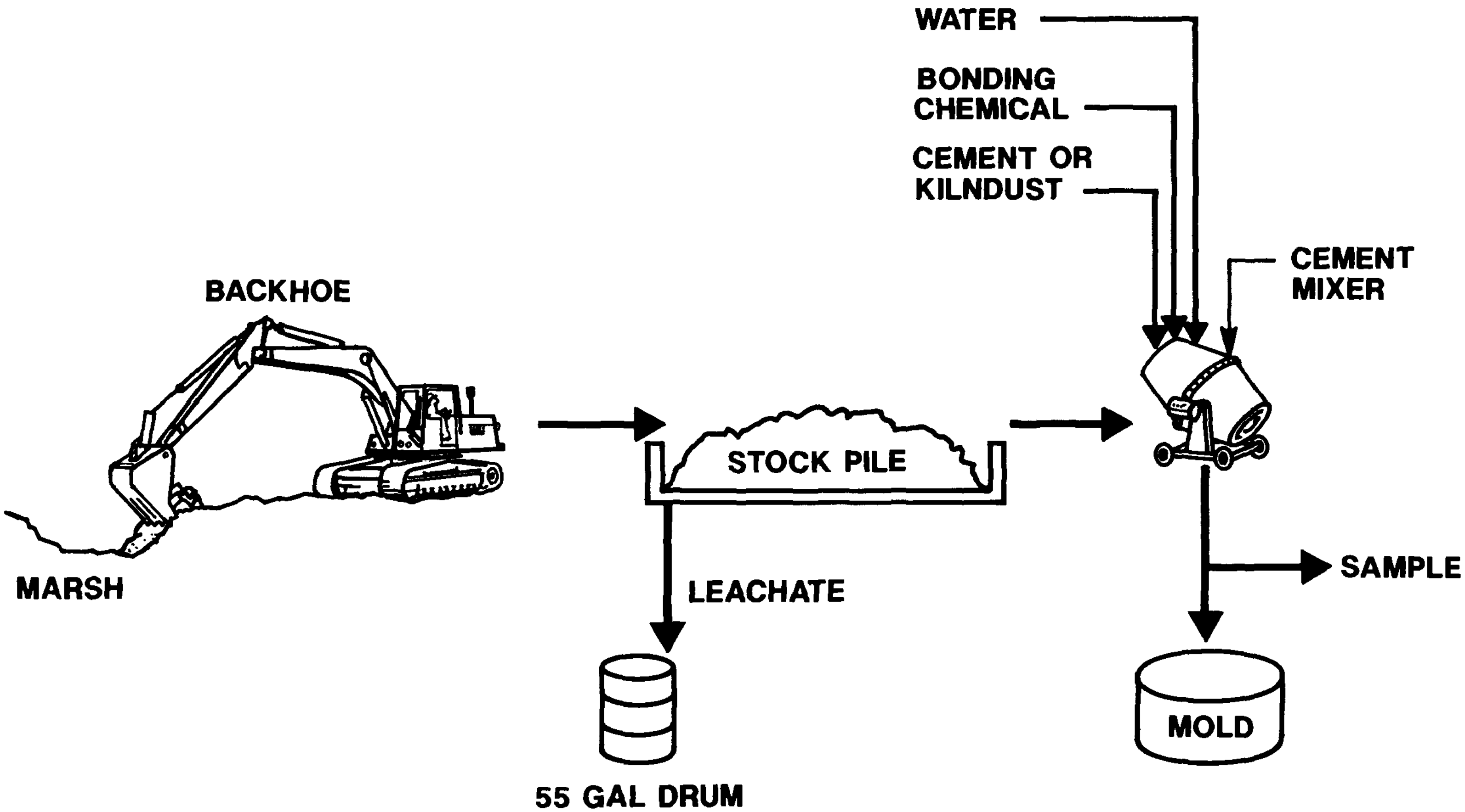


FIGURE 8

Extensive bench and pilot scale testing was performed to develop waste solidification procedures.

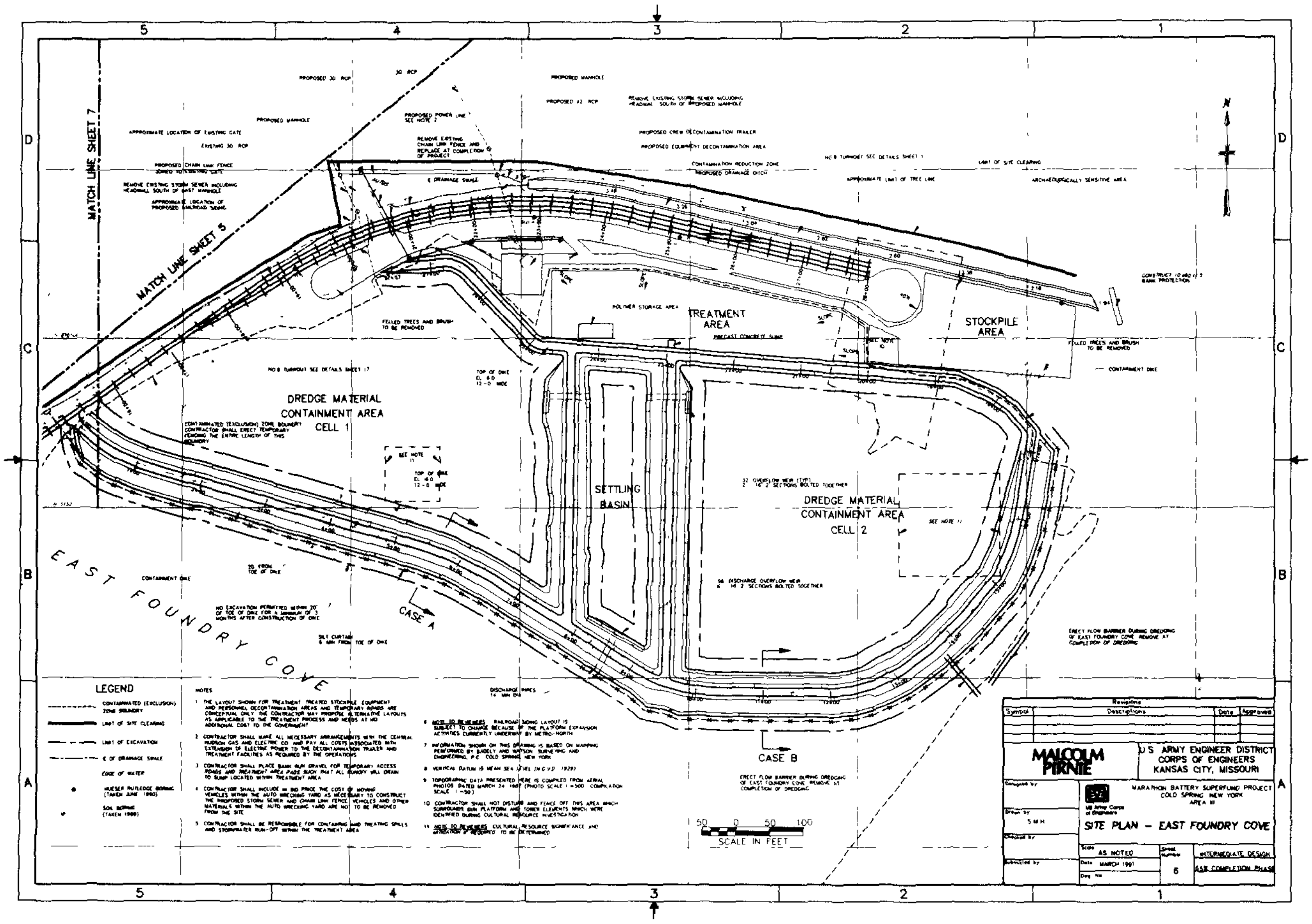


FIGURE 9

The proposed design incorporates areas for dewatering and fixation of dredged material along with a rail siding for off-site transport.

RI/FS and ERA Impacts on RD/RA at Superfund Sites

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INTRODUCTION

This paper discusses two concepts used during the Remedial Investigation/ Feasibility Study (RI/FS) process to expedite the Remedial Design/Remedial Action (RD/RA) at a National Priorities List (NPL) site: the interactive or phased RI/FS and the Expedited Response Action (ERA).

The site, located in the City of Columbus, Bartholomew County in central Indiana, was previously a small metal plating operation. Existing data collected by the State health department and the Indiana Department of Environmental Management (IDEM) indicated that soil near the site had been contaminated with various metals and cyanide.

A fast tracked approach for site remediation was facilitated by successful use of the interactive process to guide the RI, risk assessment, and FS phases of the project. The current National Contingency Plan (NCP) and Recent USEPA guidance (EPA 1988) introduced the interactive or phased methodology as a dynamic and flexible process that enables an effective RI/FS to be performed in a timely and cost efficient manner. The premise of the phased approach is that the level of investigation and analysis required in an RI/FS is determined by constant adjustment of investigation goals as new data is obtained. The goal is to collect sufficient data to support an informed decision regarding which remedy appears to most appropriate for the site - not the unobtainable objective of eliminating all uncertainty associated with decision making. Although explicit in the current NCP and EPA RI/FS guidance, experience has shown that interactive approach is sometimes employed ineffectively due to a reluctance to deal with uncertainty. This paper demonstrates that the interactive RI/FS process is a sound approach to conducting and RI/FS.

Key to the interactive process is the early formulation of remedial objectives. The remedial objectives formed through the interactive approach permits innovative methods, such as the ERA, to be employed during an RI/FS to expedite a RD/RA. The ERA that was performed at the site during implementation of the RI/FS, was ultimately consistent with the final remedy, greatly streamlined the decision process in the FS and simplified implementation of the RD/RA.

BACKGROUND

Site History and Description

The Tri-State Plating Site is located at 1716 Keller Avenue in Columbus, Bartholomew County, Indiana in a residential and small business area. The site encompasses an area of approximately 130 feet by 120 feet and formerly contained a main electroplating process building with two attached sheds, a storage building located immediately northwest of the main building, and an open yard approximately 60 feet by 100 feet adjacent to the north side of the main building. The site plan and onsite monitoring well locations are shown on Figure 1. The area surrounding the site and off-site monitoring wells are shown in Figure 2.

Metal plating operations were performed at the site for over 40 years until it was closed in May, 1984. The plating activities consisted of three major phases. In the first phase, the item was cleaned with an alkaline cleaning solution and wire brushes. This process occurred primarily outside the buildings in the north yard, with the spent solutions being dumped onto the ground. After cleaning, the item was rinsed in water, then hydrochloric acid, then water. This process occurred in several tanks located inside the building. The second phase of the operation consisted of the item being placed in a vat containing a nickel solution, followed by another rinse, then placed into a "black" chrome solution vat. The solution in this phase also contained cyanide, cadmium, copper, lead and other metals. Finally the third phase consisted of sanding, polishing, inspection and boxing for shipment. During the plating operations chemicals from the solutions being used were allowed to drip on the floors while transferring between tanks. The floors were subsequently washed down and the chemicals were discharged to the local combined storm/sanitary sewer system. These discharges finally resulted in a "shock" load to the local POTW that interrupted the biological treatment processes, and ultimately led to the plating operations being closed permanently.

Numerous site investigations were performed prior to the RI, to collect site specific data to characterizing contamination at the site. The major compounds found in the soils were detected at maximum concentrations as follows:

	Pre-RI Data	Phase I/II RI Data
Cadmium	1,600 mg/kg	56.7 mg/kg
Chromium (total)	52,000 mg/kg	16,400 mg/kg
Copper	7,200 mg/kg	80 mg/kg
Lead	170,000 mg/kg	156 mg/kg
Nickel	2,400 mg/kg	46.3 mg/kg
Cyanide	300 mg/kg	46 mg/kg

Geology

The City of Columbus is situated on the southwestern flank of the Cincinnati Arch and the northeastern rim of the Illinois Basin (Hill 1981). This location is characterized by Mississippian and Devonian sedimentary rock formations which dip gently westward. Beneath the study area,

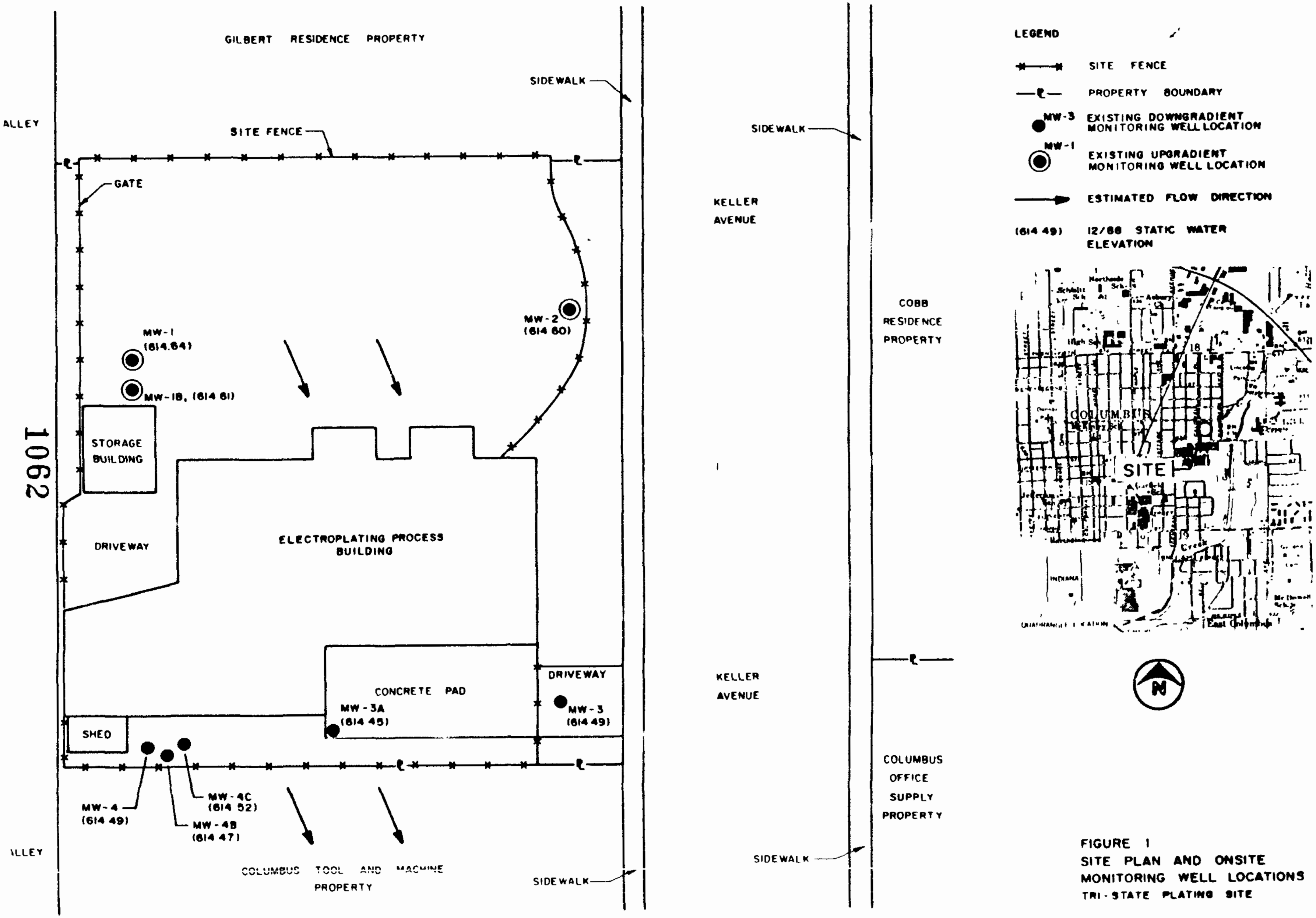

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FIGURE 1
SITE PLAN AND ONSITE
MONITORING WELL LOCATIONS
TRI-STATE PLATING SITE

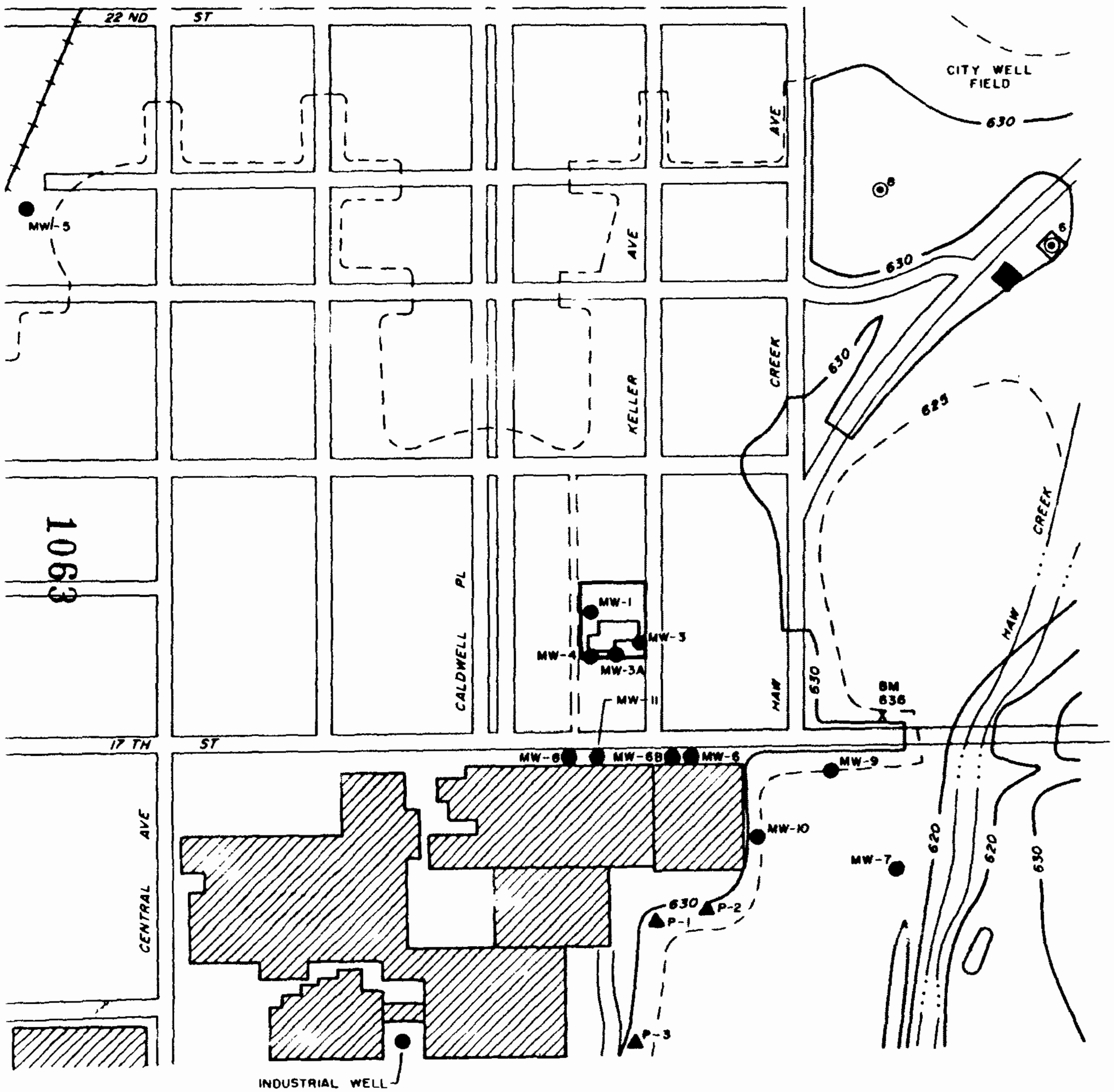


FIGURE 2
EXISTING AND PREDESIGN MONITORING WELL LOCATIONS

limestone and dolomite units of the Middle Devonian Muskatotuck Group occur at depths ranging from 95 to 135 feet. East and west of the study area, the Upper Devonian New Albany shale is encountered at shallower depths. The juxtaposition of the older Muskatotuck group exposed between younger formations creates a wide bedrock valley beneath Columbus. The bedrock valley is filled by stratified sand and gravel outwash deposits laid down during the Wisconsinian Glaciation. A generalized geohydrologic section of the study area is presented in Figure 3.

Dolomite underlies the site at a depth of 119 feet. The outwash in the vicinity of the site consists of alternating sequences of sand and gravelly sand. Thicknesses of individual layers range from a few inches to a few feet. In the vicinity of the site, the outwash deposits are covered by 3 to 8 feet of silty and clayey sediments of recent alluvial origin.

Major drainage systems in the area include the Driftwood River, Flatrock River and the East Fork of the White River. Haw Creek, a tributary of the Flatrock River flows northeast to southwest through the study area, passing approximately 500 feet east of the site.

<u>Hydrology</u>

Groundwater in the study area is unconfined and found approximately 20 feet below the ground surface at an elevation of approximately 614 ft. above Mean Sea Level (MSL). Local hydraulic gradients are flat ranging from 0.0015 ft/ft to 0.002 ft/ft. The aquifer is highly permeable with hydraulic conductivities ranging from 1700 gpd/ft sq (8 x 10^{-2} cm/sec) to 5900 gpd/ft 2 (2.8 x 10^{-1} cm/sec) (Watkins and Heisel 1982). Despite the low gradients, rather high flow velocities ranging from 1.6 to 3.2 feet per day occur in the study area.

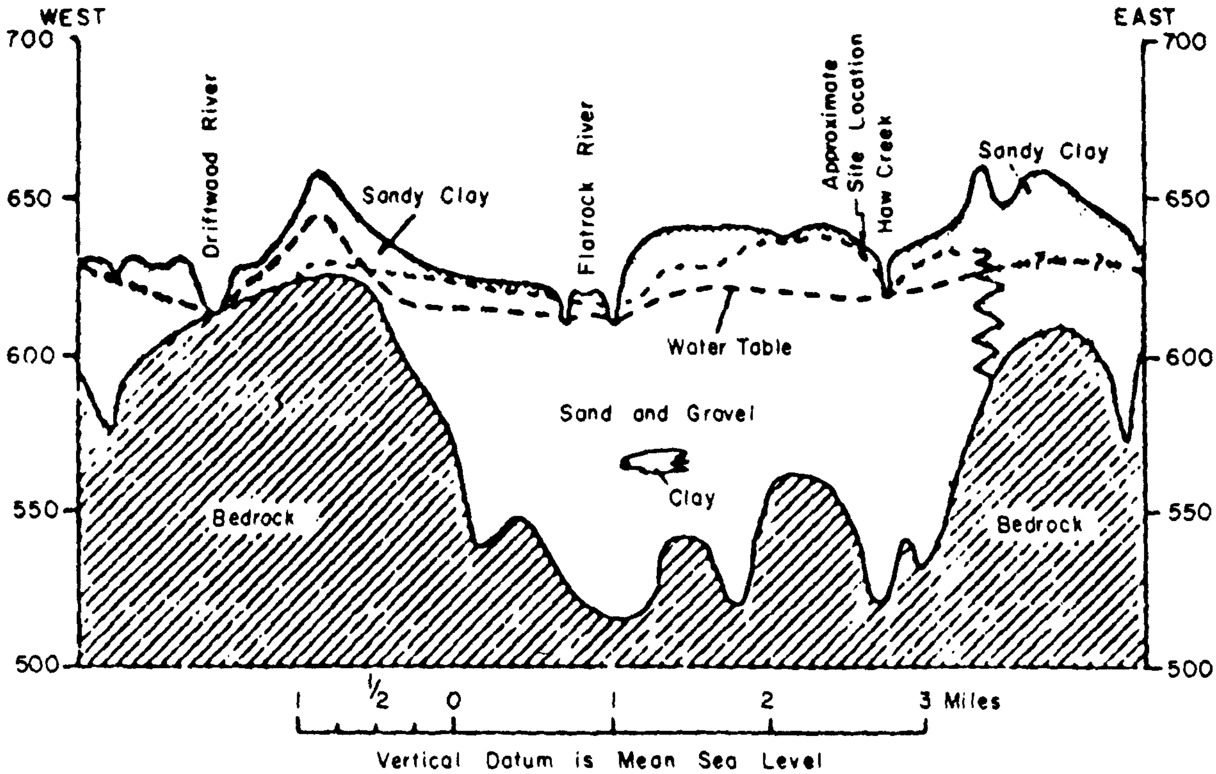
The stratified sand and gravel deposits are an abundant source of potable water. The City of Columbus secondary wellfield, consisting of nine wells drilled to 110 ft., is located 800 feet northeast of the site. The secondary wellfield is usually pumped 500,000 gallons per day (gpd) during winter months, 2,000,000 to 3,000,000 gpd during spring and 5,000,000 gpd during the summer. These rates are on the increase due to the recent drought that has affected the midwest and other parts of the country.

The aquifer is also used for industrial purposes. A significant amount of water is withdrawn from the aquifer by several industries located 250 to 800 feet south of the site. The closest industry withdraws approximately from 300 to 500 gpm about 260 days per year.

Under normal conditions, regional groundwater flow is influenced by the heavy pumping demands from the public well field and industrial users. Near the site, influences from the well field are minimal, however flow direction does appear to be influenced by an industrial well located south of the site. A water table contour map, constructed from monitoring well and piezometer water level measurements in April, 1990 is shown in Figure 4. Although not observed during the investigation, it is expected that the natural regional flow when no pumping occurs is southeastward towards Haw Creek.

<u>DISCUSSION</u>

A fast tracked approach for site remediation was facilitated by successful use of the interactive process to guide the remedial investigation (RI), risk assessment, and feasibility study (FS) phases of the project towards ultimate site remediation. Key to the success of the interactive approach



SOURCE: Watkins, F.A. and Heisel, J.E. Electrical - Analog - Model Study of Water Resources of the Columbus Area, Bartholomew County, Indiana. U.S. Geological Survey and Indiana Department of Natural Resources, Water-Supply Paper, 1981.

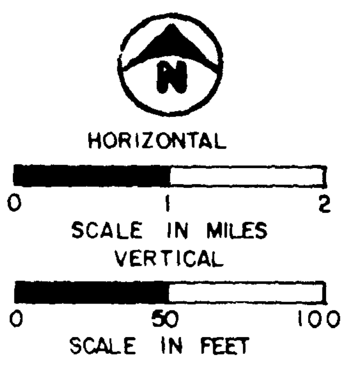
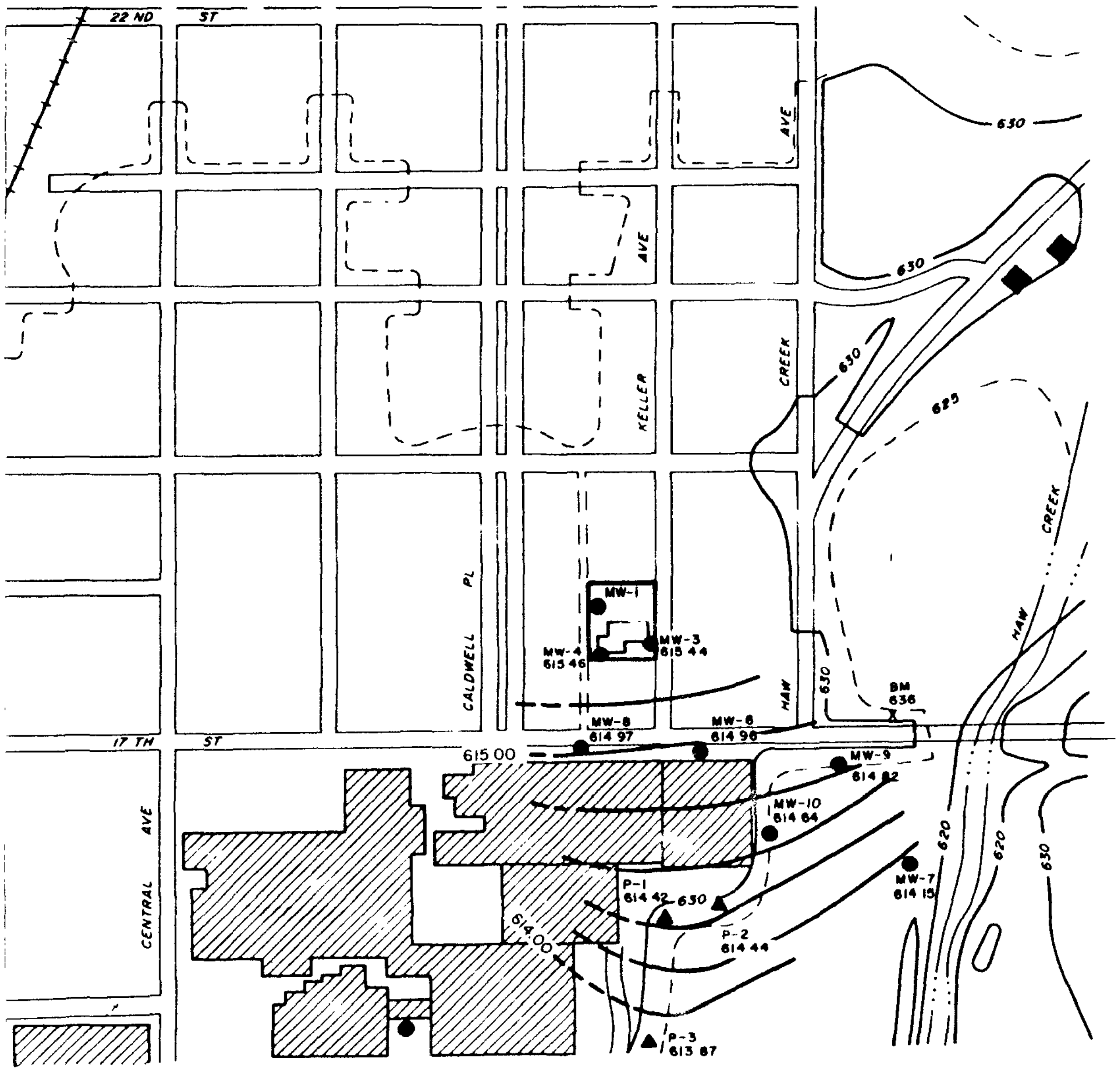


FIGURE 3
GENERALIZED
GEOHYDROLOGIC
SECTION
TRI-STATE PLATING SITE



LEGEND

● MW-7 MONITORING WELL

▲ P-3 PIEZOMETER

SOURCE

USGS 7.5' TOPOGRAPHIC MAP
COLUMBUS QUADRANGLE, INDIANA,
DATED 1962, PHOTOREVISED 1980,
SCALE 1" = 2000'

N

0 250 500
SCALE IN FEET

FIGURE 4
APRIL, 1990
WATER TABLE CONTOURS

was the early establishment of preliminary remedial objectives. As site characterization progressed, it was realized that early formulation of preliminary remedial objectives and cleanup action levels could be supported by the initial data base. The preliminary remedial objectives developed through the interactive process helped to overcome several severe data gaps and assisted in guiding site characterization towards a selection and implementation of the final remedy. It also led to the performance of an ERA. The following discussion summarizes each component of the project from the aspect of how the results were interactively used to guide the next step toward the ultimate site goal of groundwater remediation.

Phase I RI

The purpose of the Phase I RI was to characterize contamination in several media with the intention that several exposure pathways would be evaluated. Phase I included the collection of building wipe samples, surface and subsurface soil samples, sewer soil samples and groundwater samples. The samples were analyzed for volatile organics, extractable organics, metals, cyanide and hexavalent chromium. Based on the results of past IDEM groundwater sampling, it was initially assumed that a groundwater contamination problem was probably not associated with the site. Therefore, the initial RI groundwater investigation was minimized, developed basically to encompass the site with four shallow wells (MW-1, 2, 3, and 4) to collect samples to confirm this assumption.

The Phase I groundwater investigation provided data from four newly installed wells plus two additional industrial wells located south of the site. Water level data indicated that wells MW-1 and MW-2 were upgradient and MW-3 and MW-4 were downgradient of the main process building. The analytical data revealed groundwater contamination at the downgradient site boundary in MW-4. The groundwater was contaminated primarily with metals, specifically high concentrations of chromium in excess of Federal Maximum Contaminant Levels (MCLs). The total and hexavalent chromium concentrations at MW-4 were 1,620 and 1,600 ug/l, respectively. MW-1 also had elevated levels of chromium (total 46 ug/l, hexavalent 50 ug/l). Detectable levels of chromium were not found in MW-3 or MW-2 on the east side of the site nor in the industrial wells sampled downgradient of the site. Traces of phthalates were also detected but these low levels were attributed to typical laboratory contamination from plastic laboratory equipment. Other organic compounds were not detected.

The Phase I results indicated that an additional phase of investigation was necessary to delineate the extent of the groundwater problem. Prior to developing a Phase II work plan, it was decided that a preliminary public health evaluation should be conducted to evaluate risks, so that the appropriate extent of additional investigations be determined. This preliminary PHE was performed during the Phase II Work Plan development.

Preliminary PHE

The preliminary PHE examined risks in several exposure pathways, including direct contact with building interiors and soils, incidental ingestion of soils, inhalation of chromium contaminated particulates and ingestion of contaminated groundwater. The preliminary PHE found that risks in most pathways were within acceptable levels. The deteriorating buildings, however, presented a direct contact and physical hazard and the groundwater exposure route remained a potential problem.

A comparison to applicable standards and criteria was made for the contaminants found in the groundwater at the site. CrVI is a non-carcinogen by ingestion. The MCL for total chromium in drinking water is 50 ug/l. Two onsite wells had CrVI concentrations of 50 and 1,600 ug/l. Potential risk through ingestion of groundwater containing Cr VI were evaluated using standard techniques recommended by EPA (EPA 1987). Risks were examined for two current and future-use exposure scenarios; (1) groundwater reaching a domestic well and (2) groundwater reaching Haw Creek. For both the average and plausible maximum concentration the hazard index was calculated to exceed 1, indicating a potential for adverse non-carcinogenic health effects.

A simplified dilution model was employed to assess the future leaching of chromium into the groundwater. The future groundwater concentration resulting from leaching from soils was estimated to be 70 ug/l. Since the phase I RI data showed groundwater concentrations to be significantly higher, it was probable that soil concentrations somewhere under the main process building were releasing significant levels of contaminants.

Subsequently, a revised work plan was developed to establish a sampling plan for addressing the groundwater contamination problem. The PHE also led to the ERA.

<u>Engineering Evaluation/Cost Analysis (EE/CA)</u>

The initial approach towards site remediation was planned along the usual RI-FS-ROD-RD-RA sequence used on many superfund projects. However as site characterization progressed, it was realized that the preliminary remedial objectives developed through the interactive process indicated a need to address contaminated soils as a source of contamination.

Based on the preliminary PHE it was determined that although there was no immediate threat, it was possible that some time in the near or distant future this threat could be realized. A mechanism that would address the contaminated source and allow a cleanup that would protect public health, and at the same time potentially reduce investigative dollar expenditures was extremely desirable. Exploration of the available programs led to the decision to attempt a non time-critical removal effort under an Expedited Response Action (ERA). The first step under this mechanism is the EE/CA report.

The EE/CA is very similar to a focused feasibility study. Once the decision to conduct the Expedited Response Action (ERA) has been made, basic guidelines for determining the suitability of an ERA must be met before initiation of an EE/CA. The criteria include the following:

- That a threat exists sufficient to meet the removal criteria as specified in the National Contingency Plan (NCP).
- The existing threat does not warrant a time-critical removal action to immediately mitigate the threat.
- The ERA is consistent with the final remedy and attains or exceeds applicable or relevant and appropriate public health and environmental requirements.
- The remedy can be accomplished within the statutory limits of $2 million for cleanup costs and 12 months for completion of the ERA.

If these criteria are met, the remedial contract A/E firm may begin generation of the EE/CA report.

At that time, in USEPA Region 5, the large majority of EE/CA's are prepared by A/E firms under the Removal Program. Depending on the complexity of the site and any additional data that must be obtained prior to the selection of the recommended removal action alternative, EE/CA's generally are completed within two months. The cost of preparation of the EE/CA is typically $100,000. The Removal Program in Region 5 has overseen the preparation of EE/CA's by A/E firms that range from a minimum cost of $40,000 to those that exceed $150,000 and have taken as short as four weeks to in excess of three months for preparation and submittal of the final document. The EE/CA cost analysis level of effort was greatly reduced by using the generated output of the CORA cost model supplemented with the A/E firm's further analysis and input. A final EE/CA for Agency review was completed within two weeks at a cost of less than $10,000. This is a significant cost and time savings as compared to previous EE/CA submittals in Region 5.

The identification of potential removal action alternatives based on CORA and augmented by the A/E firms judgement and experience indicated that the site remediation should be broken into two categories; soil removal alternatives and building removal alternatives. Both of these source control alternatives were measured against the "no action" alternative, which is used as a baseline against which the adequacy of other alternatives can be measured. Under this "no-action" alternative, adequacy of other alternatives can be measured. Under this "no-action" alternative, no funds are expended for monitoring, control or cleanup of the contaminated soil. Based on the standard selection criteria, the recommended removal alternative was off-site landfill with building decontamination and demolition. This alternative was the most technically reliable for eliminating the potential migration of contaminants to groundwater. It was the most costly option at $970,000 but it eliminated wastes currently in place near residential areas while providing the least environmental impact to the site area.

1989 Expedited Response Action

The performance of the ERA was an innovative approach which expedited site cleanup, greatly streamlined the decision process in the FS and simplified implementation of the RD/RA.

The concentration of site related contaminants encountered at the Tri-State Plating Site were considered sufficient cause to warrant a removal action as set forth in Paragraph (b)(2) of Part 300.65 of the NCP. Criteria for implementation of removal actions in the NCP include:

- Actual or potential exposure to nearby populations, animals, or food chain from hazardous substances or pollutants or contaminants;
- Actual or potential contamination of drinking water supplies or sensitive ecosystem;
- High levels of hazardous substances or pollutants or contaminants in soils largely at or near the surface, that may migrate; and,
- The absence of other Federal or state response and enforcement mechanisms to respond to the site.

The contaminated and deteriorating structures and the amount of contamination remaining in subsurface soils continued to pose potential threats to the public and environment near the site. Based on the EE/CA source control removal action was proposed to prevent contaminants remaining in the subsurface soils from continually leaching to groundwater. The detailed plans, Technical specifications and Health and Safety Procedures for the ERA were documented in the "Contract Documents for Construction of the Tri-State Plating Site Expedited Response Action" released in December, 1988.

Under the direction of USEPA, the REM IV Team planned a remedial action designed to remove materials at the site that could cause harmful levels of contamination to be released to ground water. The plan called for the removal of the contaminated structures and soils averaging more than 57 mg/kg total chromium. This action level was based on a leaching model which estimated the average level of contamination which could remain in soil without resulting in groundwater concentrations in excess of the MCL for chromium of 50 ug/l. The leaching model was documented in a Technical Memorandum to USEPA (Brown and Buchovecky, 1988).

The removal program started in February, 1989 with an extensive soils investigation to delineate soils in excess of the cleanup action level. The sampling program involved the drilling of 18 exploratory soil borings and the collection and analysis of over 300 soils for total chromium analysis. The data from this and previous investigations were used to specify the limits of contaminated soil excavation. Also, the interior surfaces of the main process building were grit blasted to remove surface contamination and then all structures were demolished and removed to a special waste landfill for disposal under an IDEM special waste permit. Approximately 2800 cu. yds. of contaminated soils were then excavated and transported under a USEPA generator number to a RCRA-compliant hazardous waste landfill. The excavation was subsequently backfilled with laboratory verified clean soil, compacted, regraded, and revegetated.

Phase II Remedial Investigation

The Phase II investigation was conducted concurrently with the ERA. The primary objective of the Phase II RI was to identify residual contamination problems following the removal action and evaluate their potential impact on human health and the environment. Field Investigation activities were conducted in parallel with the ERA and included installation of 7 additional monitoring wells and additional sampling of subsurface soils, and groundwater. Groundwater sampling was performed before and after the ERA. The results of the Phase II RI investigation and a base line public health evaluation were summarized in the RI report released on November 22, 1989. Applicable data from Phase I and II were used in site evaluation. A summary of the significant RI findings is provided below.

The Phase II RI indicated that residual soil contamination consisted primarily of elevated levels of chromium. Although residual soil concentrations higher than background were present onsite, the geometric mean concentration was reduced to well below the 57 mg/kg ERA action level. Only about 10 percent of the 213 samples in the data base contained concentrations above the action level. These occurred primarily in deeper soils left in place after the removal action. Maximum residual concentrations in these soils ranged up to 195 mg/kg which was more than two orders of magnitude less than the maximum concentration present prior to the removal action (52,000 m/kg). Independent conformational sampling from the ERA indicated similar results as shown below.

	Western 13 Foot Excavation	Central 20 Foot Excavation	Eastern 16 Foot Excavation	All Samples
No. Samples	6	6	6	18
Geometric Mean (mg/kg)	23	45	24	27
Maximum Value (mg/kg)	41	156	49.2	156

According to the baseline risk assessment presented in the RI report, human health risks resulting from potential exposure to residual soil contamination were extremely low and did not pose a significant threat to health. The low levels of soil contamination remaining in the saturated zone, approximately 20 feet below the ground surface did not represent a significant direct contact health threat. In addition, since the source of contamination in the unsaturated zone had been substantially reduced, the contaminant levels in the saturated zone would diminish with time as groundwater flushed contaminants from the soil.

The groundwater results from Phase II indicated a pattern similar to that observed in Phase I, both before and after the ERA. Groundwater contamination consisted primarily of elevated levels of chromium. Where chromium levels were highest, the form of chromium was mostly the more toxic CrVI form. The background concentration of total chromium was 8.9 ug/l. Hexavalent chromium was not detected in the background well. The concentrations detected in MW-1 were slightly higher than Phase I (60.8 ug/l for total chromium). The concentrations in MW-4 for total and CrVI were 1810 ug/l and 1890 ug/l, respectively. The lower total chromium result is believed to be the result of inter-laboratory variability. Several other wells had total chromium values that exceeded background. A shallow downgradient monitoring well, MW-6, had a total chromium concentration of 28.4 ug/l, indicating that the plume is migrating toward the south, but was being diluted as it spreads out.

Following the ERA, groundwater concentrations at MW-4 did not change significantly indicating either that insufficient time had passed for residual contamination to be flushed from the aquifer or that a significant amount of CrVI remained adsorbed in the aquifer beneath the site. In addition, elevated CrVI concentrations appeared for the first time at the two other shallow wells on the southern boundary of the site, MW-3 and MW-3A.

Groundwater chromium concentrations observed at the site continued to exceeded the MCL of 50 ug/l. Transport modeling done to estimate potential future groundwater chromium concentrations at key off-site receptor areas such as the Columbus city well field indicated limited and remote possibilities that ground water contamination could have a negative affect on human health or the environment. However, risk evaluations indicated that ingestion of contaminated groundwater continued to pose a potential threat to human health for the hypothetical case that a potable well was installed onsite or in the path of the contaminant plume and eventual discharge to Haw Creek remained a possibility.

The presence of elevated groundwater concentrations indicated that a feasibility study to evaluate the cost effectiveness of various remedial actions was warranted. However, the RI revealed several significant data gaps concerning the extent and migration potential of groundwater contamination. Because contamination was detected in so few monitoring wells, the extent and mass of contamination to be addressed was uncertain. In addition, existing data yielded a wide range in aquifer parameters (eg. hydraulic conductivity, ground water velocity, initial mass, chemical distribution coefficient, hydrodynamic dispersion coefficients) which would make the conceptual design and projected cleanup times uncertain. There was also some question as to whether the ERA had completely eliminated the threat posed by leaching of subsurface vadose zone soils.

These data gaps did not detract from the need to evaluate various groundwater extraction and treatment alternatives. Therefore a decision was made to proceed with the FS despite the known data gaps. The data gaps would be addressed by a pilot ground water pump and treat test to be performed in parallel with the FS.

<u>ERA Pump Test and Verification Sampling</u>

Because these data gaps were recognized at the inception of the FS, additional groundwater sampling and an aquifer pump test were performed concurrently. The objectives of these investigations were to provide site specific hydrogeologic data for ground water modeling, verify the effectiveness of the ERA, demonstrate that aquifer restoration times could be shortened by removal of a quantity of contaminated water from the aquifer and provide information on pumping rates required to create an adequate capture zone.

The aquifer pump test included the following investigation activities:

- Installation of an 8 inch extraction well capable of pumping at 300 gpm;
- Performance of a 72 hour sustained rate pump test to determine aquifer hydraulic conductivity and zone of influence;
- Collection of daily discharge samples to monitor the contaminant removal rate and to determine if discharge would exceed the permit requirements for discharge to the POTW;
- Collection of daily groundwater samples from MW-4 to determine the relationship between ground water contaminant concentrations and the number of pore volumes removed; and
- Collection of a final round of groundwater sampling of all study area wells to determine the extent of contaminant removal.

The pump test was conducted continuously at 310 gpm for 12 days between November 11 and November 22, 1989. The results of the test and additional sampling were presented and discussed in the Remedial Action Report for the site issued in January, 1990. Analytical results from the pump test are presented in Table 1. The significant findings of the pump test are summarized below.

Evaluation of drawdown data to determine aquifer parameters revealed hydraulic conductivities ranging from 2006 gpd/ft^2 to 3370 gpd/ft^2 and a specific yield ranging from .04 to .24. Maximum drawdown near the well screen was 4.04 feet

TABLE 1
PUMP TEST ANALYTICAL RESULTS
TRI STATE PLATING SITE

DAILY GROUNDWATER SAMPLES

Date	M-4 Total Chromium (Filtered) (ug/l)	M-4 Cr(6+) (Unfiltered) (ug/l)
11/10/89	153	NA
11/11/89	480	NA
11/12/89	123	83.9
11/13/89	607	593
11/14/89	796	564
11/16/89	990	1100
11/17/89	343	367
11/19/89	160	156
11/20/89	151	149
11/22/89	131	141
Dupl.		
11/14/89	808	868
FB-1	ND	ND

NA = Not Analyzed
ND = Not Detected
Det. Limit = 10 ug/l

DAILY DISCHARGE COMPOSITE SAMPLES

Date	Volume	Cr ug/l	Cd ug/l	Ni ug/l	Pb ug/l	pH ug/l	Tss mg/l	Activity
11/10	0-1000 gal	2800	ND	114	117	7.69	57	Well Development
11/11	1000-28,000 gal	197	ND	ND	ND	7.62	125	Devel. & Step Test
11/12	28,000-226,200 gal	179	ND	ND	ND	7.56	NA	72 Hour Test
11/14	250,000-685,000 gal	185	ND	ND	ND	7.55	NA	72 Hour Test
11/15	685,000-1,000,000 gal	170	ND	ND	ND	7.57	NA	72 hour test

Notes: All samples unfiltered
Discharge after 11/11/89 was clear. No TSS samples collected

Detection Limits	Cd = 5 ug/l	Discharge Limits	Cd = 1200 ug/l
	Cr = 10		Cr = 5000
	Ni = 11		Ni = 5000
	Pb - 41		Pb = 600
			TSS = 250 mg/l
			pH = 6-11 units

after 72 hours and a distance drawdown graph indicated a zone of influence approximately 2000 feet in diameter. These results were in good agreement with published data for this aquifer and it was concluded that a hydraulic conductivity between 2000 and 3000 gpd/ft 2 and a specific yield of 0.2 could be used with confidence in further site specific calculations.

Daily discharge composite samples indicated that from 6 to 7 pounds of chromium were removed from the aquifer during the 12 day test. During this time, chromium concentrations in the discharge decreased from 2800 ug/l to a stable low concentration of about 180 ug/l. The POTW discharge limit of 5000 ug/l was never exceeded during well development and testing. Maximum nickel and lead concentrations were 114 and 177 ug/l, respectively, and decreased to non-detectable levels during the remainder of the test. These values were also well below discharge limits. Cadmium, another contaminant regulated by the discharge permit, was not detected in discharge samples.

Hexavalent and total chromium concentrations in daily groundwater samples from MW-4 indicated considerable fluctuation during the pump test. CrVI concentrations increased from a low of 84 ug/l to a maximum concentration of 1100 ug/l 3 days into the test. Concentrations subsequently decreased to a value of about 140 ug/l. This trend indicated movement of a contaminant pulse past MW-4 in a short period of time which suggested much more rapid movement of chromium than was previously assumed. During the RI and FS, moderate adsorption was assumed because of the steady concentrations observed at MW-4. Based on the pump test results, it was judged that the distribution coefficient (Kd) of 20 ml/g assumed in the RI and FS was too high and that a Kd of 2 ml/g or less was more representative.

Additional groundwater sampling was conducted approximately three weeks after the conclusion of the Pump test. Hexavalent chromium concentrations in all onsite wells, including MW-4, were not only below the 50 ug/l action level proposed in the FS but below detection levels as well. However, CrVI was found for the first time at high concentrations (400 ug/l) in the downgradient shallow well, MW-6. Resampling by IDEM in March, 1990 found low levels of CrVI (13 ug/l) in MW-4, verifying that the pump test had reduced onsite contamination to low levels. However CrVI was apparently no longer present at MW-6 by this time. These findings appeared to substantiate the idea that chromium contamination was moving faster than was previously assumed.

Feasibility Study

Because of the ERA, the analysis and decision process in the FS was greatly simplified. Not only had the ERA removed a significant potential source of groundwater contamination, but risks due to direct contact, incidental ingestion of soils and inhalation in several potential future exposure scenarios were reduced to acceptable levels. Therefore the FS needed to consider only one contaminated media-groundwater. The remedial objective developed in the FS was to remove and treat CrVI contamination and to restore the effected part of the aquifer to levels less than the MCL of 50 ug/l.

The Feasibility Study developed and evaluated a range of alternatives for groundwater restoration by natural attenuation and by active groundwater extraction. The Alternatives developed were as follows:

Alternative No 1:	No Action
Alternative No 2:	Monitoring
Alternative No 3:	Groundwater Extraction/ Discharge to POTW
Alternative No 4:	Groundwater Extraction/Onsite Treatment/Discharge to Haw Creek

For alternatives achieving aquifer restoration by active extraction, several alternative pumping rates were evaluated to vary the restoration times. The Feasibility Study was released for public and State comment on January 22, 1990. Significant conclusions of the FS are summarized below.

A comparative analysis indicated that active restoration alternatives were more favorable in terms of overall protectiveness, compliance with Applicable, Relevant and Appropriate Regulations (ARARs), time required to implement cleanup, long term effectiveness, and reduction of toxicity, volume and mobility of contamination. Natural attenuation under the No Action and Monitoring Alternatives was estimated to take more than 40 years, during which time, the plume would continue to present a potential hazard to anyone installing a well in the path of the plume. By comparison, active restoration would prevent further migration of the plume and would take from 5 to 13 years to achieve. The active restoration alternatives were, however, more expensive and difficult to implement.

The FS established that the no action alternative was not acceptable and that groundwater extraction using pumping wells and discharge to the POTW was a viable and cost effective alternative. The aquifer pump test verified that discharge to the POTW was feasible and provided information on a suitable pumping well design and required pumping rates.

Because contamination was detected in so few monitoring wells, the ground water contamination plume addressed in the FS was simulated using a contaminant transport model. Use of the model introduced elements of uncertainty in conceptual components of the alternatives such as the actual number, and location extraction wells required to achieve cleanup. In addition, the model incorporated several assumed parameters (eg. initial mass, chemical distribution coefficient, hydrodynamic dispersion coefficients) that were highly uncertain. For example, using high and low range variables in the model during the RI gave natural cleanup times ranging from 18 to 1500 years.

The pump test results collected concurrently with the FS indicated a need to revise certain conclusions reached in the FS. The potentially lower Kd indicated by the pump test data, suggested that contaminants had moved faster and spread farther than the model used in the FS indicated. Therefore, additional monitoring wells were possibly needed to determine the presence of contamination in downgradient areas. Previous estimates of the mass of contamination in the aquifer were also based on a Kd of 20. Therefore revision of clean-up times and exposure point concentrations was also necessary. There also remained some question as to whether the ERA removal action had completely eliminated the threat posed by leaching of subsurface vadose zone soils. As a result of these findings, predesign investigations were recommended prior to design and implementation of the Final Remedial Alternative.

Pre Design Investigation

The Pre-Design Investigation activities were conducted to collect additional data necessary for preparation of an RD/RA. Specific objectives of the pre design activities were as follows:

- Provide a delineation of the current groundwater plume.
- Perform a qualitative evaluation of chemical fate tendencies of CrVI to provide preliminary pumping rate and scheduled for the extraction well(s).
- Provide the location and specification for each existing and proposed extraction well required to effectively achieve the cleanup goals of USEPA and IDEM.

The activities performed during the Pre-Design Investigation included installation of 5 additional downgradient monitoring wells and 3 piezometers to refine the extent of contamination, and collecting two rounds of groundwater samples from selected monitoring wells. IDEM collected and analyzed samples from selected wells to provide further information on the concentration trends over time.

In addition to submitting the samples for CrVI and total metals analysis, samples were also analyzed for alkalinity, sulfate, and chloride to identify anions that might compete with dichromate in exchange reactions with the soil. Also, the Eh, pH and dissolved oxygen contents were measured in the field to determine the redox potential of the samples. Unfiltered total metals at MW-4, -6 and -11 were also collected to determine the difference between dissolved and particulate concentrations.

The additional predesign investigation wells and the three piezometers installed southeast of the industry located downgradient of the site provided more information on water table gradients. It had previously been assumed that groundwater flowed to the southeast towards Haw Creek. Using water level data from the shallowest wells, the water table contour map shown in Figure 4 was constructed. The water table contour map clearly established that groundwater in the vicinity of the site flowed in a southerly direction rather than southeast towards Haw Creek. The bowed pattern of the water table contours south of the site indicated the influence of the industrial well on water levels in the area.

The water table contour map suggested the possibility that contamination from the site may be moving off site in a southerly direction. The predesign sampling CrVI groundwater results are summarized in Figure 5. The sampling results indicate that CrVI contamination was moving off site to the south. A narrow finger of high concentration in excess of 1000 ug/l appeared to extend south-southeast from MW-4 through MW-6 to P-1. Detectable CrVI contamination was found as far south as P-3. In addition, CrVI contamination reappeared again in high concentrations at MW-3 and at MW-6 after having been absent from these wells in the previous sampling round. The new well (MW-11) located south of the site between MW-6 and 8 contained 86 ug/l.

A plot of CrVI concentrations at MW-4 over time using all RI data is presented in Figure 6. The gradual reappearance of contamination at MW-4 after it had been removed to near detection levels during the pump test, suggested that an source of groundwater contamination remained and that CrVI was gradually being reintroduced into the aquifer through some unknown mechanism. Three possible release mechanisms were postulated:

- Leaching of residual chromium contamination from vadose zone soils;
- Reestablishment of equilibrium by chromium desorption after the cessation of the pump test; and
- Presence of fixed trivalent chromium (CrIII) below the water table and slow oxidation of this material to hexavalent chromium.

Poor correlation between groundwater concentrations and monthly total rainfall amounts as shown in Figure 6 plus the fact that soil chromium concentrations had been drastically reduced during the ERA indicated that this mechanism was a remote possibility. Because of the relatively long time interval required for chromium concentrations to be reestablished to pre pump test levels, chromium desorption from soils below the water table at a rates much less than removal rates during aquifer pumping was also regarded as unlikely.

The most plausible explanation was that a substantial reservoir of the less soluble and mobile CrIII ion had accumulated in the aquifer beneath the Tri-State Plating site. In the absence of chromium loadings from the plant operations and in the presence of manganese dioxide or other natural oxidizing agent, oxidation of CrIII to CrVI was occurring. This mechanism might explain why it took so long for CrVI to reappear after the pump test and also the consistent concentrations detected at MW-4 prior to the test. Field evidence that this reaction was occurring, however, was limited.

Adsorption is the dominant fate controlling CrVI mobility. However, the divalent dichromate anion, rather than the hexavalent metal cation is the species that is most strongly adsorbed (EPRI 1985). As a consequence, the activity of other anions such as carbonate, bicarbonate, sulfate and silicic acid strongly compete with dichromate for adsorption sites. Standard water quality analyses collected during the predesign investigation indicated moderately high groundwater alkalinity concentrations of about 300 mg/l. Given the potentially low density of binding sites in the sand and gravel aquifer and the high concentration of competing carbonate/bicarbonate anion, CrVI adsorption may be limited. This agreed with the tentative conclusions about the mobility of CrVI reached following the pump test. Consequently, contaminant migration velocities approaching that of groundwater, or nearly 2 ft/day might be qualitatively expected. This conclusion, in turn supported the contention that oxidation of trivalent chromium rather than desorption of CrVI was the current source of groundwater contamination.

The predesign data confirmed that groundwater contamination had spread farther and faster than anticipated in the FS. In addition, the predesign data clearly demonstrated that a residual source of chromium contamination remained onsite. Based upon the low retardation of CrVI indicated by the pump test and the high groundwater velocities at the site, it was concluded that chromium was being generated at a slow but rather constant rate and was migrating off-site rapidly.

These characteristics suggested that, rather than implementing the groundwater remedial alternative with objective of restoring the entire effected area to MCLs, the remedial response objective could be met by operating the onsite well, designed and constructed during the pump test, to prevent any additional off-site migration. The contamination that had already moved beyond the capture zone of the well would probably flush from the aquifer faster than additional wells could be installed.

Remedial Design and Monitoring

Based upon the data assembled to date, it appeared that the existing on-site extraction well could be used effectively to prevent further off-site migration. The extraction well did not need to be operated continuously to be effective. Analysis of Figure 6 indicated that, once a currently contaminated pore volume was removed, approximately 4 months would pass before groundwater concentrations again exceeded 50 ug/l. Based on the pump test results, it appeared that a contaminated pore volume could be removed in approximately 2 weeks by operating the well at 200-300 gpm. Pump test data also indicated that operation of the pump at these rates would provide a capture zone that would prevent chromium migration off-site. Therefore, to be conservative, it was recommended that pump operation be scheduled on a quarterly (3 month) basis with the pump operating for the first three weeks of each quarter. After the first three weeks, the pump would be turned off to allow CrVI concentrations to increase to 50 ug/l. Quarterly operation of the extraction well would insure that CrVI concentrations exceeding 50 ug/l would not leave the site area.

Based on current information, it was not possible to estimate how long the onsite extraction well would have to be operated. This information depended on the source and mechanism of CrVI release. The source of the contamination was suspected to be slow oxidation of CrIII in the aquifer below the site. Although not as likely, vadose zone leaching or slow desorption of adsorbed Cr (VI) could be contributing factors. Because only a year had passed since the removal action, and less than a year had passed since the pump test, these conclusions were based on limited monitoring data and were

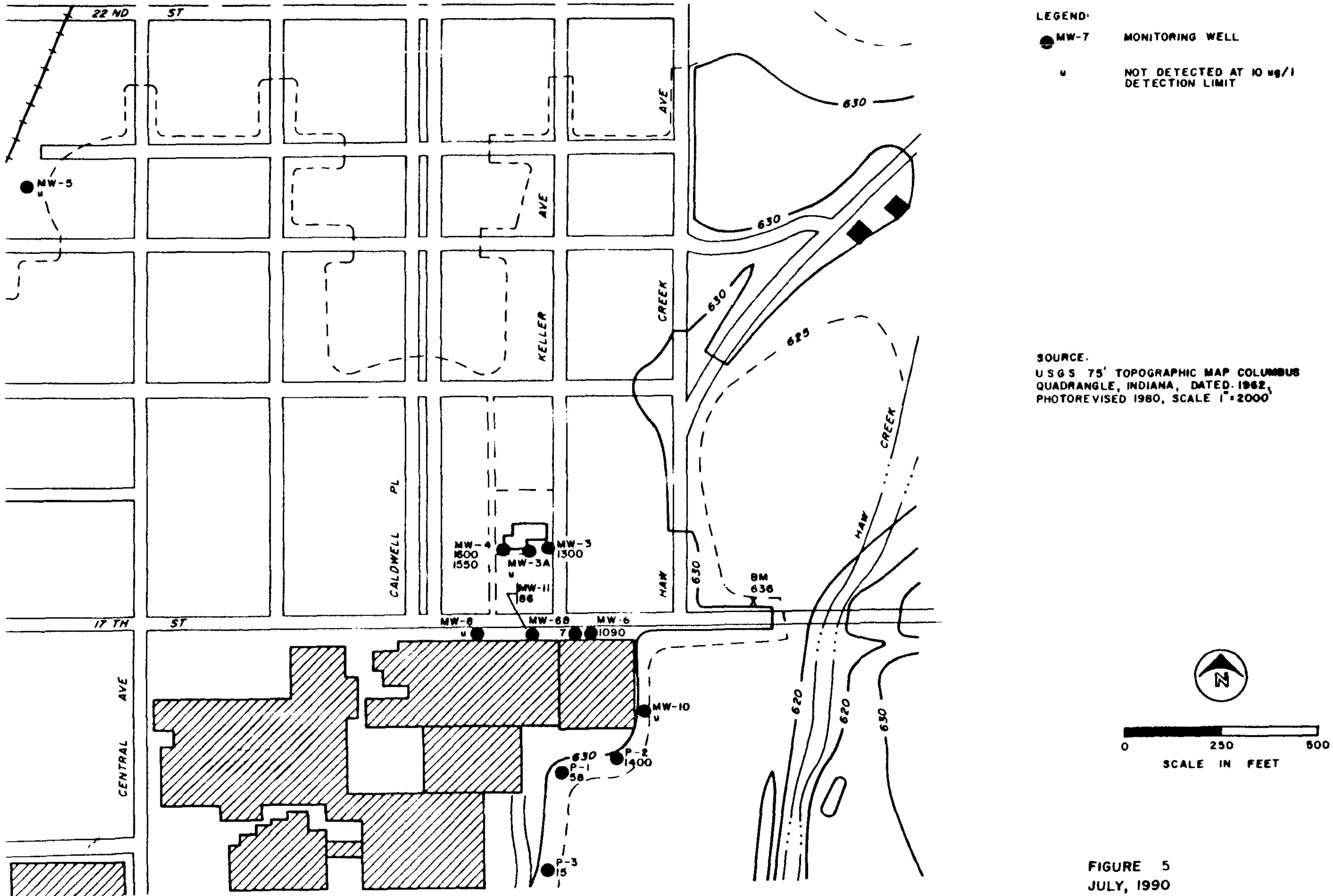


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FIGURE 5
JULY, 1990
GROUNDWATER SAMPLING RESULTS
TRI-STATE PLATING SITE

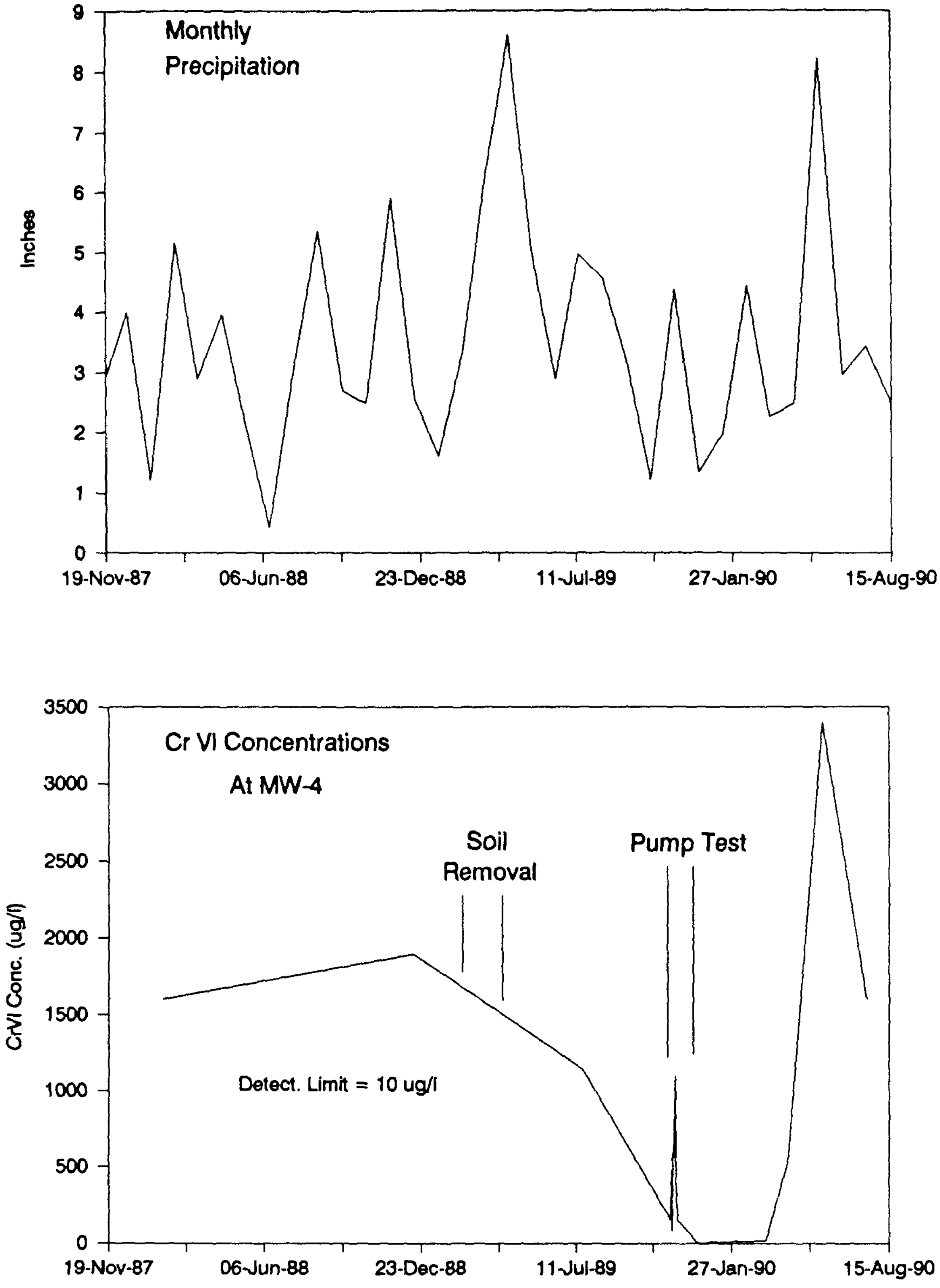

FIGURE 6
CrVI Concentrations At MW-4
And Precipitation Data

therefore difficult to confirm. Because these characteristics were still poorly defined, the source longevity was difficult to estimate.

It was decided that onsite monitoring be implemented to determine the decrease in source strength so that clean-up times could be estimated. It is recommended that the extraction well be operated in conjunction with the onsite source monitoring for at least 2 years in order to provide an adequate data base for planning future courses of action.

On-site Monitoring: Continued monitoring of onsite wells was specified to re-evaluate each of the possibilities discussed above. In addition, onsite monitoring would allow the effectiveness of the extraction well to be evaluated. It was recommended that five of the eight onsite monitoring wells (MW-1, 3, 3A, 4, 4B) be sampled on a quarterly (3 month) basis. The remaining onsite wells (MW-2, 1B and 4C) had never shown any evidence of contamination.

The sampling would coincide with the extraction well operation cycle such that each quarterly sample is collected at the end of the quarter just prior to pump operation in the next quarter. This insured that samples were representative of the "equilibrium" concentration for each quarter. These equilibrium concentrations would be plotted with time to determine any trend showing the decrease in source strength. Quarterly monitoring data would also be compared with monthly precipitation data from Columbus Utilities to evaluate the possibility that contamination is the result of vadose zone leaching.

Quarterly onsite samples would be analyzed for CrVI and filtered and unfiltered total chromium. The first two rounds of unfiltered quarterly samples would also be analyzed for manganese dioxide. The presence of manganese dioxide would indicate whether CrIII oxidation is occurring. If manganese dioxide is absent or present in low concentrations then it will be unlikely that oxidation of a CrIII reservoir is the source of contamination.

If initial quarterly monitoring data suggested that CrIII oxidation is the source of current contamination, then it would be advantageous to consider applying an oxidant to the site to speed up oxidation and mobilization of CrVI. Evaluation of the use of an oxidant would involve bench scale testing of subsurface soil samples to determine an optimum oxidant and application method.

Quarterly monitoring would be conducted for at least two years to provide an adequate data base for planning future actions. If groundwater concentration trends indicate a steady decline it will be possible to project cleanup times by extrapolation. If, after a period of time, no significant decrease is noted, additional onsite subsurface investigations of soil concentrations below the water table may be necessary to further investigate the nature of the source. This would involve drilling of several test borings to collect soil samples for analysis.

Off-Site Monitoring: Concentrations significantly above the FS cleanup action level of 50 ug/l are present in the ground water at distances of over 600 feet south of the site. Because the downgradient limit of this contamination is undefined, specification of additional off-site extraction wells was premature without further monitoring and evaluation.

However, it was realized that once the off-site migration was reduced by the extraction well, the down gradient contamination may flush from the aquifer rather rapidly because of the high migration velocities. It was recommended that prior to installing additional off-site monitoring or extraction wells, the onsite well be operated for at least two years and the down gradient wells be monitored to determine the natural flushing rate. If the natural flushing rate is high, then clean up levels may be reached in a reasonable time frame and it would not be necessary to install additional extraction wells.

To meet the off-site monitoring objectives noted above, it was recommended that the piezometers south of the site be replaced with monitoring wells. These wells along with MW-6, 6B, 7, and 10 would be monitored on a quarterly basis. All other off-site wells would be sampled annually. During this period monitoring of Haw Creek would be performed to insure that the plume will have no impact on surface water. At least 4 surface water sampling stations would be established and monitored on a monthly basis. Samples would be analyzed for CrVI.

In the event that natural flushing progresses slower than expected, further plume delineation south of the site may be required before a downgradient extraction system could be specified.

CONCLUSIONS

Current Status

The Remedial Designs/Remedial Action contract was awarded to a Region III Alternative Remedial Contracting Strategy (ARCS) firm in October 1990. As of April 1991, the Remedial Design is 100% complete and the Remedial Action has been initiated. Because of the expedited approach taken on this site, inception to RA implementation required 3 years. This period is much quicker than the typical superfund project. The success is due to several factors including the sound interactive RI/FS approach and the innovative methods (eg. ERA) that were employed.

The expedited Remedial Design can be attributed to the strategies employed during the course of the Remedial Design. As a consequence the contractor was primarily tasked to design a pump house and the associated piping from the existing extraction well to the city sewer system. The other aspects of a typical Remedial Design, and Remedial Action such as source removal, design of the extraction system, aquifer parameter delineations, placement of extraction well(s), etc., had already been completed through innovative techniques employed early on in the RI/FS process.

The expedited Remedial Design, which entailed preparation of a work plan, design of the selected remedy, preparation of plans and specifications, bidding documents, site closure and operation and maintenance plan, cost estimates, quality assurance plans, and health and safety plan has been completed at a cost to the agency of less than $100,000.

The remedial Action will be initiated in June 1991 after procurement of bids and award of the contract. The total remedial action is anticipated to be completed in two years, after pumping has been initiated and at a cost of approximately $300,000.

Impacts of the Interactive RI/FS Approach

The Tri-State Plating Project included the standard components usually seen in the typical Superfund project. It included a remedial investigation, a baseline risk assessment, a pump and treat pilot test, a feasibility study, and a predesign investigation. These components are the major tasks described in "Guidance for Performing Remedial Investigations and Feasibility Studies Under CERCLA". With minor variations, this sequence of operations is gaining acceptance as the state of the practice in hazardous waste site remediation. The aspect that made the Tri-State Plating project particularly successful, was the interactive way in which the results of one component were used to direct activities in the others. Although the interactive or phased approach is explicit in the current NCP and EPA RI/FS guidance, we believe that it is seldom used as effectively as it was at the Tri State Plating Site to expedite investigations and site clean up.

Key to the success of the interactive approach at the Tri-State Plating site was the early establishment of remedial objectives. Early in the RI stage, a preliminary public health evaluation identified excess health risks associated with chromium in groundwater. A remedial objective was established to prevent the release of contaminants to groundwater and to eventually implement a groundwater clean up. Despite the existence of data gaps at each stage along the way, the driving remedial objective enabled the subsequent investigation activities to focus on chromium contamination and determining site factors relevant to groundwater remedial actions. By specifying the remedial objective early, project decision makers were equipped with decision making tool to evaluate whether the data gaps effected the overall approach. In each instance, the decision was that the data gaps were important but could be answered by appropriate investigation in the next phase.

Often, the interactive approach is not effective because there is a perception that no decisions concerning remedial objectives can be made until a comprehensive RI is performed. Upon completion of an initial RI and presentation of the results in an RI report, data gaps are usually identified. Frequently, discussion of remedial objectives, development of possible remedial alternatives and other decision activities are postponed pending completion of additional phases of the RI to address the data gaps. Based on our experience at the Tri-State Site, we feel that this perception and course of action is unwarranted. Available data can always be used to begin formulating a course of remedial action for the site.

Site assessment uncertainties will always exist at each stage in the RI/FS process. However these uncertainties should not hinder the development of preliminary objectives and development of preliminary response objectives. RI data at each stage may not be fully descriptive of the site, but any data collected provides some information that can be used to begin the formulation of remedial objectives.

Impacts of the ERA

The ERA portion of the project is not typical of most superfund sites. However, it was developed as a direct result of the interactive approach discussed above and had a significant impact on the final outcome. In order to remove the source of contamination, the former metal plating building and contaminated subsurface soils were removed during an ERA even before the FS was started. After completion of the ERA, the FS was greatly simplified in that the only remaining media of concern was groundwater itself. The selected remedial action to address groundwater contamination, pump and treat, was further simplified by conducting an aquifer pump test in parallel with the FS. This resulted in a preliminary technical evaluation of the pump and treat design prior to actual initiation of the remedial design (RD) phase. The remedial action (RA) was also expedited because the actual test well was designed so that it would be part of the final remedy. Thus, in many instances, the RI/FS and Expedited Response Action which was performed on this site served as pre-design activities for the final remedial action.

Use of the ERA approach is now being replaced with a new concept called the Interim Rod. The Interim Rod can be used to effectively serve the same function as the ERA at the Tri-State Plating Site.

Interim RODs

The USEPA now intends to address situations that dictate the need to take quick action either to (1) Protect human health and the environment from an imminent threat in the short term, while a final remedial action is being developed or (2) institute temporary measures to stabilize the site or operable unit and/or prevent further migration or degradation by conducting interim action Record of Decisions in lieu of expedited response actions. An interim action, like an ERA, is limited in scope and only addresses areas and/or media for remediation and will be followed up by a final operable unit Record of Decision. Interim actions may be implemented for a completely separate operable unit or may be a component of the final ROD, dependent upon the reasons for conducting the action (i.e., removing soils to eliminate the source of contamination of groundwater versus providing a temporary alternate water supply and sealing wells that are pumping from a contaminated aquifer).

Since an interim action may be conducted during any phase of the Remedial Investigation/Feasibility Study to mitigate the more immediate threats, there may not be sufficient time to prepare a comprehensive RI Report of FS Report.

In fact, preparation of an RI/FS report is not required for an interim action. However, for the purpose of fulfilling the NCP's Administrative Record requirements, there must be documentation that supports the rationale for the action. A summation of site data collected during field investigation should be sufficient to document a problem in need of response; in addition, a short analysis of what remedial alternatives were considered, which ones were rejected, and the basis for the evaluation (as is done in a focused FS) should be summarized to support the selected action. The Interim action decision documentation are outlined in Tables 2 and 3.

TABLE 2

DOCUMENTING INTERIM ACTION DECISIONS
OUTLINE FOR THE PROPOSED PLAN

The Interim Action Proposed Plan should include the following information:

1. Site Description: This section should focus on site characteristics addressed by the limited action.

2. Scope and Role of Operable Unit: This section of the document should specify how the interim response action fits into the overall site strategy. The point should be made that, to the extent possible, the interim action will be consistent with any planned future actions.

3. Summary of Site Risks: This section should provide the rationale for taking a limited action. This should be supported by facts that indicate the action is necessary to stabilize the site, prevent further degradation, or that the action can accomplish significant risk reduction quickly. The information should relate only to the limited scope of the action. Qualitative risk information may be presented if quantitative details are not yet available, which will often be the case.

4. Summary of Alternatives: A very limited number of alternatives should be analyzed for interim actions; in some cases, only one plan of action will be appropriate to consider. The alternative descriptions should reflect the pertinent Applicable and Relevant and Appropriate Regulations (ARARs) associated with the action. ARARs are important for the following aspects of an interim action: any portion of the remedy that is final, materials that are treated or managed off-site, and any release that will occur during implementation. Requirements are not applicable or relevant and appropriate if they are outside the scope of the interim action.

5. Evaluation of Alternatives and the Preferred Alternative: The comparative analysis should be conducted in relation to the limited role and scope of the remedy. Criteria that are not pertinent to the selection of interim actions (e.g., long-term effectiveness of a temporary cap) need not be addressed in detail. Rather, their irrelevance to the remedy decision should be noted.

6. Statutory Findings: The findings should be discussed in terms of the limited scope of the action.

TABLE 3

DOCUMENTING INTERIM ACTION DECISION
OUTLINE FOR THE ROD

The ROD, documenting the selection of an interim action remedy, should contain the following modifications.

1. Declaration:

- Statutory Determinations: The declaration statement should read as follows:

  This interim action is protective of human health and the environment, complies with (or waives Federal and State applicable or relevant and appropriate requirements) for this limited-scope action, and is cost-effective. This action is interim and is not intended to utilize permanent solutions and alternative treatment (or resource recovery) technologies to the maximum extent practicable for this [interim action/operable unit]. Because this action does not constitute the final remedy for the [site/operable unit], the statutory preference for remedies that employ treatment [although partially addressed in this remedy] that reduces toxicity, mobility, or volume as a principal element will be addressed by the final response action. Subsequent actions are planned to address fully the threats posed by the conditions at this [site/operable unit]. Because this remedy will result in hazardous substances remaining on site above health-based levels, a review will be conducted within five years after commencement of the remedial action as EPA continues to develop final remedial alternatives for the [site/operable unit]. The review will be conducted to ensure that the remedy continues to provide adequate protection of human health and the environment. Because this is an interim action ROD, review of this site and of this remedy will be continuing as part of the development of the final remedy for the [site/operable unit].

2. Decision Summary

- Scope and Role of Operable Unit: This section provides the rationale for taking the limited action. To the extent that information is available, the section should detail how the response action fits into the overall site strategy. This section should state that the interim action will be consistent with any planned future actions, to the extent possible.

- Site Characteristics: This section should focus on the description of those site or operable unit characteristics to be addressed by the interim remedy.

- Summary of Site Risks: This section should focus on risks addressed by the interim action and should provide the rationale for the limited scope of the action. The rationale can be supported by facts that indicate that temporary action is necessary to stabilize the site or portion of the site, prevent further environmental degradation, or achieve significant risk reduction quickly while a final remedial solution is being developed. Qualitative risk information may be presented if quantitative risk information is not yet available, which often will be the case. The more specific findings of the baseline risk assessment should be included in the subsequent final action ROD for the operable unit and the ultimate cleanup objectives (i.e., acceptable exposure levels) for the site or operable unit.

- Description of Alternatives: This section should describe the limited alternatives that were considered for the interim action (generally three or fewer). Only those requirements that are applicable or relevant and appropriate requirements (ARARs) to the limited-scope interim action should be incorporated into the description of alternatives.

- Summary of Comparative Analysis of Alternatives: The comparative analysis should be presented in light of the limited scope of the action. Evaluation criteria not relevant to the evaluation of interim actions need not be addressed in detail. Rather, their irrelevance to the decision should be noted briefly.

- Statutory Determinations: The interim action should protect human health and the environment from the exposure pathway or threat it is addressing and the waste material being managed. The ARARs discussion should focus only on those ARARs specific to the interim action (e.g., residuals management during implementation). The discussion under "utilization of permanent solutions and treatment to the maximum extent practicable" should indicate that the interim action is not designed or expected to be final, but that the selected remedy represents the best balance of tradeoffs among alternatives with respect to pertinent criteria, given the limited scope of the action. The discussion under the preference for treatment section should note that the preference will be addressed in the final decision document for the site or final operable unit.

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Excavation/Off-Site Incineration RD/RA - Optimization of the Planning/Investigation Process Based on Two NPL Site Case Studies

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INTRODUCTION

The purpose of this paper is to address the question of how much site investigation work is justified prior to implementation of remedial actions involving excavation and off-site treatment/disposal. This question is addressed by analyzing two recently completed NPL site remediations (case studies) which consisted of excavation and off-site incineration of solid waste materials. Each case study is analyzed by comparing actual total costs for site characterization and remediation with estimated total costs for two hypothetical sensitivity cases in which the amount of sampling and analysis for further site characterization prior to implementation of the remedial action is varied. The results presented in this paper could be used to assist Project Managers responsible for similar projects in deciding if sufficient site characterization data (especially the horizontal and vertical extent of contamination) exist for the cost-effective procurement of the remediation contractor. If sufficient data were not collected during the Remedial Investigation (RI), additional data could be collected during the Remedial Design (RD) phase.

It is important to consider the performance of sampling and analysis during the RD for excavation and off-site treatment remediations because total overall costs could be higher in cases of insufficient or excessive information concerning site characterization. Insufficient site characterization data could lead to higher remediation costs due to the perception of higher waste quantity uncertainties by the bidding remediation subcontractors and/or failure to be able to take full advantage of potential volume discounts offered by treatment/disposal facilities. The collection of excessive site characterization data could result in the needless expenditure of funds for sampling and analyses with no significant cost savings during the remedial action. Although it is clear that the optimum amount of sampling and analysis for site characterization is based on a cost/benefit analysis between characterization costs and improved information benefits, there currently is no general guidance on how to establish the optimum for a given site.

BACKGROUND

In this section background information is provided for each of the case studies. In addition, the approach taken to analyze each of the case studies is presented and discussed.

Site A is located in a rural area near a large National Forest. The entire site area covers approximately 45 acres including the specific areas of concern which cover roughly 3 acres. For a 50-year period a wood-tar, waste material was generated from a process for production of charcoal. The process involved heating wood in the absence of oxygen to produce charcoal, methanol, acetic acid and wood-tar. The wood-tar was deposited onto the ground where it eventually formed several surface impoundments and other areas throughout the site. The composition of the wood-tar is such that although it is not classified as a RCRA waste, it contains elevated levels of phenols and polynuclear aromatic hydrocarbons (PAHs). The Record of Decision (ROD) for the site specified excavation and off-site incineration of the wood-tar in order to reduce potential risks to human health.

Site B is located on an approximately 10-acre property in an industrial/residential area. The on-site facility was used for operations involving copper recovery from scrap wire. A chemical process for removal of wire insulation produced a waste material which consisted primarily of elemental carbon. The black carbon waste material contained percent levels of copper and lead. Carbon waste samples also exhibited elevated levels of tetrachloro- ethylene, and polychlorinated biphenyls (PCBs). The carbon waste material was placed on the ground surface in a pile near the center of the site property. The ROD for the carbon waste Operable Unit specified excavation and off-site incineration of the carbon waste pile to prevent the further spread of contamination to groundwater and to eliminate human health risks associated with other potential pathways.

It is stated in the RI/FS and RD guidance documents that accuracies for cost estimates should be order of magnitude estimates at the Feasibility Study stage (i.e., +50/-30 percent) and within +15/-10 percent at the final design stage. These are useful theoretical benchmarks, yet for many remedial alternatives it is difficult or impossible to determine overall cost estimate accuracies. Overall cost estimate accuracy depends on the accuracies of a large number of site-specific factors which are often unique. Even if it was possible to definitively assess overall cost estimate accuracies, it is likely that optimum final design cost estimate accuracy depends on site-specific factors. For excavation and off-site treatment remediations the primary factor affecting overall cost estimate accuracy is the estimate of waste quantity. To a great extent, the degree of site characterization to improve the accuracy of waste volume estimates becomes a site-specific judgment call by the cognizant Project Manager. The primary factor affecting a Project Manager's ability to effectively make this decision is the amount of experience this individual has gained on previous similar projects. The approach taken in this paper is to analyze two case studies so that the results could assist Project Managers involved with future projects with similar characteristics.

DISCUSSION

A minimal amount of intrusive investigative effort was expended during the RI/FS and RD phases to define waste quantities for each of the actual case studies. Therefore, the two hypothetical sensitivity cases considered for each site involved increasing levels of site characterization. The hypothetical cases were developed assuming more sampling and less uncertainty (better estimates) regarding waste quantity.

The overall approach taken was to estimate incremental costs for additional site characterization and compare them with the corresponding incremental cost savings which may be achieved during the remedial action. Incremental costs for additional site characterization consisted primarily of costs for performance of test pits and completion of relevant laboratory analyses. Incremental cost savings during the RA phase included anticipated reductions in the unit prices ($/ton of waste) bid by the remediation contractor. Anticipated reductions in unit prices would result from two factors; quantity discounts offered by treatment facilities and bid restructuring based on perception of waste quantity uncertainty. It has been assumed that if remediation contractors believe that there is a high probability that the actual waste quantity will significantly exceed the estimated waste quantity there will be a tendency to increase unit prices for waste disposal with or without corresponding reductions in other bid line items (e.g., lump sum amount for mobilization).

A summary of the assumptions regarding site characterization and remediation parameters for Site A study cases is shown in Table 1. Case A1 represents the actual case study for Site A. Cases A2 and A3 represent the two hypothetical sensitivity cases considered for Site A. The incremental total characterization cost for Case A1 is for surface measurements of the extent of the tar deposits based on visual observations. Incremental total characterization costs for Cases A2 and A3 are based on collection of an additional sample for every 2,000 and 1,000 ft^2 respectively.

The total waste quantity remediated was 2,300 tons; however, the final design estimate was only 700 tons (Case A1). This low estimate was due to the significant quantity of tar which had migrated via subterranean movement from the original source areas. It was assumed that as a result of the additional sampling the final design estimate would have improved to 1,600 and 2,200 tons for Cases A2 and A3 respectively.

The adjusted remediation bid unit prices shown in Table 1 represent the expected line item values in the winning bid (lowest responsive bid). These adjusted remediation bid unit prices decrease with increased levels of site characterization due to quantity discounts offered by the treatment facility and an adjustment by the remediation contractor based on the perception that actual waste quantities will be significantly greater than estimated quantities. The effects of the quantity discounts are represented by the Base Remediation Bid values in Table 1. The adjustments by the remediation contractor are represented by the Adjustment to Remediation Bid Due to Uncertainty values in Table 1. The Weighted Average Unit Price Following Negotiation values shown in Table 1 are the average unit prices which will be actually paid to the remedial contractor at the completion of the remediation. These unit prices differ from the bid prices for Cases A1 and A2 because it has been assumed that following the discovery of the additional waste during the course of the remedial action it will be possible to negotiate a unit price discount for the majority of the "extra" waste. To quantify this effect it has been assumed that the Variation in Estimated Quantity clause in the Federal Acquisition Regulation (52.212-11) applies which states that price negotiations can be initiated when the actual quantity exceeds 115 percent of the estimated quantity. The Weighted Average Unit Prices Following Negotiations multiplied by the actual waste quantity (2,300 tons) yields the total costs associated with the remediation of waste line item. These costs are computed and compared with the value for Case A3. In order to obtain relative or incremental costs, the cost for Case A3 was set to zero and the A3 cost was subtracted from the total costs for Cases A1 and A2.

A summary of the assumptions regarding site characterization and remediation parameters for Site B study cases is shown in Table 2. Case B1 represents the actual case study for Site B while Cases B2 and B3 are hypothetical sensitivity cases. Once again, the incremental total characterization cost for Case B1 is low because the carbon waste quantity estimate was based on surface measurements and the assumption that the carbon waste was placed on the surface of a relatively flat area.

The total waste quantity remediated was 1,300 tons; however, the final design estimate was only 760 tons (Case B1). This low estimate was due to numerous unexpected field conditions including: the presence of additional carbon waste below the ground surface; the increased density of the waste due to constant heavy rains during the remediation; and a significant increase in weight due to the presence of large rock fragments mixed with the carbon waste at the bottom of the waste pile. It was assumed that as a result of the additional sampling the final design estimate would have improved to 1,000 and 1,200 tons for Cases B2 and B3 respectively. The development of the Incremental Total Remediation Costs (Table 2) by analyzing the anticipated remediation bid values was performed as it was for Site A. It was assumed that only a small quantity discount would be realized between Case B1 and Case B2; and that no further quantity discount would be realized between Case B2 and Case B3. Following the start of the remedial action it was not possible to negotiate a quantity discount with the remediation contractor in Case B1. Therefore, it was assumed the negotiations would also not be possible for Cases B2 and B3.

TABLE 1
SITE "A" – SUMMARY OF SITE CHARACTERIZATION AND REMEDIATION PARAMETERS FOR STUDY CASES

	CASE A1	CASE A2	CASE A3
CHARACTERIZATION PARAMETERS			
Area of Concern (SF)	128,000	128,000	128,000
Sampling Frequency (# of Test Pits/SF)	0	1/2000	1/1000
Total Number of Test Pits	0	64	128
Number of Samples (TCL Semi–Volatile Organics)	0	64	128
Incremental Total Characterization Cost ($)	3,000	79,000	144,000
REMEDIATION PARAMETERS			
Actual Waste Quantity (Tons)	2,300	2,300	2,300
Final Design Waste Quantity (Tons)	700	1,600	2,200
Base Remediation Bid – Unit Price ($/Ton)	1,043	972	967
Adjustment to Remediation Bid Due to Uncertainty ($/Ton)	86	20	0
Adjusted Remediation Bid – Unit Price ($/Ton)	1,129	992	967
Weighted Average Unit Price Following Negotiations ($/Ton)	1,046	987	967
Incremental Total Remediation Cost ($)	182,000	46,000	0

TABLE 2
SITE "B" – SUMMARY OF SITE CHARACTERIZATION AND REMEDIATION PARAMETERS FOR STUDY CASES

	CASE B1	CASE B2	CASE B3
CHARACTERIZATION PARAMETERS			
Area of Concern (SF)	23,000	23,000	23,000
Sampling Frequency (# of Test Pits/SF)	0	1/2300	1/500
Total Number of Test Pits	0	10	46
Number of Samples (TCL Volatiles and PCB/Pesticides)	0	5	23
Incremental Total Characterization Cost ($)	5,000	15,000	35,000
REMEDIATION PARAMETERS			
Actual Waste Quantity (Tons)	1,300	1,300	1,300
Final Design Waste Quantity (Tons)	760	1,000	1,200
Base Remediation Bid – Unit Price ($/Ton)	1,300	1,200	1,200
Adjustment to Remediation Bid Due to Uncertainty ($/Ton)	30	10	0
Adjusted Remediation Bid – Unit Price ($/Ton)	1,330	1,210	1,200
Weighted Average Unit Price Following Negotiations ($/Ton)	1,330	1,210	1,200
Incremental Total Remediation Cost ($)	169,000	13,000	0

RESULTS AND CONCLUSIONS

- The tradeoff between incremental site characterization costs and incremental remediation costs for Site A is shown in Figure 1. The three study cases for Site A are located on a dimensionless abscissa in order of increasing levels of site characterization. The cost points are connected with smooth lines for illustrative purposes, however in practice these lines are discontinuous. Shaded bands indicate a range of values which may occur based on the use of a uniform probability distribution of values surrounding the data points indicated. This figure illustrates that the total cost (i.e., sum of the two curves) for Case A2 is lower than the total cost for either Case A1 or Case A3 by $19,000 to $60,000. This figure illustrates that there are potentially significant total cost impacts for cases distant from the site characterization optimum.

- The results for Site B are shown in Figure 2. Conclusions similar to those for Site A can be drawn from these results. The total cost (i.e., sum of the two curves) for Case B2 is lower than the total cost for either Case B1 or Case B3 by $7,000 to $146,000.

- In general, it appears that it is better to perform too much sampling rather than not enough. When waste quantity estimates are very low the potential for severe cost increases exist, especially if subsequent negotiations with the remediation subcontractor are less than successful.

- The waste quantity discount structures used in this study were the prices encountered for the specified waste materials during the specific time periods of these remedial actions. Waste quantity discounts depend on: nature of the waste material, market conditions, absolute waste quantities, etc. All of these factors should be considered for each site- specific situation.

- It may not be possible to perform cost-justifiable site characterization during the RD phase due to time constraints or other conditions. In these cases it may be possible to partially recover potential savings resulting from waste quantity discounts by structuring the bid pricing form to request prices for a variety of possible waste quantities.

- Although not included in the above analysis, an important consideration may be the costs associated with increasing previously authorized expenditure levels while the RA is in progress. Both the administrative costs associated with making changes and the opportunity costs associated with the incremental funds required could be significant.

- A secondary conclusion from the above data involves the establishment of realistic contingencies for RAs of this type. The 8 percent and 10 percent contingencies for change orders/claims recommended in the RD guidance for contracts below $2M and above $2M respectively may be inadequate.

- The conclusions of this paper are that the degree of site characterization can be important for excavation and off-site treatment. However, this may not be true for other types of remediations such as excavation and on-site treatment. Bid prices may not be as sensitive to estimated waste quantities for other types of RAs.

DISCLAIMER

The work described in this paper was not funded by the U.S. Environmental Protection Agency. The contents do not necessarily reflect the views of the Agency and no official endorsement should be inferred.

INCREMENTAL COST ANALYSIS FOR SITE "A"

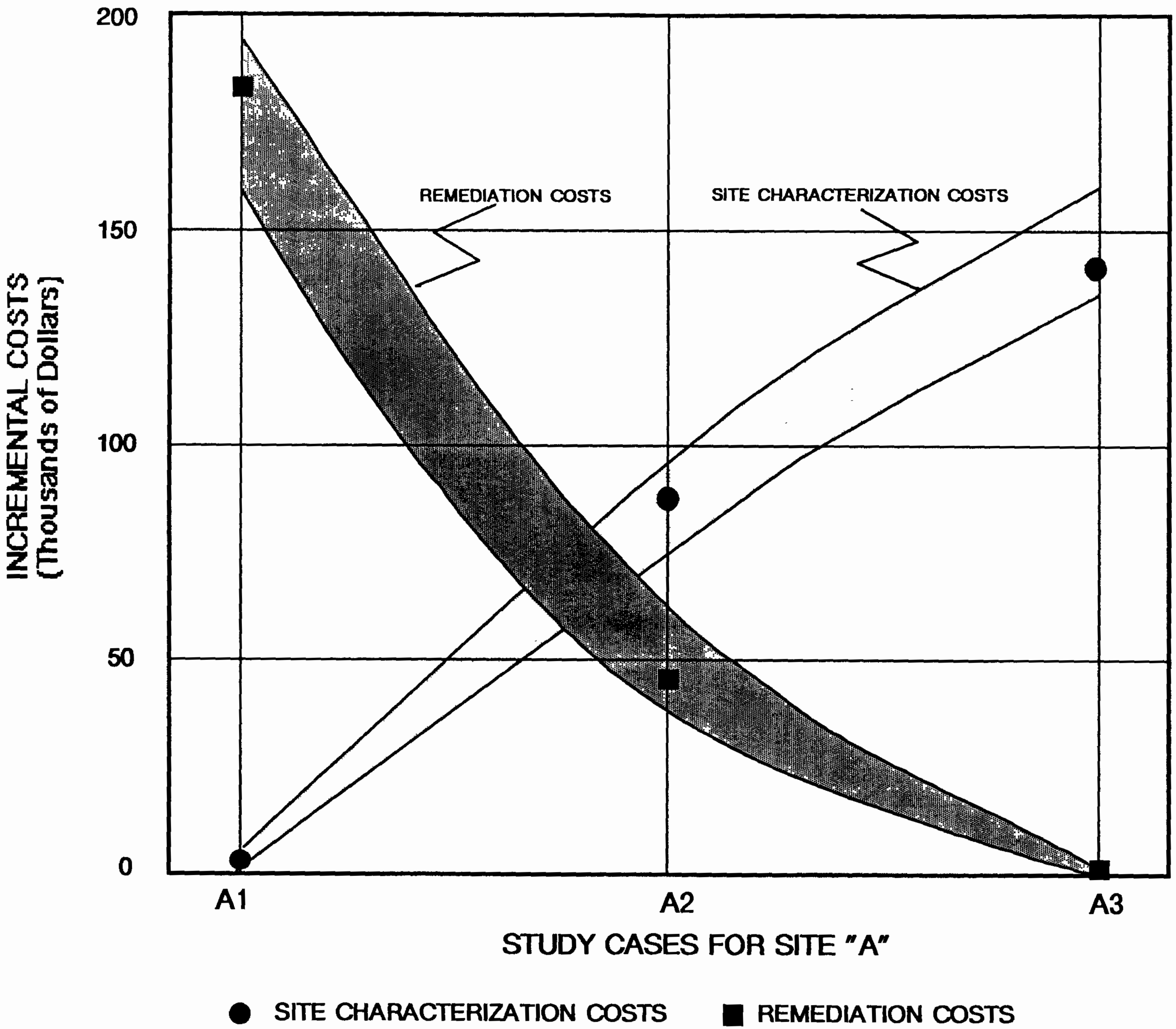
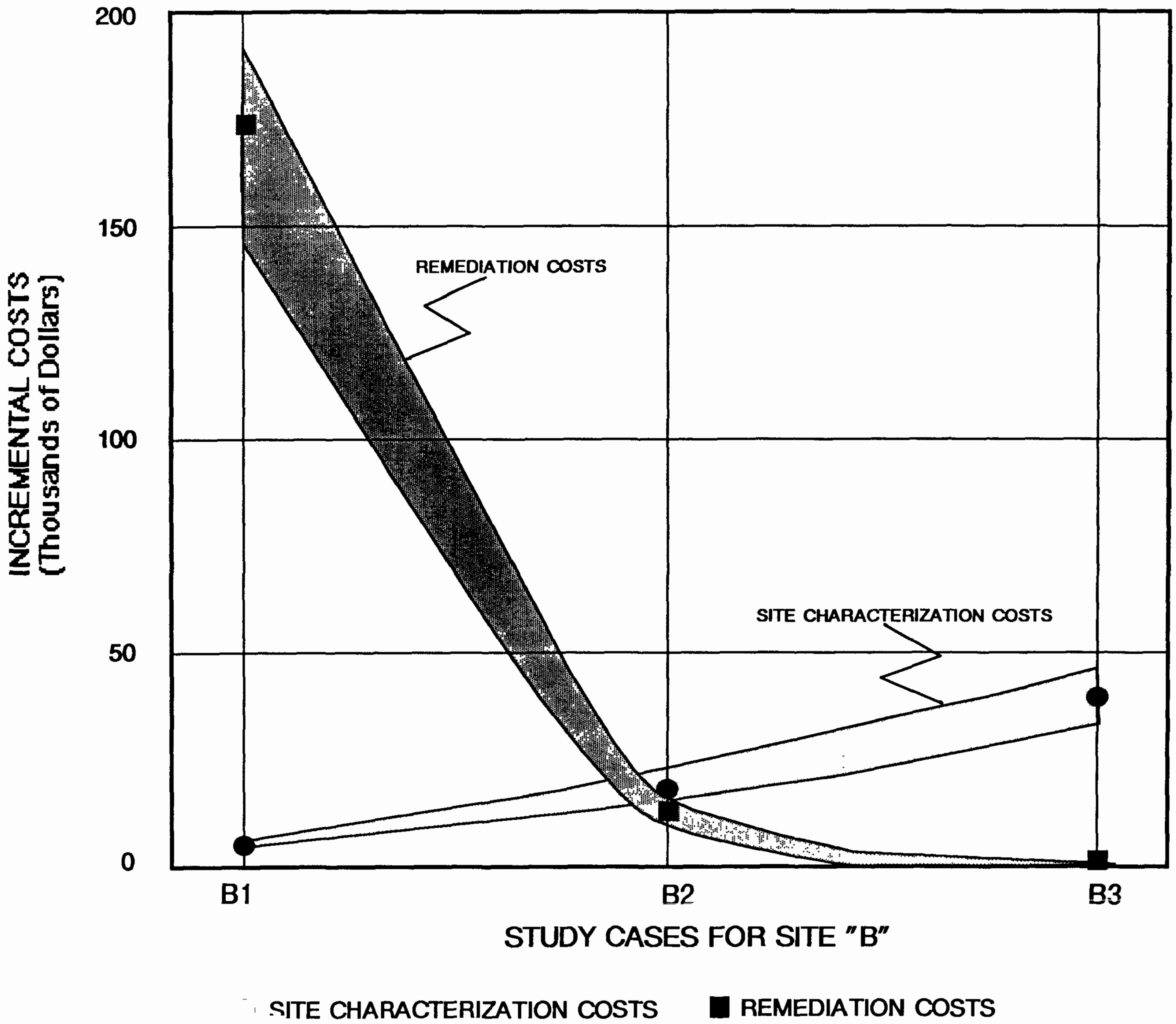


FIGURE 2 - INCREMENTAL COST ANALYSIS FOR SITE "B"



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Writing a Record of Decision to Expedite Remedial Action: Lessons from the Delaware City PVC Project

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INTRODUCTION

Fortune has not been kind to the Delaware City PVC Superfund Project Remedial Action phase. Entering its second year of construction, the project is behind schedule, over budget and completion is like a distant star — motion towards it is hardly perceptible.

Any construction project of this scope and complexity will contain hidden problems and frustrations that even the best engineer cannot anticipate. For instance, it has been one of the rainiest years ever in northern Delaware; personnel have drifted in and out creating a lack of continuity. Yet there are specific difficulties the project shares with other Superfund projects that can be attributed solely to the administrative process. It is ultimately constructive to consider the problems on this project, to attend to the administrative aspects we do control, and learn from past mistakes. A useful place to look for this purpose is the remedy selection process and its record of decision (ROD). The ROD is a convenient window into the mind set that governed the site investigation, feasibility study and remedy selection. It is the one document that best memorializes the conceptual frame work of the Superfund project. In the case of Delaware City PVC, many of the problems encountered in implementation can be traced to the ROD.

The 1985 ROD is typical of its era. It contains strengths and innovations in the recovery and re-use of resources. In some respects these innovations overshadowed the project's fundamental weaknesses--a sketchy remedial investigation, a conceptually limited feasibility study, and unspecified goals. Yet it has no lack of detail. Perhaps it is enough to note that the ROD specifies well locations, diameters and pumping rates, but not soil cleanup goals. As the project proceeded, amoeba-like, it divided in two. One effort was to meet the requirements of the ROD, the other was to do something to improve the environment. There is surprisingly little overlap.

It is easy enough to second guess a five year old document. This paper proposes to go beyond fault finding to a critical examination of the decision process as it actually occurred for this site. My purpose is to show how many of the delays encountered in remedial action can be traced to the ROD and suggest improvements to the decision documentation that will expedite remedial action on future projects. The conclusion is consistent with the October 1990 Clean Sites proposal "Improving Remedy Selection: An Explicit and Interactive Process for the Superfund Program". I hope to suggest additions to those recommendations.

BACKGROUND

The Delaware City PVC Superfund Site began with a facility which has manufactured polyvinyl chloride (PVC) since 1966. It is located in the Atlantic Coastal Plain near a major estuary. The plant is part of an industrial complex which includes a refinery, a coal fired power station and numerous chemical companies.

PVC is one of the most common and valuable polymer products and is found in a wide range of products from containers and tubular goods to medical equipment. Worldwide production is in excess of 11 million tons annually or about a quarter of all plastic production (Braun, 101). Relatively speaking, PVC is environmentally friendly. It is produced from petroleum hydrocarbons derived from natural gas which were once considered waste. The by-products of its manufacture are reusable. PVC products are readily recycled but may be safely incinerated or landfilled.

The Delaware City facility produces about 130 tons a day of PVC resin which is then shipped to producers to make into goods. The plant specializes in emulsion grade dispersion resin which is clear in color and is used in medical products such as disposable gloves and syringes, tubing and fittings. The plant is a major producer of this high quality resin. Off-grade batches are sold for rougher use, e.g., automotive bumpers.

The plant process is typical of PVC manufacture. Vinyl chloride monomer (VCM) arrives by rail car from Baton Rouge. It is processed in 3,000 gallon batches with de-ionized water, heat, pressure and hydrogen peroxide as a catalyst. Polymerization occurs at 180 degrees F and 180 psi after four to six hours in a stainless steel reactor. Unpolymerized vinyl chloride monomer boils off as the pressure is dropped and is reclaimed for use in the next batch. The reactor vessel is then cleaned and a new batch begun. Leaving the reactor, the PVC resembles white latex paint. It is dried by spraying into heated air and shipped as pellets. The plant has eight reactors and operates continuously.

Environmental problems at the site originated with the handling of waste water, sludge, and disposal of off-grade resin batches. To maintain the quality of the product, it is necessary to clean the reactors after each batch. Until the mid 1980s reactor cleaning was performed by hand using organic solvents. Process water and cleaning water ran through an unlined drainage ditch to a pair of concrete aeration lagoons. There it was stripped and treated by bio-degradation. Retention time in the lagoons was about one day. After treatment the water was discharged to a stream under a National Pollution Discharge Elimination System permit. Storm water from the plant also ran through ditches and collected in unlined reservoir ponds. It was pumped to the aeration lagoons for treatment prior to discharge.

Solid wastes containing traces of solvents and vinyl chloride originated from on-site disposal of off-grade resin batches, sludge, and solids deposited in the ditches. Every two years or so the concrete lagoons were drained and bottom sludge removed by drag line. The sludge was buried on site. One area containing about 25,000 cubic yards of buried sludge was capped in 1979. By this time, EPA, the State and the responsible party all recognized the risk of ground water contamination from the site.

The waste water treatment system has been improved in the last five years. Most importantly, solvents are no longer used in reactor cleaning. That is now accomplished with high pressure water wash. Also, a primary clarifier was added to the system. It eliminates solids and reclaims unpolymerized VCM. These improvements were made independently of the Superfund project.

The leaky waste water system and solid waste burial inevitably resulted in ground water contamination. Ethylene dichloride (EDC), trichloroethylene (TCE) and vinyl chloride monomer (VCM) were noted in a residential well 300 yards down gradient from the plant in 1982. The responsible parties undertook an informal remedial investigation (RI) on their own. In 1984 they signed a consent order with EPA and the State of Delaware for a feasibility study (FS) and implementation of remedial action plans. Note that the ROD that was eventually reached under this agreement was not subject to the re- authorization act of 1986 (SARA). The FS began in 1984 with an updating of the field investigation and was finished in 1986. The ROD was signed later that year. An amendment to the consent order was added in 1987. It updated the language, required work plans for design and established a schedule of deliverables. However, it did not provide stipulated penalties for non-compliance.

The consent order of 1984 recognized two "Areas of Work" that eventually became operable units (OUs). The plant and some adjacent property had been sold in 1981. By the time design work began in 1987, the original owner retained nothing at the site except the liability. Complicating the matter, it had been taken over by a third company. The project was divided between the current and former owners of the plant. Each one proceeded in RD/RA with its own design consultants. In every important way the site became two distinct Superfund projects. While this division of work was administratively convenient, it has caused technical headaches in design, implementation and especially in establishing soil cleanup goals. It also affected the human relations aspect of the project. The responsible parties perceived that their interests were diverging and potentially in conflict. An atmosphere of distrust affected communications and opportunities to avoid duplication were lost.

Operable unit 1 (OU 1) is the plant itself with emphasis on the waste water treatment system but also including soil contamination from solid waste burial and sludge in the drainage ditches. The greater part of operable unit 2 (OU 2) is ground water recovery and treatment but includes solid waste and contaminated soil on a plot of land which was not transferred with the plant in 1981.

FINDINGS

The ROD addresses two broad areas--ground water recovery and source control. The hydrogeology of the area presents some unusual problems and was the focus of most of the attention. About a thousand feet inland of the site lies a pleistiocene buried river valley, a thick and highly transmissive sand and gravel. The contaminat plume from the site moves inland perpendicularly to this valley and divides, a branch moving in each direction along the valley. Recovery wells straddle the valley to both ends of the plume. The recovery rate will be about 450 gallons per minute. Even so, a single pass through of the plume is projected to take a minimum of eight years of around the clock operation. Several pore volume flushes are thought necessary to achieve the ground water cleanup goals.

Recovered ground water is pumped back to a site adjacent to the plant through three miles of pipeline. The ROD called for reuse of the ground water resource as make-up and cooling water for the plant. The plant has always used purchased utility water consuming some $70 thousand worth a year. However, since the plant no longer uses EDC, it did not want to re-introduce it to the system. Although the ground water was lower in dissolved solids than utility water, the ramifications of handling deionization resin beds contaminated with EDC, TCE and VCM were unknown. The question also arose of responsibility for spills or leaks from the ground water delivery system. Therefore the plant declined to take the water and the other party put in an air stripper to treat the water prior to surface discharge. The possibility remains of using the stripped water in the plant if the two parties can reach terms. Ironically, however, re-use of the recovered ground water in the plant was regarded by the State as an important innovation of the ROD at the time it was written.

Unlike ground water recovery, source control was shared by both operable units. The sources on OU 2 were old disposal and storage areas. Their contribution to ground water contamination was not quantified in the RI, but they are a diminishing source. By contrast, the leaking lagoons, unlined ditches and earthen storm water basins on the plant were continuous sources. The principal effort at source control was lining these surface impoundments. In actual practice, the plant's elimination of EDC and installation of a primary clarifier decreases contamination significantly before the water ever reaches the treatment system. A secondary source on the plant was the contaminated soils in the ditches and impoundments.

Soil cleanup goals. The ROD is silent on the matter of soil cleanup goals except to say that in the work areas that became OU 1, acceptable levels will be determined at the design stage. The design document for the drainage ditches, off-grade batch pits and storm reservoir ponds concludes that the source of contamination is the sludge itself, not the soil, and that sludge and soil can be distinguished from each other visually. It provides for excavation of the sludge down to the soil interface with an additional six inches of soil taken out for good measure. This material, except for sludge that was recoverable for re-use, was to be sent to a RCRA facility for disposal according to the ROD. Any soil excavated for construction purposes was to be kept on site for fill material. The regulatory agencies agreed to using the visual criterion to determine soil sample points for analysis.

Chemical analysis of samples from the OU 2 area, which had been used as storage for the resin product, showed that the buried white waste material is not necessarily contaminated. Further testing showed only weak correlation between visually identified waste resin and the three contaminants of concern. There was also a period of confusion over analysis methods and detection levels. In convoluted fashion these revelations led to acceptance of level of 2-4 ppm on OU 2 for the three contaminants. The responsible party at OU1 briefly established a level of 5-8 ppb, the detection limits in soil, for the same contaminants. The reasoning for trying to achieve this level of residual contamination was obscure but apparently the party believed that EPA required it and it was feasible. During excavation, it became clear that the 5-8 ppb criterion was not practical. EPA established 250-500 ppb for both units in order for construction to proceed. This level is thought to be reasonably conservative, but it is at best an administrative compromise since the total quantity of contamination in the ground and its impact on ground water remain unknown. On both operable units, soil contamination has proven much more extensive than was determined in the informal RI.

Whereas Clean Sites recommends the development of national standards for selected contaminants, at Delaware City PVC there was inconsistency for a time from one side of the fence to the other. This can be attributed directly to the ROD postponing the important decision on cleanup goals to the design stage and then the division of the design between the operable units.

Disposal. Disposal became the most contentious issue area of the project. Without knowledge of the extent of contamination in soil on the site or of its contribution to the ground water problem, the ROD specified disposal of "unrecoverable material" in a RCRA hazardous waste management facility (HWMF) for the area that became OU 1. While the responsible party for OU 1 was shipping 4,000 cubic yards of soil for disposal at a cost of $1.2 million, on the other side of the fence at OU 2, contaminated soils and resin were being scraped together in a pile and capped according to the ROD's selected remedy. The fill is not lined however, so the contamination was to remain in contact with soil above the water table.

Why the ROD selected two distinctly different remedies-- simple capping and hazardous waste disposal--for the same contaminants is unclear. The description of the capping operation in the ROD did not involve extensive earth moving, only grading of the area to be capped. In construction however, considerable bulldozing and consolidation of soils has occurred, so it would not seem that movement of soils about the site was the issue. If one party had responsibility for all of the contaminated solid waste in both work areas, the logic of consolidating it in a single capped fill would have been more apparent. The ROD did not list such consolidation as a considered alternative. It did discuss the excavation and removal of soils and sludges on the OU 2 work area, but this was rejected because it was much more expensive than capping which offered "comparable protection".

The RI identified only the sludge pits, impoundments and storage areas as sources, not the widespread low level soil contamination. Consequently, data on the extent of soil contamination in the plant was never developed. The ROD recorded the decision to dispose in a HWMF without knowledge of the potential volume or environmental risk of the contaminated soil.

Liners and tanks. The considered remedies for the plant waste water treatment system were 'fix-up' solutions from the inception of the FS. The new system would look just like the old except that its bottom would be sealed. An alternative of replacing the leaking concrete aeration lagoons with above ground tanks was not considered in the FS and therefore not mentioned in the ROD. After design work was nearly complete on lining the lagoons and other impoundments, the responsible party made a verbal proposal to replace all or some of them with above ground tanks. In the four years elapsed since the ROD was signed, this had become its nationwide corporate policy. Experience with tanks at other facilities had been favorable both economically and environmentally. Even though the initial cost was higher, reliability was better than lined earthen impoundments and maintenance was easier. However, since this approach was not mentioned in the ROD, it presented an administrative problem for the EPA and the State agency. Could such a drastic change be accommodated in the language of the existing ROD? What unknowns would be entailed in re-opening the ROD? Both agencies feared a loss of momentum on the project if the ROD were re-opened just as construction was finally about to begin. The responsible party perceived this as inflexibility. The end result was discouragement with the tank proposal and pushing ahead to implement the liner remedy.

The surprise came when the first excavation for a new storm water collection pond was made. Groundwater was encountered about 3 feet above its anticipated depth. The lined impoundments all had to be re-designed to be shallower and still maintain volume. A third storm water pond was added to make up the difference in volume. Costs increased as the square footage to be lined increased. Space became a problem; there was barely enough room on the property for all the impoundments.

In retrospect, the proposal to use tanks where possible deserved greater attention. During construction there were many problems with lining the impoundments. They are not simple basins. The liners are penetrated by piping and must tie in with cement flumes and gates. Also, lining requires long periods of favorable weather. Tankage would have been simpler to construct and would have allowed for air emissions control in the future. Redesign of the lined impoundments and trouble with installation in the poor weather have been the chief factors in the schedule overrun.

Ditches and pipes. Waste water ran from the reactors and cooling towers to the treatment system through two unlined ditches called North and South. North Ditch also drains rain water from about 4 acres and South Ditch from 20 acres. Sludge in the bottom of the ditches was recognized as a potential source of ground water contamination. All alternatives considered in the ROD involved excavation of contaminated sludge and soil. The selected alternative was to line the ditches with a single layer of polyethylene protected by a foot of clay with soil and sod on top. An alternative proposal which was screened out in the FS was to use piping instead of a ditch. This was rejected because of the possibility of solids build-up from the used process water.

In construction, the contractor proceeded with excavating and lining North Ditch while the impoundments were being re-designed as described above. Problems arose early when it was discovered that visible PVC resin was not just confined to the bottom of the ditch but also spread below the soil surface beyond its present banks. Excavation for the ditch alone created more soil for RCRA HWMF disposal than was anticipated in the FS for the entire project.

Last summer was one of the wettest in Delaware's history. Repeatedly the delicate grading of the ditch was washed away before the lining could be installed. One afternoon shower could ruin a week's work. The expanded excavation area was filled, compacted and re-graded several times before it could finally be lined. Experience with rain during construction showed that the clay cover would be subject to erosion by water running through the ditch. Consequently, a concrete bed with sealed joints was placed on top of the liner. (A discussion of this lining system is found elsewhere in these proceedings.)

Since the ROD, the plant has upgraded its treatment system to include a primary clarifier. The process water now loses most of its solids in the clarifier and is piped directly to the aeration basins. It is apparent that the ditch does not drain the ground it passes through but receives the rain water it carries from a culvert at its head. In other words, a pipe would have sufficed. However, the selected remedy was implemented as specified in the ROD. Now rain water runs 300 feet through a state-of-the-art double lined ditch.

CONCLUSIONS AND RECOMMENDATIONS

The Delaware City PVC ROD has faults of both omission and commission. It was not specific with regard to environmental objectives (soil cleanup goals) and it was overly specific on remedy selection. Both sets of faults originate in an inadequate RI/FS. Two other developments exacerbated the problems. One was the division of the site into OUs on administrative/legal instead of technical grounds, the other was the perception that the ROD could not be changed in the face of new information and improving technology.

The RI was strong and detailed on ground water recovery issues. However, it failed to identify possible sources of ground water contamination fully. Without this knowledge, and without an adequate understanding of contaminant transfer from soil to ground water, there was no technical basis for setting soil cleanup levels. Consequently, the decision was put off.

Among Clean Sites' recommendations is "establishing site cleanup objectives and setting cleanup levels before developing remedial alternatives". A mandate of this nature would have prevented postponing establishing cleanup levels to the design stage where it was further complicated by the division into operable units.

The FS with regard to the plant waste water system was too narrow in scope. The production process was not examined for opportunities to replace solvents or remove and recycle the VCM from the waste water stream. The FS was not informed of developments in the industry such as solids removal, and the switch to above ground tanks. While the ROD cannot easily incorporate remedies not in the FS, it can provide for contingencies. The Delaware City PVC ROD actually contains a good example of this practice. For this site, the preferred treatment for ground water was use in the plant. However, subsequent developments favored air stripping before use. This contingency was discussed in the ROD and adopted with an Explanation of Significant Differences. Regrettably a wider range of approaches was not considered for the waste water treatment system; there was no discussion in the ROD of above ground tanks, the elimination of solvents, use of the clarifier or piping. The mention of these technologies as meeting minimum requirements, as in the case of the air stripper, would have removed the administrative obstacle of "re-opening the ROD".

Finally, for contingencies that cannot be anticipated, regulators should acknowledge the time lag between remedy selection and implementation. In the case of Delaware City PVC it was nearly four years. Responsible parties and remedial project managers need to continue the search for quality improvement in the design stage and have the flexibility to adapt to better technology. For these older RODs the need is to simplify the re-opening exercise and make everyone familiar with it. New RODs should be clear on objectives, that is, where the project is going, but less prescriptive on how it gets there.

The Superfund process needs the pivot of a firm decision at the conclusion of the FS to propel the project into design and implementation. Yet we must differentiate between indecision on goals and the flexibility to achieve good engineering. When the ROD refocuses on environmental objectives, it will bring out the best performance from the designers. Reaching the ROD will be like lighting a beacon, not putting on blinders.

DISCLAIMER

The opinions expressed in this paper are those of the author and do not necessarily reflect the position of the Delaware Department of Natural Resources and Environmental Control.

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Site Characterization Data Needs for Effective RD and RA

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INTRODUCTION

As the number of Superfund sites in the Remedial Design (RD) and Remedial Action (RA) phases has increased, the adverse impacts of inadequate design data have become apparent. This paper addresses: types of data most often found to be inadequate and/or have the greatest impact on effective RD and RA, examples of why these data are needed, data needs for particular remediation features, and suggested ways to improve site data collection and presentation. Most design problems that result in schedule slippage and both RD and RA cost overruns result from inadequate site characterization data. Those data gaps affect not only the high tech treatment processes but also the more mundane aspects of remediation.

Work through the RI/FS phase is generally the domain of scientists, while engineers have the functional lead during RD and RA. Often the engineers have very little involvement during the problem definition or RI/FS phase and the scientists have insufficient follow up in the RD and RA phases. As a result, too many Records of Decision (ROD) and consent decrees are accomplished which dictate remedies which are ineffective or marginally effective, much more costly than anticipated, or impossible to implement. Also many design engineers are accustomed to working from a clearly defined problem, unlike those found at most subsurface and ground water contamination sites. Therefore, it is imperative that the scientific disciplines be available through both the design and remediation periods to better define site conditions and to interpret those conditions for the designer in order for him or her to assure the adequacy and implementation of the design.

A few examples of problems associated with incomplete site characterization data and/or full appreciation of site conditions are listed below:

(1) Soils properties and their handling characteristics are often poorly evaluated or even ignored when considering various technologies. This is especially true for thermal treatment.

(2) Volatile emissions during excavation and handling of contaminated soils are often not anticipated.

(3) Lack of information on temporal and spatial variations in contaminant loading in ground water remediation decisions can lead to inefficient designs.

(4) No pre-ROD consideration of availability of utilities resulting in underestimation of costs.

(5) Poor understanding of the impermeability of slurry wall key layer leading to unacceptable leakage.

(6) Ground water treatment processes which focus on the contaminants of interest but ignore total ground water chemistry, especially the anions and cations present, will impact the effectiveness of the treatment process.

(7) Solvent extraction of explosives from soil is feasible, however, the unrecognized instability of the residue can be disastrous.

(8) Cap designs which utilize the cost effectiveness of geosynthetics but require slopes on which geosynthetics are not stable or caps which require the use of low permeability clays but don't evaluate the availability of suitable clay borrow material can be impractical to construct or very costly.

BACKGROUND

Four major categories of site characterization data can be identified as needed for complete site characterization to effectively remediate subsurface contamination, including source remediation. These data categories are:

(1) Site Data

(2) Geochemical Data

(3) Geotechnical Data

(4) Hydrogeological Data

The term "geochemical" is used rather than the more narrow "chemical" term in order to emphasize the importance of our understanding the chemical processes operating in the geological environment in order to implement effective remediations. The importance of quality analytical chemistry is already well understood and appreciated, however, our understanding of ongoing chemical processes needs improvement. The following paragraphs identify some commonly overlooked data requirements and include examples of problems resulting from the data gaps.

Site Data needs are often overlooked in the pre-ROD/consent decree phase and even well into design. Unforeseen cost increases, time delays, and contract modifications can and do result. Some common data needs include:

(1) Topographic Surveys - The need should be readily apparent, however, this aspect is often overlooked. In some instances, available general topographic mapping is used without verification. Consequently during RA, excavation or fill overruns or underruns or impossible site drainage are discovered which require contract modifications. Property boundary surveys and adequate horizontal and vertical controls are also included in this category.

(2) Utility Availability - Water, gas, power, and sewer services required for remedy implementation must be identified. In addition, leaking industrial sewer lines might be contamination sources and previously unidentified utility lines crossing a remediation site can cause contract shutdown pending their relocation or protection.

(3) Borrow Availability - In some areas suitable borrow is scarce. The costs of trucking suitable material from a distant borrow pit will add significant cost and transportation problems if not recognized. As an example, a 50-acre cap with an average of 3 feet of soil, requires almost 250,000 cubic yards or approximately 14,000 truckloads of suitable earth borrow material.

(4) Transportation Network - The proximity of suitable roadways and/or rail lines is important to remedies requiring the transportation of heavy equipment and earth materials into the site or contaminated or treated wastes from the site. Local opposition to frequent heavy truck traffic and damage to streets and roads, especially through residential areas, must be anticipated.

Geochemical Data collection can often be improved upon to more confidently select effective remedies and better effect quality RD and RA. Some examples include:

(1) Multiple Sampling Rounds - In too many cases, remediation decisions are made which are based on single or poorly timed, multiple ground water sampling rounds. Time allowed for RD often doesn't provide for seasonal sampling. As a result, chemical loading may exceed treatment plant capability, or the plant may be overdesigned, or the operating plan is not optimized to accommodate variations in loading.

(2) Anion/Cation Analysis - These analyses are inexpensive, yet if they are overlooked in ROD preparation, the designed treatment train may be either more expensive than anticipated or ineffective if not detected during RD. Eh, pH, and TOC are other chemical parameters which can affect effective RD.

Geotechnical Data must be gathered for many types of remedies, both for purposes directly related to the remedial process and for design auxiliary to the actual remedial process, such as building foundation design or excavations.

(1) Soil Moisture Content - The natural moisture content of site soils, especially fine-grained soils, is valuable information both in the pre-ROD and RD phases. As examples, the moisture content of contaminated soil to undergo thermal treatment affects fuel consumption and the moisture content of a fine-grained foundation soil can be an indicator of the soil's strength and consolidation characteristics.

(2) Atterberg Limits - These parameters define the plasticity of fine-grained soils, give the geotechnical designer an early indication of the strength of that soil, especially when evaluated with moisture content, and can be an indicator of contaminated soil handling and processing characteristics. The test is relatively inexpensive but the results can be very useful.

(3) Soil Strength Parameters - Generally not needed prior to the RD phase. Some design features requiring soil strength testing include structure or building foundations, significant excavations, dredging, and slurry wall trenches. Blow counts from Standard Penetration Tests can be used for an early indication of soil strength.

(4) Gradations - Some representative gradation or particle size distribution analyses done in the RI/FS phase can be very helpful in estimating approximate permeability and for designing efficient monitoring wells. Gradations are required for the design of such things as collection drains and withdrawal wells and in evaluating soils handling and processing characteristics.

(5) Excavatability - While there is no one test or set of tests to define this design parameter, valuations and judgments should be made in the pre-ROD phase concerning excavatability when excavations of any kind are required in the remedy. Excavatability includes such factors as whether the material can be machine excavated, the necessity for blasting, the existence of large boulders, the need for dewatering, etc.

(6) Landfill Settlement - Remediations often include capping an existing landfill and perhaps incorporating a gas collection and venting system. Many such landfills are still settling with attendant surface disruption capable of adversely impacting the effectiveness of the cap and vent system. Carefully surveyed settlement data collected throughout the RI/FS phase is invaluable for remedy selection and as design data. Settlement data collection should continue through RD and RA and into the operations and maintenance phase if displacements are continuing and significant.

Hydrogeological Data is routinely collected both during the RI/FS and RD phases. However, several aspects will be discussed which are sometimes slighted but can be very important to selection of an effective remedy and to proper design and implementation.

(1) Multiple Water Levels - In order to understand the hydrogeological character of the site in sufficient detail to select an effective remedy, it is important that enough water levels be obtained to define both the vertical and horizontal flow directions seasonally and as they respond to both natural and manmade recharge and discharge. We are working at a ground water contamination site in the Plains States at which the regional flow is severely distorted locally by irrigation pumping during several months of the year.

(2) Detailed Stratigraphy - In too many cases, stratigraphic detail has not been well developed due to poor sample recovery often coupled with too infrequent sampling intervals, lack of geophysical logs, improper sampler selection, field geologists poorly trained in logging methods, or combinations of the above. Even relatively minor variations in lithology have a strong influence on contaminant migration and plume development. This is an important factor during pre-ROD, RD, RA, and even into the operation and maintenance phase of both ground water and vadose zone remediation.

(3) Secondary Porosity Features - Joints, defoliation planes, bedding planes, root holes, etc., often strongly influence the overall gross permeability of bedrock materials and fine-grained soils, especially clays. In too many cases these features are not targeted during site exploration and if they are, the vertical features are difficult to intercept and analyze. Careful consideration of these features is warranted during the RI/FS phase and remedy selection for problems such as contaminated bedrock aquifers, multiple stacked aquifers, and slurry walls keyed into an "impermeable" layer. For sites such as these, additional characterization will also be needed during RD.

The various types of site characterization data discussed in this paper are not needed or at least not to the same degree for all features of site remediation. The following remediation features were considered:

(1) Withdrawal & injection wells
(2) Internal drains
(3) Slurry walls
(4) Slurry wall key layer
(5) Caps
(6) Chemical Stabilization
(7) Ground water treatment
(8) Landfills
(9) Thermal treatment
(10) Soil washing
(11) Excavations
(12) Dredging
(13) Vapor extraction

Table 1 presents a summary of site characterization data determined to be useful or needed for remediation. The table also suggests in which phase or phases of the remediation process it is advantageous to acquire the data.

TABLE 1

	DATA	Withdrawl & Injection Wells	Internal Drains	Slurry Walls	Slurry Wall Key Layer	Caps	Chemical Stabilization	Ground Water Treatment	Landfills	Thermal Treatment	Soil Washing	Excavation	Dredging	Vapor Extraction
		REMEDIATION FEATURE												
Site Data	Topographic Surveys	1	1,3	1,3	1,3	1,3		1	1,3	1	1	1,3	1,3,4	1
	Utility Availability	1	1	1				1		1	1			1
	Borrow Availability		2	2		1			1					
Geochemical Data	Transportation Network			1		1	1	1	1	1	1	1	1	1
	Multiple Sampling Rounds	1,3,4	1,4	1,4	1			1,3,4						1,3,4
	Anion/Cation Analysis	1,3,4	1,4	1	1			1,3,4					1,3	
	Soil Moisture Content		1	1,3	1	2,3	1,3		1,3	1,3	1,3	1,3	1,3	1,3,4
Geotechnical Data	Atterberg Limits	1	1,3	1,3	1,3	2,3	1,3		1,3	1	1	1	1	1
	Soil Strength Parameters		2	2		2,3		2	2	2	2	2,3	2	
	Gradations	1,3	1,3	1,3	1,3	1,3	1		2,3	1	1	1	1	1
	Excavatability		1	1	1		1			1	1	1	1	
Hydrogeological Data	Landfill Settlement		1,3	1.3		1,3,4								
	Multiple Water Levels	1,3,4	1,3	1,3,4	1,4	1	1,3		1,3,4	1	1	1,3		1,3,4
	Detailed Stratigraphy	1	1,3	1	1,3		1		1			1,3	1	1
	Secondary Porosity Features	1,3	1,3	1,3	1,3				1,3			1,3		1

Recommended Times to Collect Data

1. Limited data in RI/FS phase, greater amount in RD.
2. Data collection begins in RD.
3. During RA.
4. During operation and maintenance.

DISCUSSION

Site characterization should be an iterative process beginning with preliminary assessment and site investigation, continuing through RI/FS, RD and RA, and in some cases, into operation and maintenance. We identify information needs, collect data, analyze the data, identify additional information needs, collect new data, evaluate the new data and re-evaluate old data, etc. This process operates in varying degrees in the investigation, design, and remediation of contaminated sites. The effectiveness and degree to which it is utilized is dependent on the commitment of the client or program manager to the iterative process, the technical competence of those performing the work, and the timely input of the appropriate technical specialist.

There is a saying which states "We see what we know." In retrospect, the wisdom of this saying is apparent in the hazardous waste remediation program as we have progressed from it's infancy to what it is today. A very simple example is what we would see in an aquifer sample as it comes from the sample tube. Ten years ago, the hydrogeologist might have seen sand with reasonably high permeability and a likely plume migration pathway. Today's more knowledgeable hydrogeologist sees a cross-bedded, clean, medium-grained sand with thin, clayey sand interbeds and flecks of organic carbon. He or she sees the sand as a plume pathway but recognizes the cross-beds as potential downward DNAPL migration routes, wonders about the impact of the organic carbon, and sees adsorbtion potential in the clays of the interbeds. A geotechnical engineer tasked with designing a slurry wall sees a sand not likely to have significant slurry losses, he or she visualizes what the gradation of the mixed clean and clayey sands might be and how suitable that mixed material might be for trench backfill, and recognizes that the calcareous powder on the tip of the drive shoe together with less than full sampler penetration likely represents the presence of boulders. All have looked at the same sample but see it differently based on their knowledge and experience.

Our challenge is to gather and report as much of the necessary data as possible to satisfy the needs of all of the specialists involved in the identification, evaluation, design, and remediation of contaminated sites. Furthermore, we must attempt to accomplish this task in a cost and time effective manner. In the case of subsurface contamination problems, exploration (drilling, sampling, and well installation) is one of the most costly and time consuming activities. It is incumbent upon us to maximize the amount of information obtained from each hole and to utilize the field staff to gather as much surface site information as possible at the time they are in the field gathering subsurface data. It is much less costly to anticipate what the likely future data needs are and to collect some of those data at the RI phase than to have to remobilize to the field and drill and sample new holes in the early RD phase to gather that data. That is redundant and costly in time and money. As an example, a few Atterberg Limit or gradation tests from a chemical sampling or monitoring well hole takes almost no time and adds very little cost while the benefits are significant.
There are steps we can take to achieve the broader site characterization which we now know to be needed. The process must include a means of recognizing the total data needs and evaluating the risks of something less then full site characterization. The first step involves bringing together experienced representatives of the multiple disciplines involved in the total RI through RA process to discuss and summarize their data needs and to explore methods of collecting and reporting these data in the most cost effective manner. The end product might be a site characterization summary with a checklist of data needs for various contamination scenarios and likely or selected remedies. Quantative or at least semi-quantative contingencies for specific data gaps associated with particular remedial features should be included. The contingencies would give decision makers an idea of potential cost impacts caused by incomplete site characterization and help them better evaluate the benefit to cost ratio of additional investigation.

The invisible walls separating the various disciplines must be lowered and communication encouraged. The walls are caused by a number of things: technical jargon, professional jealousy, lack of understanding of the role of the other team members, physical separation, poor leadership, the pressure to meet short deadlines causing narrow vision, etc. All must communicate in terms understood by others and be sure their needs are understood. Environmental problem solving has brought together specialists who have not had long working relationships and roles are still being defined.

Perhaps we can learn from the civil engineering profession. Over the past 60 to 70 years, the engineering geology specialty has developed and matured to serve that profession. The engineering geologist uses his or her knowledge of geological processes to paint a clear and concise picture of geological site conditions related to the work. The geologist must develop an understanding of basic civil engineering and the physical properties of earth materials in order to recognize and evaluate those geological features which will affect the proposed project. Their reports must be understood by the civil engineer to be effective. The need for a similar specialty discipline(s) is apparent in the area of subsurface nation investigation and remediation, especially the site characterization aspects. There is indication that the specialty may be developing, however, we should recognize the need and actively work to promote its maturation. The very effective transition into this area of work by several firms specializing in engineering geology and the closely related geotechnical engineering branch of civil engineering reflects the applicability of the applied science approach. A few universities offer engineering geology or geological engineering and some have done a good job of modifying their curricula to focus on environmental applications.

In order to obtain the complete site characterization so very important to the evaluation and remediation of hazardous waste sites in the most cost effective manner, site characterization specialists are needed. These specialists should have solid foundations in geology, hydrogeology, or chemistry, and training in the basics of civil, chemical, and environmental engineering and the other scientific disciplines mentioned. The additional training may be either formal course work or on-the-job. Their function would be to investigate, evaluate, and report site conditions in light of the needs of the decision maker and the designer. The challenge is great in that the growth in the environmental field has been explosive. The most broad based and knowledgeable people must be made available to train and support the many bright but inexperienced people so that they know in order to be able to see and report.

CONCLUSIONS

Site characterization is a very important factor in the identification, evaluation, remedy selection, design, and remediation of subsurface contamination sites. Proper characterization is required to define the health risk, select and effect a remedy, and to assure cost effectiveness. As more sites are remediated, the need for more complete site characterization to meet the stated goals becomes more apparent. The task requires satisfying the needs of multiple disciplines in the most effective manner. Our challenge is to assure recognition of the need by the client or program manager and to develop specialists knowledgeable of those needs and capable of adequately characterizing the site in a cost effective and understandable manner. The EPA RPM and regional technical specialists are in a position to be leaders in encouraging and assuring the necessary integrated iterative approach for satisfying the data needs for effective RD and RA.

New Bedford Harbor, Massachusetts
Review of the Remedial Investigation/Feasibility Study Process
and its Impact on Remedial Design/Remedial Action

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INTRODUCTION

New Bedford Harbor is located in southeastern Massachusetts and consists of over 17,000 acres of estuary, harbor and bay. Bottom sediments are contaminated with polychlorinated biphenyls (PCBs) and heavy metals, with PCB levels exceeding 100,000 parts per million (ppm) in some spots. The site was placed on the National Priority List in 1982 and numerous investigations and studies have been carried out since that time. The site was divided into operable units in the fall of 1989 and a Record of Decision (ROD) was signed for the "hot spot" area in April 1990 which calls for dredging and incinerating of approximately 10,000 cubic yards of the most highly contaminated sediments. Remedial design for the hot spot is underway. The Feasibility Study for the remainder of the site was released in August 1990 and the ROD is scheduled for mid 1991.

The Army Corps of Engineers is responsible for remedial design and remedial actions at this site and has also been extensively involved in the Remedial Investigation/Feasibility Study (RI/FS) process through the performance of an Engineering Feasibility Study (EFS) and Pilot Study which evaluated dredging and dredged material disposal methods. The Pilot Study, which involved on-site dredging and disposal of contaminated sediments, introduced the local community, state and other groups to the technical aspects of the project at an early stage.

The New Bedford harbor site is unique in both its physical features as well as in the technical and political/institutional challenges associated with its remediation. Numerous decisions made during the RI/FS stage will effect the remedial actions and deserve to be reviewed for consideration at similar large, complex sites. These include the decision to perform the extensive studies which focused on dredging and dredged material disposal, the participation of the state/local community in the early stages of the project and the decision to divide the project into operable units. This paper reviews the RI/FS period and discusses the extensive evaluations performed by the Corps of Engineers and their impact on the ongoing remedial design work, as well as the eventual remedial actions.

BACKGROUND

SITE DESCRIPTION

New Bedford, Massachusetts is a port city located in southeastern Massachusetts (Figure 1) where site investigations conducted in the late 1970's found PCB contamination in various locations throughout the harbor. Further investigations identified two electrical capacitor manufacturers as major users of PCBs from the time their operations commenced in the late 1940's until 1977, when EPA banned the use of PCBs. These industries discharged wastewaters containing PCBs directly into the harbor and indirectly via the municipal wastewater treatment system. (1)

Additional field studies carried out since the late 1970's have shown PCB concentrations in marine sediment to range from a few ppm to over 100,000 ppm. Water column concentrations were found in excess of federal ambient water quality criteria. Fish and shellfish PCB concentrations were found in excess of the U.S. Food and Drug Administration tolerance limit of 2 ppm for edible tissue. In addition to PCBs, heavy metals (notably cadmium, chromium, copper, lead) were found in the sediment in concentrations ranging from a few ppm to over 5,000 ppm. (2)

As shown in Figure 1, the site is divided into three geographical areas, the Acushnet River Estuary, the Lower Harbor and Upper Buzzards Bay. The estuary is an area of approximately 187 acres which is bordered by the Wood Street Bridge to the north and the Coggeshall Street Bridge to the south. Contamination is highest in this portion of the site with PCB levels in the sediments generally greater than 50 ppm and exceeding 100,000 ppm in the hot spot which is located at the northern end of the estuary. Metals concentrations reach 5,000 ppm in this portion of the site.

The Lower Harbor area consists of approximately 750 acres which extends from the Coggeshall Street Bridge south to the Hurricane Barrier at the harbor entrance. Sediment PCB concentrations are lower in this area and range from below detection to approximately 100 ppm. Metals levels are also reduced with a maximum level of approximately 3000 ppm.

The Upper Buzzards Bay portion of the site extends south from the hurricane barrier, encompassing an area of approximately 16,000 acres. Sediment PCB and metals concentrations are considerably lower in this portion of the site but several localized areas near sewer and stormwater outfalls have sediment PCB concentrations that exceed 50 ppm. (2)

REMEDIAL INVESTIGATIONS/FEASIBILITY STUDIES

New Bedford Harbor was added to the National Priorities List in July 1982. This resulted in EPA performing a comprehensive assessment of the PCB problem in New Bedford and led to a Feasibility Study of remedial action alternatives for the Acushnet River Estuary portion of the site. This FS was completed in August 1984 and presented five clean-up options for the estuary portion of the site. Four of these options involved dredging and on-site containment of the contaminated sediments. EPA received extensive comments on these options from other federal, state and local officials, potentially responsible parties, and the general public. Many of these comments concerned the ability of a dredge to remove the contaminants, the environmental impacts of dredging, and the long term effects of onsite containment of contaminated sediments. EPA decided that additional study was necessary and had the Corps of Engineers perform extensive evaluations of dredging and dredged material disposal alternatives for the estuary portion of the site.

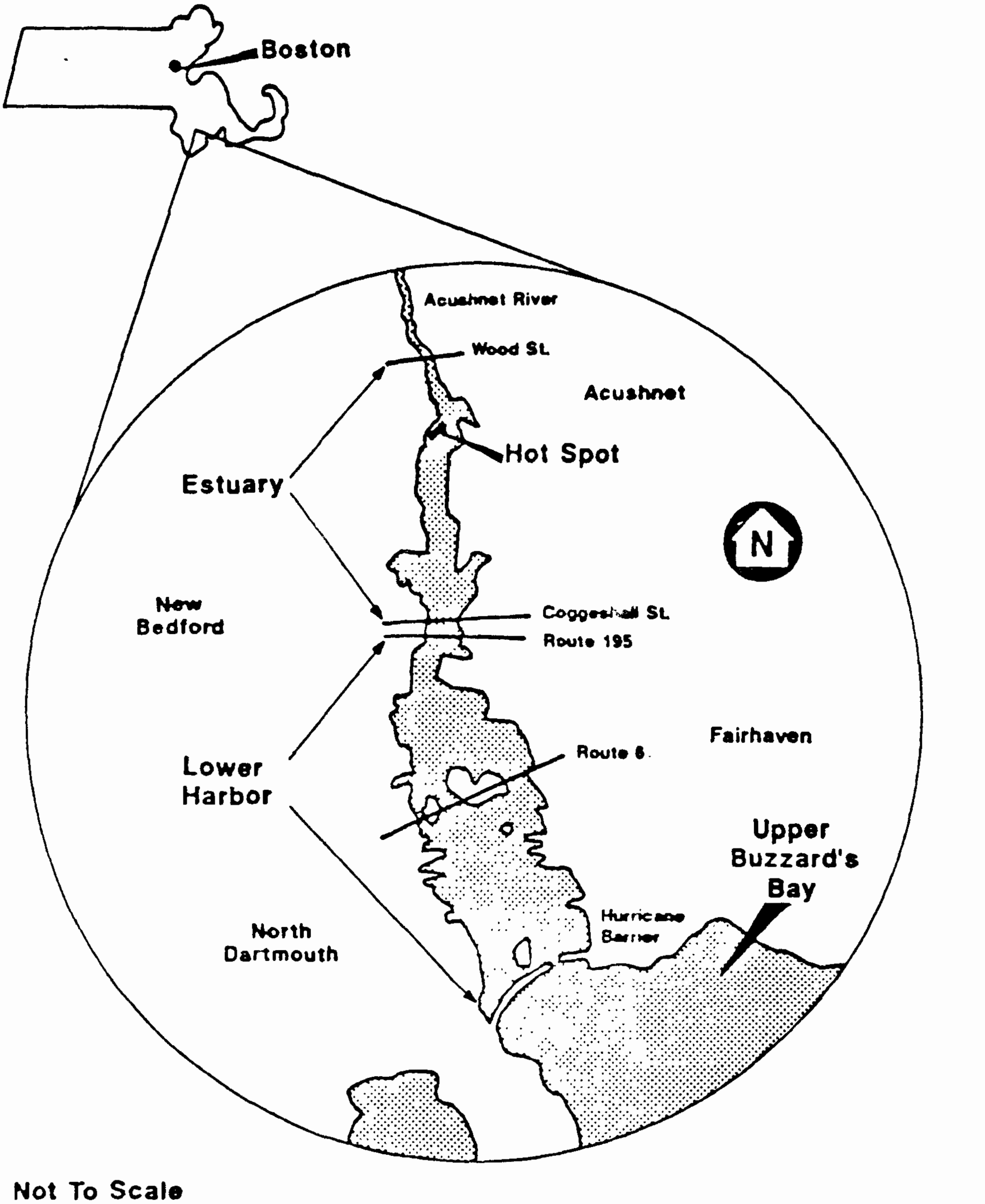

Figure 1
New Bedford Harbor, Massachusetts

Subsequent to the initiation of this work by the Corps of Engineers, EPA began work on an additional FS to provide a range of remedial alternatives for the entire site. This effort was expanded when the site was divided into operable units in the spring of 1989. The first operable unit addressed the 5 acre "hot spot" located in the northern portion of the site. A Feasibility Study was prepared for this area as well as for the remainder of the site. The results of the Corps of Engineers work were incorporated into and forms a critical component of these studies.

CORPS OF ENGINEERS STUDIES

The Corps of Engineers was initially requested to perform an Engineering Feasibility Study of dredging and disposal alternatives. A major emphasis of the EFS was placed on evaluating the conceptual design of dredging and disposal alternatives, their implementability, and their potential for contaminant releases. The scope of the effort included field data collection activities, literature reviews, laboratory and bench scale studies, engineering and economic analyses, and analytical and numerical modeling techniques to assess engineering feasibility and to develop conceptual alternatives. The objectives addressed in the EFS involved:

* developing a baseline characterization of the Acushnet River Estuary through sediment sampling, hydrographic and topographical surveys and measurements of the hydrodynamics and ongoing sediment/chemical transport,

* assessing the magnitude and migration potential of contaminant releases due to resuspension of sediments during proposed dredging operations,

* performing laboratory and bench scale testing developed specifically for dredged material to gather technical data needed for predicting the behavior of the dredged sediments if placed in either confined disposal facilities or contained aquatic disposal sites, and

* combining the technically feasible dredging and disposal technologies into implementable alternatives and providing concept design cost estimates for each implementable alternative.

Early in the course of the EFS, the Corps recommended and EPA recognized the benefits of including a field evaluation of dredging and disposal alternatives to supplement the laboratory and modeling efforts of the EFS. This was particularly appropriate for the evaluation of dredging technologies, which are difficult to simulate or model and whose performance is highly dependent on site specific factors or conditions. (3)

A pilot project was performed in the Acushnet River Estuary during 1988 and 1989. The project evaluated the effectiveness of three types of hydraulic dredges, a confined disposal facility and a contained aquatic disposal cell. The confined disposal facility was a diked retention basin constructed on the New Bedford shoreline. Contained aquatic disposal involved dredging a cell or pit in the harbor bottom, filling this cell with contaminated sediment then capping the cell with clean sediment. Data generated as part of the EFS were used to design the components of the pilot project, to estimate contaminant release to surface water and groundwater during the pilot project, and to provide the basis for the monitoring and evaluation program for the project.

CAPPING VERSUS DREDGING

The merits of capping the contaminated sediments in place versus dredging with onshore/shoreline containment has been raised as an issue repeatedly at this site. In particular, the principally responsible parties (PRPs) prefer a capping alternative and have presented a complete remedial alternative using capping for EPA's consideration. Several factors considered in weighing the capping alternative against other remedial alternatives include the following:

* the impacts of capping on the bathymetry of the shallow water estuary,
* the overall advantages and disadvantages of a containment versus a removal alternative, and
* the extensive long-term restrictions necessitated by the capping alternative, and the affiliated operation and maintenance requirements.

The EFS and Pilot Study evaluated contained aquatic disposal which includes a capping component. The information obtained during these studies was used in our evaluation of the PRP capping proposal and in the development of capping alternatives which appeared in the FS for the Estuary, Lower Harbor/Bay.

DISCUSSION

RESULTS OF CORPS OF ENGINEERS STUDIES

The EFS resulted in the conceptual design of several cleanup alternatives for the estuary portion of the site. These alternatives were evaluated for their implementability and potential for contaminant release. Contaminant release estimates were provided for each alternative as well as for the various components of the alternatives. The information was also used in the design of the Pilot Study. The Pilot Study consisted of the on-site evaluation of three types of hydraulic dredges (cutterhead, horizontal auger, and Matchbox) along with two disposal alternatives (confined disposal facilities, contained aquatic disposal). The study was conducted in the estuary portion of the site and involved the removal of approximately 10,000 cubic yards of sediment. (3) The activities were intensively monitored with the focus to:

* determine the dredge's ability to remove the contaminated sediment from the harbor,
* determine the sediment resuspension and contaminant release caused by the dredging operation,
* determine the movement of contamination away from the immediate vicinity of the dredging operation, and
* evaluate contaminate release associated with the disposal activities.

Monitoring for impacts to water quality throughout the harbor during dredging operations was also a critical component of the Pilot Study in addition to the monitoring to address the techni-cal objectives of the study. Physical, chemical and biological monitoring techniques were utilized before, during and after the dredging operations. The monitoring found only localized impacts that were attributable to operational or meteorological events.

The major technical finding of the pilot study are outlined below.

* The dredges could remove the contaminated sediment while minimizing overdredging. Initial PCB levels of 200-500 ppm were reduced to approximately 10 ppm with the removal of approximately an 18 inch layer of sediment.

* Contaminant release can be restricted to the immediate vicinity of the dredging operation. Levels of total suspended solids and PCB in the water column returned to background levels within 500 feet of the dredging operation.

* Dredge operating techniques were developed to meet the objectives of minimizing overdredging and contaminant release.

* Monitoring techniques were developed and implemented that obtained data to address the technical objectives of the study and provided assurance that operations were not degrading conditions throughout the harbor.

The information developed from these studies was incorporated into the EPA Feasibility Study for both the "hot spot" and the Estuary, Lower Harbor/Bay portions of the site. The input enhanced the presentation of the operational and cost aspects of the alternatives and provided contaminant release estimates. The site specific nature of the data generated through the pilot study increased our confidence in these numbers and significantly decreased the unknowns as we move into remedial design/remedial action.

APPLICATION OF STUDY RESULTS TO REMEDIAL DESIGN

Much of the information obtained from the Pilot Study will be directly applicable to the remedial design for the "hot spot" operable unit, as well as for the remedial design and action for the Estuary, Lower Harbor/Bay portion of the site. Major components that are being directly applied to the "hot spot" remedial design include:

* A cutterhead dredge was selected during the pilot study as the piece of equipment best suited for work in New Bedford Harbor. This dredge will be specified for use in the hot spot along with specific operating procedures developed during the study.

* Sampling procedures and monitoring protocols developed and implemented during the pilot study will be utilized to monitor water quality conditions throughout the harbor during hot spot remediation. Monitoring will be conducted by a separate government contractor.

* The experience gained in constructing the confined disposal facility will facilitate any future CDF designs associated with the remedial action for the Estuary, Lower Harbor/Bay.

The overall cost of the remedial design will be reduced, along with any uncertainty over the effectiveness of these procedures.

STATE/LOCAL COMMUNITY INVOLVEMENT

Considerable concern and opposition was voiced with the release of the August 1984 Feasibility Study which proposed alternatives that included dredging. As mentioned previously, these concerns focused on the ability of dredges to remove the contaminated sediments and the environmental impacts associated with the operations. The studies performed by the Corps of Engineers were designed to address the technical questions, but an equally important decision was the involvement of the other federal, state and local agencies in the process leading to a Record of Decision. A project group headed by EPA was formed and met monthly over the course of the study period to discuss project progress and to allow input into decisions being made in the course of the project. Numerous detailed technical presentations were made as information was obtained through the course of the studies. The group played an important role in the planning and implementation of the pilot study. The group was also exposed to many technical issues which may not have surfaced until the remedial design phase of the project. These include:

* the construction of disposal facilities along the shoreline,

* contaminant levels within the effluent discharged from these disposal facilities,

* contaminant release associated with dredging and disposal operations, and

* appropriate monitoring techniques and action levels.

The pilot study also allowed the project group to view the construction activities that would be associated with fullscale remediation. "Open houses" were held for the local community workgroup and other interested individuals to view the work. The study highlighted the operational constraints that effect our ability to address the technical concerns highlighted above. As we move into remedial design/remedial action, the experience of the pilot study and the information gained from it should provide a firm foundation for proceeding with the remedial design phase of the process.

OPERABLE UNITS

The decision made in the spring of 1989 to divide the project into operable units was also critical. The first operable unit involves the hot spot which is a 5 acre area in the northern end of the Acushnet River Estuary which contains approximately 45% of the PCBs present on the site. The remainder of the site includes over 1000 acres with widely varying PCB levels. The hot spot provides the opportunity to address a large percentage of the contamination in a relatively small area. This approach has accelerated the remedial design/remedial action schedule. Reducing the time between the completion of the pilot study and the start of remedial activities is an important point in terms of public perception. It will also allow the pilot study site and facilities to be utilized in the remedial action, thereby reducing the cost of the design and construction effort. Further phasing of the hot spot design and remediation will allow for quicker implementation of the remedy. The first phase will address site preparation, allowing site activities to begin prior to the completion of the design of the complex water treatment, incineration, and ash handling portions of the remedy.

CONCLUSION

Sites like New Bedford Harbor are complex both technically and administratively. Technical challenges at the site include the physical features, widespread contamination and its unconfined nature. Administrative challenges result from the communities effected, the numerous state and federal agencies with a regulatory role and the unique nature of the site. As more sites like this are identified, lessons learned at New Bedford can be applied to allow for a less complex process leading to site remediation. The major points to emphasize include:

* The advantage of specific studies, preferably pilot studies to address the site specific concerns regarding both the effectiveness and impacts of remedial action.

* The involvement of the other groups (state, local communities) in the process from the very early stages.

* The step by step approach to a large complex site proceeding from studies to discrete operable units to expedite the remediation process yet to allow a learning process as the project proceeds.

Numerous reports prepared for the New Bedford Harbor site address the questions of dredging and disposal methods and their effectiveness. The information may be applicable to ongoing work at other sites. Copies of these reports are available from the authors.

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The Pre-Design Technical Summary

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INTRODUCTION

The Pre-Design Technical Summary (PDTS) is a compilation of available site information prepared by the remedial project manager (RPM) to provide the designer with a clear understanding of the technical objectives of the remedial action. Guidance is being developed in the Design and Construction Branch on preparation of the PDTS. This paper will provide a summary of that guidance.

The objective of developing a PDTS is to provide a smooth transition from the Record of Decision (ROD) into the design process. The preparation and use of the PDTS should ensure that the designer will understand the technical objectives of the design as well as provide the designer with an up-to-date inventory of all available information that may be pertinent to the design. The PDTS also will serve the RPM as the initial building block for developing a comprehensive statement of work for the remedial design.

At a minimum the PDTS should accomplish the following:

- define initial site conditions:
- describe the selected remedy;
- summarize available data;
- identify applicable regulatory requirements; and,
- state all known unresolved issues.

The Remedial Investigation/Feasibility Study (RI/FS) and ROD will be the sources for much of the information to be summarized or referenced in the PDTS. However, the guidance will identify additional site-specific information that may be known to the RPM or RI/FS contractor that is not included in the RI/FS or ROD but should be included in the PDTS.

BACKGROUND

Remedial designers, including ARCS (Alternative Remedial Contract Strategy) firms, the USACE (U.S. Army Corps of Engineers), and the USBR (U.S. Bureau of Reclamation), recently stated the need for a document that provides a concise summary of all significant site-specific information used when transitioning from the ROD into remedial design. The Superfund Remedial Design and Remedial Action Guidance[1] manual issued in June, 1986, called for a "Pre-Design Report" to be prepared by the lead RI/FS party and provided to the lead design party. The stated objective of the Pre-Design Report is "to describe the engineering parameters and institutional concerns of the selected remedy, and package all pertinent information for effectively transferring the project to the lead design party." The RD/RA guidance manual, however, provides little description on what information the Pre-Design Report should contain, and it is likely that few Pre-Design Reports were ever prepared and used.

The U.S. Air Force has seen the need for this type of site-specific transition document and now prepares a "Requirements and Management Plan (RAMP)[2]" prior to negotiation of the design contract for new construction projects. The RAMP addresses such topics as project design information, site-specific requirements, environmental issues, access information, and long-range base planning.

The Design and Construction Management Branch began developing Pre-Design Technical Summary guidance because it was apparent that the summarization of site-specific information would serve several significant purposes. The PDTS will serve the RPM both as a building block in developing a comprehensive design statement of work and by ensuring that the designer fully understands the objectives of the remedial action. The PDTS will serve the designer by providing an up-to-date inventory of data. Use of the PDTS also should alert the RPM and designer to data gaps and help to avoid delays by identifying, early on, any potential road blocks such as property access and acquisition needs, permits to be obtained, or unresolved issues. The document also could prove to be an invaluable source of information that can be used to maintain continuity in the event there is a change in RPMs or if there is a significant delay between issuance of the ROD and start of design.

COLLECTION OF THE PDTS INFORMATION

For Fund-lead projects (i.e., those projects financed by Superfund) it will be the responsibility of the RPM to either collect or oversee the collection of the Pre-Design Technical Summary information. For potential responsible party (PRP) lead sites, the PRP can be required to collect the PDTS information before finalization of the Administrative Order of Consent (AOC). The PRP would be responsible for collecting and submitting the PDTS information to the RPM for review and approval; the information would then be used to develop the Statement of Work to be included in the AOC. The collection of PDTS information is equally important for a PRP-lead site in that it will ensure that all parties involved in the AOC (as well as the PRP's designer) fully understand the objectives and scope of the remedial design and remedial action.

Collection of the PDTS information should begin before or shortly after the ROD is signed. For Fund-lead projects, it may be useful for the RPM to arrange a meeting with experienced regional staff, the RI/FS contractor, and state and local officials familiar with the site to discuss and collectively develop most of the statements.

The PDTS information should be kept brief, using bullet points and tables to present data. Supporting information can be referenced or included as attachments. The information can be compiled simply (e.g., a checklist) or as a more detailed formal document, depending mainly on the complexity of the site. The sources of information to be included in the PDTS should be well documented.

CONTENT OF THE PDTS

A draft guidance document[3] has been developed by the Design and Construction Management Branch; the guidance includes an outline of the information to be addressed by the PDTS. Each outline element is fully explained and examples are often provided. For simple design projects, many of the items need not be addressed--the content should be modified according to the complexity of the RD/RA.

The outline provided in the draft PDTS guidance document is as follows:

PRE-DESIGN TECHNICAL SUMMARY

I. Site Conditions

A. Site description

1. Site history and current status
2. Chemical, physical, and geological characteristics of site
3. Proximity to homes and schools/land and groundwater use surrounding site
4. Basis for property lines on drawings
5. Likely future use of site

B. Real estate issues

1. Real estate requirements assessment
2. Restrictions or special agreements on easements or access roads

C. Availability of utilities

1. Location and availability
2. Existing agreements or conditions

II. Selected Remedy

A. Description of selected remedy

B. Selected cleanup levels

III. Availability of Data

A. Physical/chemical data collected to date

B. Data retrieval

IV. Technology/Design Approach

A. Waste characterization

B. Treatment scheme

1. Schematic diagram
2. Pre-treatment requirements
3. Treatment design criteria

C. Long-term monitoring requirements

D. Sole source or first time usage of a technology and innovative/SITE technology

E. Treatability study

F. Special design limitations

G. Flexibility in design

H. Schedule constraints that could impact rate of treatment or unit size

I. Confirmation monitoring

V. Materials

A. Volume estimation and basis of calculations

B. Spatial requirements, staging, etc.

C. Durability of materials

D. Materials/equipment availability

E. Mixed materials

VI. ARARS/Permits/State Involvement

A. ARARs list

B. On-site versus off-site waste management

C. Permits for off-site actions/land use restrictions

D. Extent of State involvement

VII. Unresolved Issues

VIII. Health and Safety Concerns

IX. Other Concerns

A. Community relations activities

B. Confidential information

C. Other RD/RA requirements

X. Appendix

A. Bibliography--existing site information

B. References

STATUS OF THE PDTS GUIDANCE

Initial development of the PDTS guidance document began with a meeting of a work group comprised of representatives from USACE, USBR, several design firms, and the Design and Construction Management Branch. This group met to discuss the types of information that should be addressed in a PDTS; i.e., the major site or design related data or information that was often inadequately stated or not provided when projects were turned over to the designer. A guidance document incorporating the suggestions of the work group was drafted. A draft of the PDTS guidance was sent to Regional Superfund Branch Chiefs for review in late November 1990. Comments have been received, and the guidance is being revised in consideration of those comments.

The PDTS guidance will not be issued as a "stand-alone" document but will be incorporated into a more comprehensive guidance document pertaining to "scoping remedial design" that also is being prepared by the Design and Construction Management Branch. This new document will include guidance on developing the Remedial Management Strategy (addressing contracting strategies, phasing alternatives, funding constraints, and roles of participants), preparing statements of work, establishing schedules, and cost estimating. Drafts of the "scoping remedial design" guidance document will be reviewed by an existing work group that currently is revising the 1986 Superfund Remedial Design and Remedial Action Guidance. A draft of the "Scoping Remedial Design" guidance is scheduled to be prepared by September, 1991.

SITES WHERE PREPARATION OF A PDTS HAS BEEN REQUIRED

Although PDTS guidance is still in the developmental phase, a Pre-Design Technical Summary was prepared for a site in Region VII--the Groundwater/Surface Water Operable Unit, Galena Subsite, Cherokee County, Kansas[4]. The PDTS was prepared by the RI/FS contractor under the direction of the RPM. The RPM found the document to be very useful in that it provided the designer (USACE), which had no prior knowledge of the site, with detailed information as to what EPA wanted to accomplish at the site. The PDTS proved to be a valuable source of much of the information needed to begin the design.

Another PDTS is being prepared in Region VI in response to a requirement in an Administrative Order of Consent (AOC)[5]. The AOC requires the PRPs to prepare and submit a PDTS to EPA for review and approval. The RPM made minor modifications to the text of the draft PDTS guidance to reflect the fact that the PRPs will be preparing the PDTS. The modified guidance was then made an attachment to the AOC.

CONCLUSION

The purpose of developing a PDTS is to provide the designer with a clear understanding of the technical goals and objectives to be achieved by the remedial design. The PDTS also will serve to aid the RPM in developing a comprehensive statement of work for design.

The intent is not to place an added burden on the RPM but to ensure that the information provided by the RPM to the designer is as complete as possible and that the resulting design effort will be as free from misunderstanding as the RPM can make it.

DISCLAIMER

This report has undergone a relatively broad initial, but not formal, USEPA peer review. Therefore, it does not necessarily reflect the views or policies of the Agency. It does not constitute any rulemaking, policy or guidance by the Agency and cannot be relied upon to create a substantive or procedural right enforceable by any party. Neither the United States Government nor any of its employees, contractors, subcontractors or their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use or the results of such use of any information or procedure disclosed in this report, or represents that its use by such third party would not infringe on privately owned rights.

We encourage your comments on the utility of this paper and how it might be improved to better serve the Superfund program's needs. Comments may be forwarded to the attention of Kenneth W. Ayers, Design and Construction Management Branch, USEPA, Mailcode OS-220W, Washington DC 20460.

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VIII. DESIGN ISSUES

ACCELERATING THE ROD TO REMEDIAL ACTION PROCESS: Sand Creek Industrial Superfund Site (OU1), Commerce City, Colorado

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May, 1991

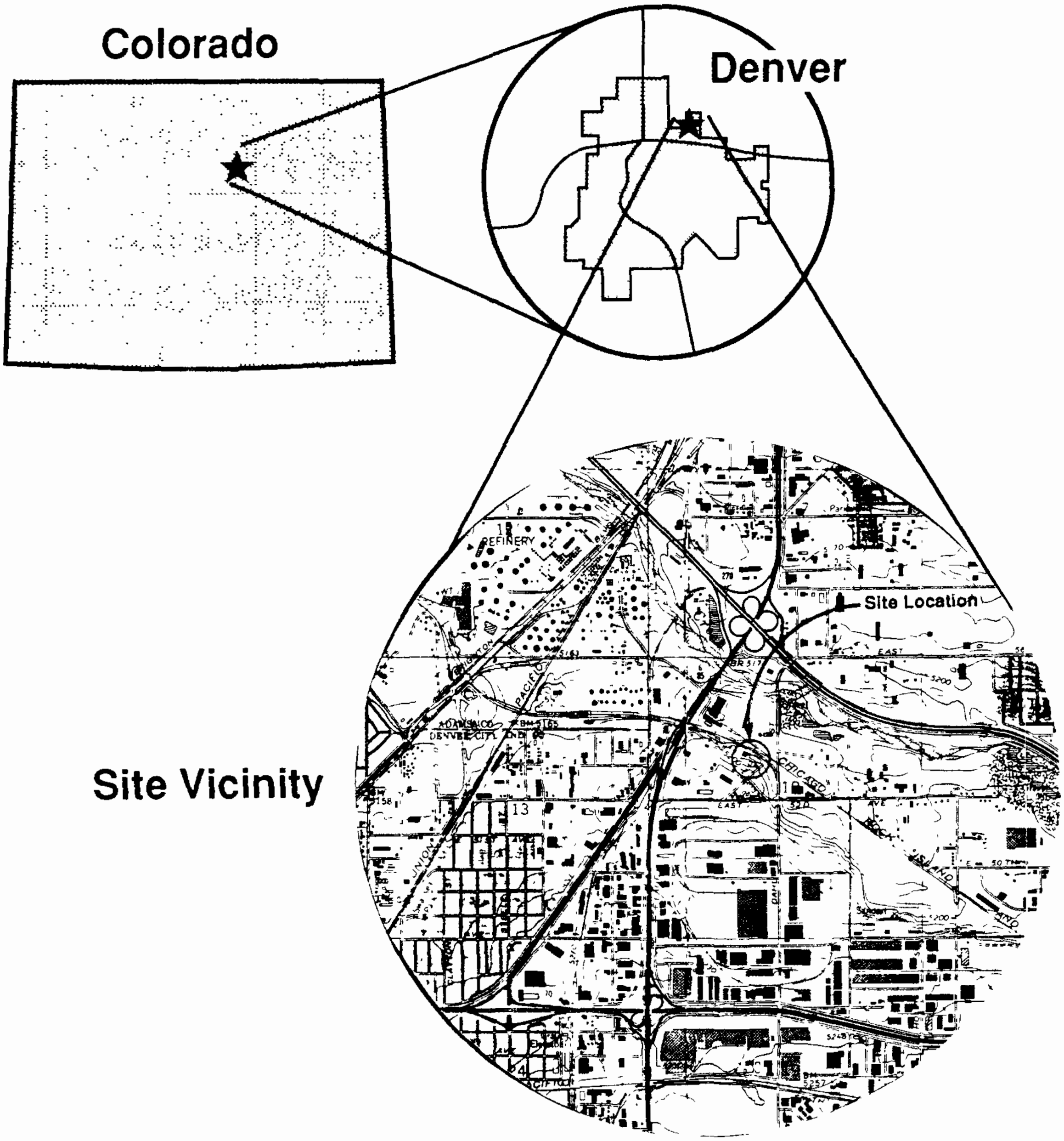
INTRODUCTION

A goal of the United States Environmental Protection Agency (EPA) has been to reduce the length of the average Remedial Design and Remedial Action (RD/RA) in the Superfund site cleanup process. This paper compares the cost and duration of RD efforts from other Superfund sites to the RD for the Sand Creek site.

The Sand Creek Superfund Industrial site (Sand Creek) is located in Commerce City, Colorado, a suburb north of Denver. (Figure 1). The site and surrounding area are primarily occupied by trucking firms, petroleum and chemical supply/production companies, warehouses, and small businesses. There is a small residential population in the study area which is adjacent to the northeast border of the site. The portion of the site for which the RD effort has been completed was a former pesticide and herbicide manufacturing facility.

EPA Region VIII commitments required that the RD for the site be completed within nine months of the Record of Decision (ROD). Facilitating the task was the Region's decision to waive negotiations with the Potentially Responsible Party (PRP) due to lack of financial viability. The RD was for an incineration/ demolition/ and soil vacuum extraction (SVE) remedy expected to costs $7-8 million. The RD package was completed in six months. The RD effort, accomplished with URS Consultants, Inc. URS (the ARCS contractor), included nearly $500,000 of additional field work not originally provided for in the Remedial Investigation and Feasibility Study (RI/FS).

The Sand Creek RD was completed within six months of the ROD signing and ranks within the fastest 20% of the 437 completed RDs across the nation. The intent of this paper is to discuss the planning, scheduling, and implementation of the Sand Creek RD effort in comparison with current EPA guidance for streamlining the RD/RA process as provided in OSWER Guidance.[1]



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USEPA
Sand Creek
Remedial Design

Site Location Map

Figure No. 1

BACKGROUND

The Sand Creek Superfund site comprises approximately 480 acres and contains four known contamination source areas; The Colorado Organic Chemical Company property (OU1), the L.C. Corporation acid pits (OU2), the 48th and Holly landfill (OU3), and the area-wide ground water contamination associated with the Sand Creek Industrial Superfund site area (OU4). (Figure 2).

The OU1 area was used to manufacture pesticides from 1960 to about 1968, under the name of Times Chemical. Since 1968, when a fire destroyed three of the buildings on the site, several health agencies have found unacceptable conditions at the plant. These have included unsatisfactory waste management practices and worker safety conditions, violations in storage and handling of flammable liquids, and soil containing high levels of thermally-altered pesticides and other chemicals. A second fire occurred at the plant in 1977. In 1984, in response to an EPA order, the Colorado Organic Chemical Company removed waste drums and contaminated soil and fenced-off the area, including an area just north and east of the Colorado Organic Chemical Company property, which has been affected by contaminated surface runoff.

The primary contaminants found in the OU1 area are:

Arsenic
Chromium
Dieldrin
Heptachlor
Chlordane
2-4 D
4,4 DDT

The remedy to be designed by URS was for the following: the excavation and off-site incineration of approximately 1,000 cubic yards of soil contaminated with greater than 1,000 ppm of HOCs generally composed of 2-4 D; the demolition of the contaminated buildings and structures for off-site disposal of the debris; and vacuum extraction of the VOC-contaminated subsurface soils as a ground water contamination source control measure.

The EPA's guidance for expediting RD/RA work suggests the development of a remedial management strategy document to specify project goals and determine project phasing. The Sand Creek project utilized the ROD for the description of project goals and the ARCS work assignment Work Plan to determine project phasing.

The specific language of the Statement of Work provided to URS prior to development of the Work Plan was designed to provide for maximum contractor flexibility. The EPA Remedial Project Manager's role was to oversee the development of the RD package and to expedite the administrative review and approval process for the

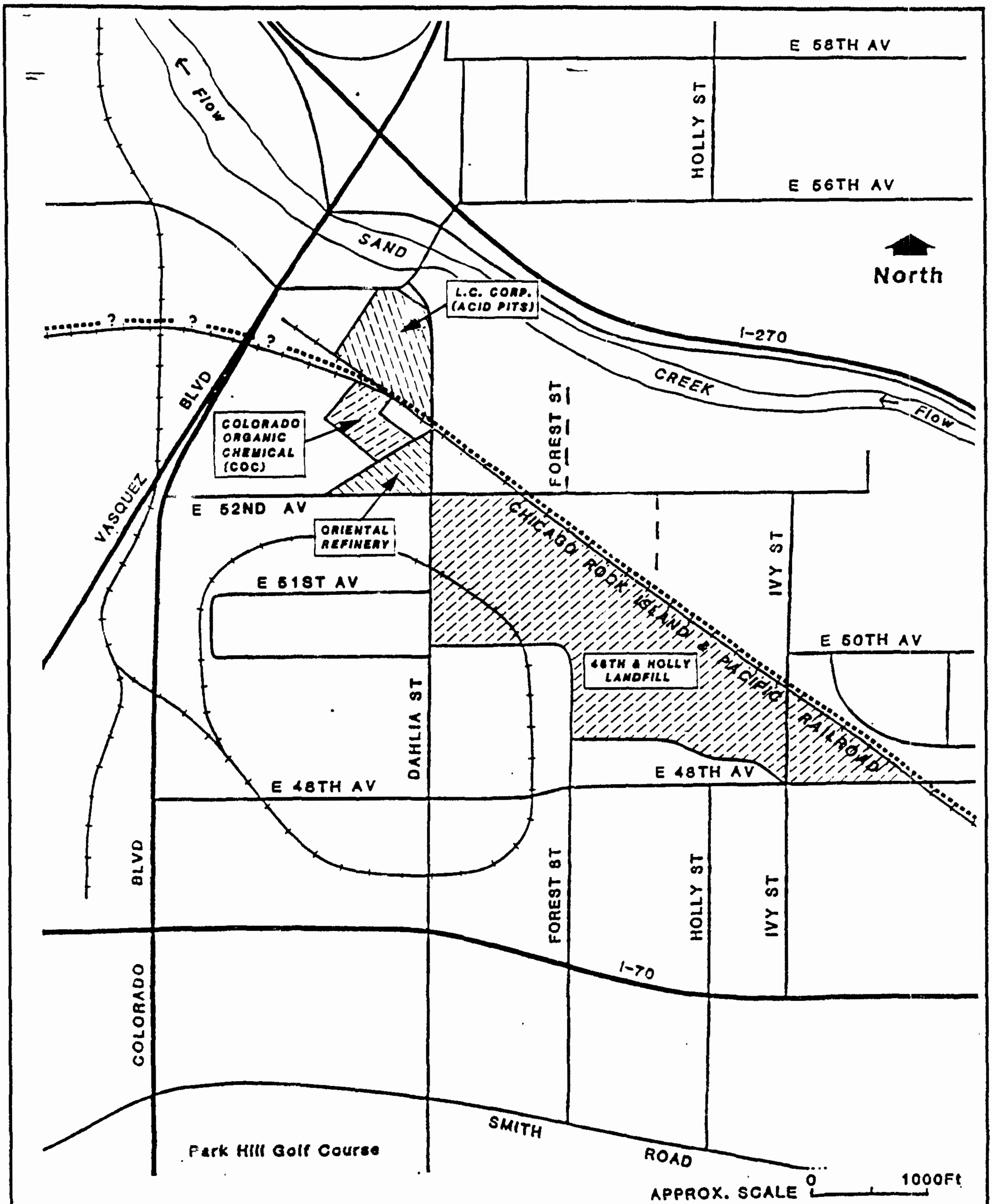

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FIGURE NO. 2

URS CONSULTANTS	USEPA Sand Creek Remedial Design
Date: 1/3/91	Sand Creek Industrial Superfund Site Boundaries

numerous documents produced in the RD effort.

The specific tasks which were provided to URS in the Statement of Work are as follows:

It is critical that the RD efforts anticipated under tasks #1, #2, and #3 be completed by March 15, 1990. It will also be necessary for URS to begin work for tasks #1, #2, and #3 during development of the work plan for this work assignment.

1. Prepare design specifications for excavation and off-site incineration of those soils contaminated with greater than 1000 ppm concentrations of HOCs. This activity will include soil sampling to determine the extent of those soils with concentrations above industrial use action levels and those soils contaminated with greater than or equal to 1,000 ppm HOCs. Air and airborne particulate monitoring before, during, and after excavation activities will be necessary to assess potential impacts on the surrounding area. Design of an air monitoring plan will be necessary for this task.

2. Prepare design specifications for remediation of those soils approximately five (5) feet below the soil surface, using vacuum extraction technology. The soil contamination to be remediated with vacuum extraction is primarily from volatile organic compounds. This task will include design of the treatment system for the extracted gasses, as well as design of an air monitoring plan for the vacuum extraction remedial actions.

3. Prepare design specifications for demolition and off-site disposal of the buildings and possibly the storage and formulation tanks on the property. This activity will include sampling the buildings and tanks to determine the type of disposal unit necessary for the debris.

4. URS shall provide assistance to the EPA's community relations efforts as needed. This is likely to take the form of providing assistance at public informational meetings, and providing photographs of remedial actions similar to that which will be designed under this work assignment.

Task 1 included additional soil sampling because the RI/FS for the site covered the entire 480 acres and did not focus primarily on the OU1 area. One of the results of the RI/FS was to divide the site into operable units. The information in the site-wide RI/FS was sufficient to identify the COC area (OU1) as the area of immediate concern due to the severity of the contamination. The site-wide RI/FS was also adequate to select a remedy for the OU1 area, but lacked sufficient detail necessary to proceed to RD. As an example, soil incineration appeared warranted, but limits of the excavation had not been delineated.

The OU1 Area (shown in Figure 3) is in the northwest part of the Sand Creek site and is in a zone of low moisture and moderate climate at the north edge of the Denver Metropolitan area, in a political subdivision called Commerce City. The site is situated on a series of low soil benches grading toward Sand Creek to the North. The soil is generally sandy, silty with some clay lenses and contains some cemented outcroppings. It is bounded on the north by the Colorado and Eastern Railroad tracks and on the east by Dahlia Street. The south boundary abuts property owned by Asamera Oil Company and is approximated by a fence line. The western boundary is a fence separating the site from a gravel processing facility. A large warehouse under separate ownership is on the site and has been occupied during the period the RD was prepared.

Several other buildings, tanks and pads, are located on the site which were used in the manufacture of pesticides and herbicides by Colorado Organic Chemical Company (COC) and its predecessors. One building is occupied by the former owner of COC and is being used as an industrial real estate office. Most buildings show moderate-to-high levels of contamination.

Surface soils contain a variety of chemical products and byproducts including pesticides, herbicides and small amounts of thermally-altered products including dioxin. Evidence of compliance with earlier cleanup orders is apparent where the top few inches of soil were removed after the 1977 fire. Some poorly drained areas showed high concentrations of HOCs.

Subsurface soils show some high concentrations of VOCs, semi volatiles including tentatively identified compounds, other organic compounds and metals. A zone immediately above the groundwater is heavily contaminated with petroleum residues, and in some parts of the site, a free-phase material floats on the groundwater surface.

Groundwater is found in a relatively complex system 15 to 45 feet below surface. The groundwater contains much of the same contamination as is found in the subsurface soils and the plume of floating material.

Access to most of the site is controlled by a locked fence.

During the course of the RD, access to the site by the EPA and the contractor was limited to the sampling activities, surveying and the vacuum extraction treatability study. Periodic management visits were conducted for quality assurance and supervisory purposes.

The principal participants in the RD are the EPA (Region VIII Superfund Branch), the Colorado Department of Health, URS and its subcontractors, Brown and Caldwell Consultants (Sampling and Analysis), Datum Exploration (drilling), Groundwater Technology,

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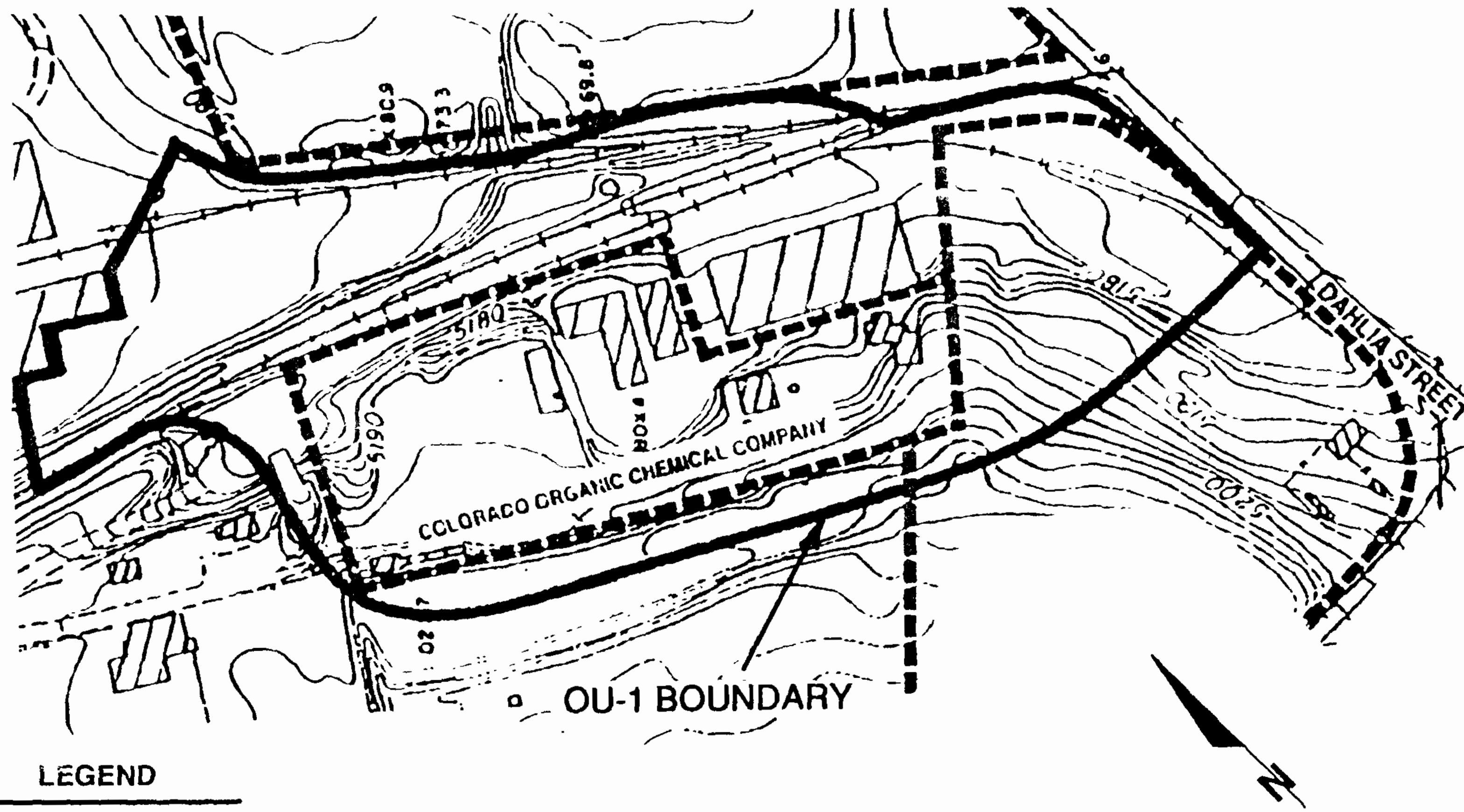

LEGEND

Symbol	Meaning
(hatched box)	STRUCTURE
(line with cross ticks)	RAILROAD TRACK
(heavy solid line)	OU-1 BOUNDARY
(heavy dashed line)	PROPERTY BOUNDARY
"ORIENTAL REFINERY"	PROPERTY NAME

100 50 0 100 200 Feet

SCALE

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Sand Creek
Remedial Design

Property Boundary Map

Figure No. 3

Inc. (vacuum extraction pilot testing), and Shannon and Wilson (geotechnical testing).

DISCUSSION

To facilitate the eventual contracting for RA, the Sand Creek RD was divided into the four separate parallel tasks as shown in the Statement of Work. These were:

1. Excavation and incineration of approximately 1,000 square yards of soil.

2. Vapor extraction of the sub-surface soil.

3. Demolition and disposal of the tanks and contaminated structures.

4. Air monitoring before and during the RA.

Task number 4 combines the requirements for air monitoring specified in the first three tasks. Note that the original scope of work included a fourth task of community relations assistance, which was deleted from the work assignment during the development of the Work Plan. At that time, the fourth task of air monitoring was substituted.

Rather than preparing one large set of plans and specifications for all tasks, the four tasks were deemed too diverse to attract sufficiently competitive bids for a single contract. Each was developed into a separate set of contract documents for that specific task. This was developed with the assumption that the RA would be assigned to either the U.S. Army Corps of Engineers or an EPA prime contractor, who would most likely oversee the remedial work but subcontract some or most of the specialized tasks.

Superfund guidance specifies the employment of a multi-step process to be followed in a typical RD:

Work Planning;
Data Acquisition;
Sample Analysis/Validation;
Data Evaluation;
Treatability Study;
Preliminary Design - 30%;
Intermediate Design - 60%;
Pre-final/Final Design - 90-100%; and
Post-Remedial Design Support.

As the work assignment was received in September, 1989, and the deadline for completion of the RD was scheduled for March 15, 1990, some elements of the work were required to be started almost immediately. Figure 4 is a composite bar chart schedule for a RD, showing the progression and interrelationship of the design elements. It also contrasts the "fast track" schedule pursued at Sand Creek with a "normal" RD. One of the major differences between the two is the parallel approval steps at milestones where work does not halt to await approvals. At Sand Creek, the contractor was in close contact with the EPA and others in the approval system to identify items of the design deliverable which were likely to be modified. Phone conversations were frequent and face-to-face meetings occurred weekly. Such interaction is vital to the success of an accelerated schedule.

It was determined that the field sampling and analysis elements had the longest lead times and that preparatory work could begin on certain design elements before the laboratory results were completed. Therefore, the Sampling and Analysis Plan (SAP) and the Quality Assurance Project Plan (QAPjP) proceeded apace with (and somewhat ahead of) the Work Plan. To gain more control over the schedule of receipt of laboratory data, it was decided that non-CLP laboratories would be used to the greatest extent. Laboratory costs would therefore be part of the project budget, rather than accounted for separately, as is the typical practice.

By the time the Work Plan was submitted in late October, mobilization activities for the field sampling effort were ongoing. The sampling work began on November 1, 1989, and was essentially complete one month later. For the most part, weather remained favorable during this period, and the work was completed without incident.

Following the field work, over-lapping of design tasks went into effect. As the analysis and data evaluation were performed, the design of the excavation, vacuum extraction, demolition and air monitoring were progressing.

The successful completion of design depended upon the results of the testing to provide scope, areas, quantities, and difficulty of remediation. It was therefore planned that the early stages of the design should be developed with a great degree of flexibility to accommodate unforeseen requirements and variances from early assumptions. The final design data report was not published until March, almost concurrent with the 90 - 100% final design delivery. During the analysis, preparation and evaluation of the data, however, the contractor, his subcontractors and the EPA worked in close communication so that the trends and preliminary conclusions shaped the design. Where further data was required to verify conclusions or to fill gaps, decisions were made to rapidly acquire samples and perform quick turn-around analyses. Discussions took place prior to the end of the Work Plan development, allowing a realistic budget to be developed which anticipated unexpected field sampling results.

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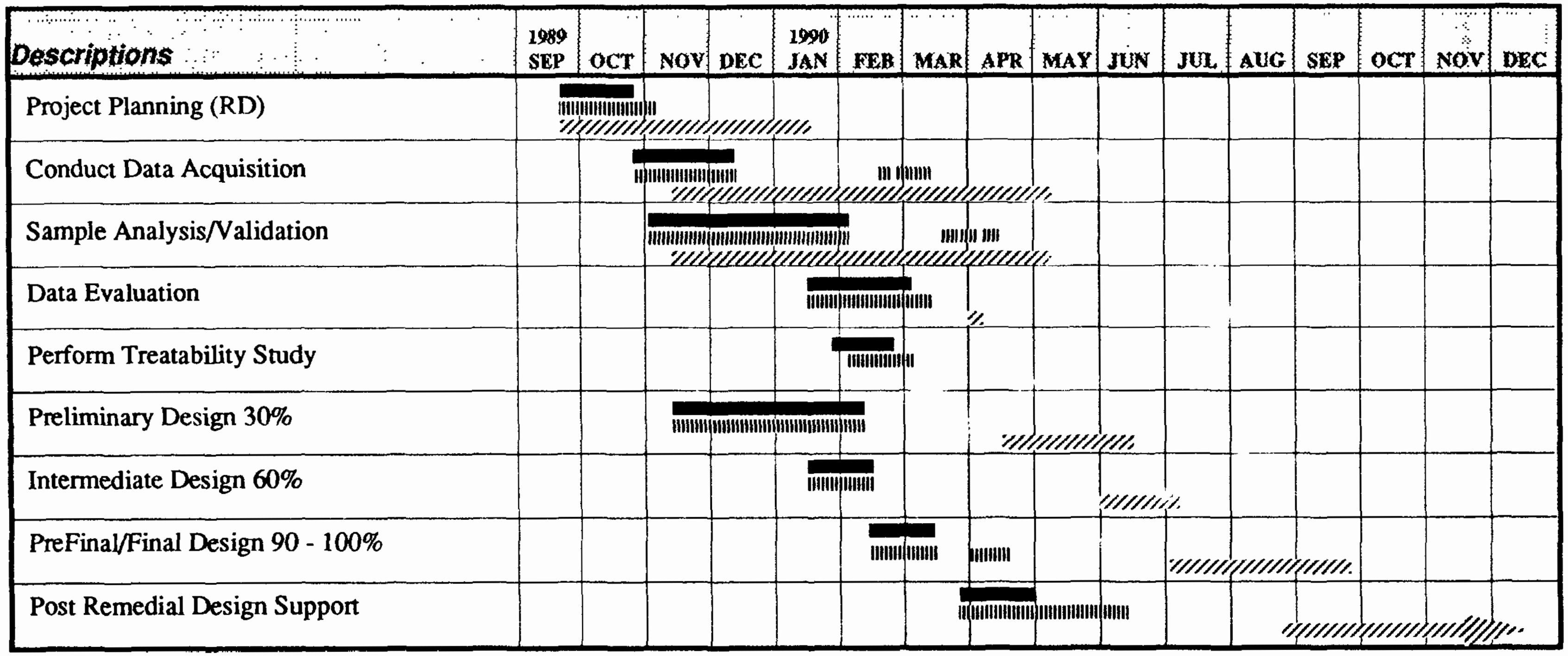
Figure 4
Work Assignment Schedule

Sand Creek Remedial Design
EPA REGION 8



LEGEND
Projected
Actual
EPA Guidance

2

Environmental Protection Agency

Similarly, work proceeded on the plans and specifications for the soil vacuum extraction system without waiting for the final vacuum extraction pilot test report, which was also delivered in March. The progress of the test and its early findings were communicated to the design team prior to completion of the pilot test report, allowing the newly acquired information to be promptly integrated into the design. The level of advance planning taking place during Work Plan development allowed the contractor to incorporate last minute information while minimizing the risk of repeating efforts.

The schedule contained in the Work Plan for the RD is shown in the bar chart (Figure 4). Actual performance is also shown in hatched lines. As shown, there are no major variances except that the RA did not follow immediately after the design as was planned. This was due to factors beyond the control of the project participants and relating to the State Superfund contract for the State of Colorado's 10% share of RA costs. The RA work assignment is now under way.

Whenever a project is described as "schedule driven" or "fast track," it is particularly important to recognize the presence of two distinct classes of needed information: what you know is missing (the known unknowns) and what you haven't thought of or can't yet conceive of needing (the unknown unknowns). The planning process must prepare for each and retain sufficient flexibility to accommodate a reasonable response to the intermediate findings.

Unexpected Problem I

For Sand Creek OU1, the SAP is a good example. The planning team considered three primary data needs: the existing data, data needed to support the range of design options and those data that might alter the entire scope of the RD, such as an unexpected dioxin discovery. The first category of data needs seems fairly obvious, but in reality, the longer existing data has been in the files, the more suspect it becomes. Primary data such as boring logs, lab analysis reports, and Quality Control (QC) runs get collated into summary reports with all the customary typos and interpretive biases. A case in point at Sand Creek was the Task 1, halogenated soil removal, which, after significant retrospection, turned out to be based on one grab sample under a dripping tank tap. Unfortunately, the tank was long gone and the exact sample location unrecoverable because sample locations had not been surveyed. With total unit costs of potentially up to $2,600 per cubic yard for incineration alone, precise quantities of contaminated soil requiring incineration are very important. The project team knew that the data point strongly suggested a problem (2-4 D at 1.5% by weight), but also needed to better define the boundaries of contamination to control excavation (known unknown). Consequently, the plan had the highest sample density in this vicinity, but had additional areas of increased coverage surrounding the hot spot to be sure the project team would not miss the area which approximates the action level for the soils and 1,000 ppm HOCs contour, the limit of excavation. In this way, the sampling approach was tailored to the design data needs for each area of the site.

When the design process was nearing completion, sampling yielded two unsuspected results. The initial data showed much lower levels of halogenated substances, none above 1,000 ppm. Two explanations seemed possible, either the initial data point identifying a problem was erroneous or the problem was smaller than the first sampling grid. At this point, the team also knew that there was not a problem too large for the chosen remediation option. A supplemental sampling on an even finer grid was devised and executed, ultimately locating a small pocket of contaminated soil requiring off-site thermal destruction.

Unexpected Problem II

The site sampling efforts prior to the RD also revealed a major unknown. Although it was generally known that the site had been screened for dioxins (a common micro-contaminant in some phenoxy pesticides) no existing data confirmed the contaminants' presence. Since this was suspect result for a pesticide facility, a large confirmation sampling effort was undertaken. A coarse grid surface sampling was accomplished and samples analyzed using quantitative techniques for the 2,3,7,8 isomer. This effort showed the chemical to be present below action levels and located on the uphill edge of the site, substantially away from the area of manufacture. However, the incinerators targeted for the site's soils were not licensed for wastes containing any dioxin.

Since the ROD had no named remedy for dioxin contaminated wastes and the dioxin hits were on the fringes of the Operable Unit boundary, the dioxin soils issue was not included in the RD/RA effort and it will be addressed by the PRPs as a separate effort. The solution was a classic "work around." This preserved the integrity of the ROD's logic, the schedule and budget.

Unexpected Problem III

Another unknown occurred at the installation of the vacuum extraction pilot test equipment. To everyone's surprise, a free-phase hydrocarbon layer (commingled with pesticide contamination) previously unreported or detected, was present in one of the observation wells with an unknown lateral extent. After some review, it was concluded that the presence of the large amount of hydrocarbon would threaten the economics of vapor extraction (Task 2) by competing with the targeted volatile halocarbons for space on the activate carbon. Further, the impact would be on operation costs, i.e. increased carbon filter change out rates, and not on the constructed size of the extraction units. Impact on the other tasks appeared minimal because construction staging mandated that the site be cleared first (Task 3) for access for Task 2, vapor extraction. Task 1, the soil removal, need not be effected either way. Therefore, by proceeding to completion on all design tasks, the only significant impact of the free-phase hydrocarbon on the ultimate timing of the soil vacuum extraction task: either immediately after Task 3 completion or after removal of the free-phase hydrocarbon.

Unexpected Problem IV

Schedule evaluation was a constant task and was reevaluated at each new discovery. Not all discoveries were in the field. Early planning of the RA indicated two procedural tasks with potentially significant impacts on the schedule: subcontractor procurement and laboratory data turnaround. In the case of procurement, the Federal Acquisition Regulations were mandatory. Certain bidding steps and approvals are specified. By scheduling these in detail, the team identified several instances where procurement was the critical path. Early emphasis was placed on subcontractor bidding for drilling services. With the URS procurement staff working closely with the EPA contracting officers, procurement efforts met or exceeded scheduling needs.

Planning of the schedule also revealed a potentially fatal flaw in laboratory analyses turnaround. Although the EPA Contract Lab Program was initially targeted to handle the sample flow, careful examination of the total data package needed indicated that numerous requests would have to go through the EPA's Special Analytical Services (SAS) which requires a deliberate bidding process among program contract laboratories.

Charting out the time necessary to procure laboratories under SAS, it was quickly evident that the project schedule would be heavily impacted. An alternative of using a combination of EPA Regular Analytical Services and URS team lab subcontractors offered the best apparent schedule. Although this combination of services put more analytical costs in the project budget, the project stayed within the authorized funding and met the scheduling objectives.

CONCLUSIONS

The authors feel that the Sand Creek OU1 RD demonstrates several significant conclusions.

1) Remedial Designs can be accomplished very quickly in situations where the physical size and scope of the remediation is at least within the order of magnitude of the size and scope of the options chosen in the ROD.

2) Careful planning and scheduling of all aspects of the effort is important and should include paying continuous attention to updates throughout the RD.

3) Any design sampling efforts should be focused on objectives oriented to the needs of the designers. This is addressing the known unknowns.

4) Expect the unexpected. Do not be surprised if previous sampling results cannot be exactly duplicated. Have in place the communication pathways, the technical resources and budget contingencies to react quickly to surprises. View each in terms of its potential impact on the project's chosen remedies and on the schedule. Decide if the issue can wait to be addressed at a later phase. Move forward on what is unaffected.

5) Conduct frequent team meetings with all active contractor, State, local government, and EPA staff. Keep this limited to the key players.

While the authors recognize the Sand Creek OU1's technical challenges may be uncomplicated when compared to some other superfund designs, the lessons learned seem universal: divide the project into manageable units. Adopt a reasonable sequence of remediation events. Conduct detailed planning and scheduling. Continuously monitor schedule performance against plan. Treat scheduling as a key objective. Be prepared to work through or around inevitable surprises. These concepts are not new. Anyone familiar with conventional construction management will see the similarity. The results of Sand Creek RD demonstrate that the techniques described can be successfully applied to remediation design despite the large amount of technical uncertainty that usually accompanies remediation efforts.

REFERENCES

[1] OSWER Directive 9355.5-02 (EPA/540/G-90/006, Guidance on Expediting Remedial Design and Remedial Action).

[2] EPA Introduction to Remedial Design Schedule Management, EPA Course held in Washington, DC, June 1989.

LIST OF ACRONYMS

COC	Colorado Organic Chemical Company
EPA	United States Environmental Protection Agency
HOCs	Halogenated Organic Compounds
OU1	Colorado Organic Chemical Company Property
OU2	L.C. Corporation Acid Pits
OU3	48th and Holly Landfill
OU4	Area-Wide Groundwater Contamination at Sand Creek Industrial Site
PRP	Polenticilly Responsible Party
QAPjP	Quality Assurance Project Plan
RD/RA	Remedial Action/Remedial Design
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Design
Sand Creek	Sand Creek Superfund Industrial Site
SAP	Sampling and Analysis Plan
SAS	Special Analytical Services
VOCs	Volatile Organic Compounds

Remedial Design of Superfund Projects: What Can Be Done Better?

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INTRODUCTION

The remedial design phase is a critical component of the Superfund process. Remedial design follows the Remedial Investigation (RI) and Feasibility Study (FS) components of the Superfund process and builds upon the knowledge base established by those activities. The purpose of the design process is to produce plans and specifications that can be implemented by a construction contractor. A successful design should produce a remedial action consistent with the goals stated by the Record of Decision (ROD). The design process is subject to a wide variety of factors that often influence the direction of the design, and ultimately the success of the remediation. The intent of this paper is to generally identify these factors and present some thoughts on how to improve the remedial design phase of a Superfund project.

BACKGROUND

What is a successful project? To some it may be completing the project within the designated schedule, to others it may be achieving a predetermined level of quality in the design, while others may judge the design by the total cost of the project. A successful project can generally be defined as a project completed:

- within the allocated time period
- within the budgeted cost
- at the proper performance or specification level

These goals appear straightforward, but in reality a Superfund project is evaluated by many different groups, each of which may have different concepts of success. One government agency may evaluate success based on achieving set goals within an established schedule and budget. Another government agency may judge success based upon adherence to all applicable regulations, or by the design resulting in minimal changes to any administrative decision making process.

The local community may evaluate success based on an elimination of health threats, real or perceived, to their community with minimal disruption to their daily lives and with little regard for the financial cost to the project. The designers may view success as achieving a comprehensive design that results in a minimum of change orders or claims. Potentially responsible parties may view success as cleaning up a site with minimal cost and regulatory interference or by a reduction in environmental liability. A construction contractor may view success as completing a project ahead of schedule while maximizing profits. Obviously, some of these concepts of success may be in conflict with each other.

By the time a Superfund project moves into remedial design it has been through an entire sequence of investigations, studies, reports, and meetings with intense technical, administrative, public, and legal scrutiny. The process culminates in the preparation of a ROD which describes both the site and the chosen remediation methods. Unfortunately, all these studies and investigations do not guarantee a thorough enough knowledge of the site to effectively complete design. As the remedial design begins a variety of decisions have to be made about items such as scheduling and funding. Oftentimes these decisions are made based on past experience, on guidelines, or on political or administrative realities.

DISCUSSION

Design Factors

As the designer begins the task of design, questions often arise as various issues develop. Sometimes these issues can drastically affect the direction the designers must take. The scope of the project may begin to change as new factors such as additional site investigation information or new regulatory requirements generate problems not envisioned by the FS or the ROD. Schedules and budgets can be affected and soon the project schedule begins to slip, or expenses begin to overrun programmed budgets. Decisions then have to be made; obligate more money, extend the schedule, find a solution, ignore the problem, etc.

The factors that arise during a Superfund remedial design may be grouped into one of several general categories:

- Technical
- Administrative
- Budgetary
- Political

TECHNICAL - Technical factors are probably the most easily defined, but are often not fully resolved due to scheduling, budget, or technical limitations. Examples of such factors might be the inability to obtain representative soil samples for design, air emissions that may need tight controls during the remedial action, or groundwater levels that may interfere with excavation and treatment of soils. The factors are generally resolvable; however, additional time and money may be required. Unfortunately, there is a real tendency to leave these factors to the construction contractor if resolution during design will result in a schedule slippage.

ADMINISTRATIVE - Administrative factors are often less easily defined and tend to be kept hidden from public scrutiny. For example, a project exists for which the ROD was prepared prior to SARA and which requires solidification of organic waste. Current technical knowledge indicates that stabilization of organic wastes is often not effective. However, because re-examining the selected remedy will require reopening the ROD, the design is proceeding utilizing solidification of the organic waste as the primary remedy.

BUDGETARY - By the time a Superfund project moves into the design phase there have generally been years of studies performed and hundreds of thousands of dollars spent. After that investment, everyone wants to see something accomplished. As a result, the design is oftentimes expected to be completed in a short time frame and on a programmed budget that may not fully account for the complexities, or realities, of the project.

POLITICAL - Politics have a very real influence on the Superfund design process. Designers are often under substantial pressure to produce results. The results are often measured in very simplistic terms (i.e., 'bean counts'). These bean counts often begin to take on a life of their own to the detriment of the project. The local community may also have a substantial impact on what is done. For example, the EPA had agreed to perform various emissions control activities on a particular site during design because of local concerns. As the initial work was accomplished, the analytical results clearly showed no health problems existed and the emissions control activities were not necessary. However, because of the promise made to the local citizens, the emissions control activities proceeded at a cost of many tens of thousands of dollars and substantial wasted effort.

Personnel and Approach to Designs

The Superfund program has resulted in the creation of a huge new industry. Challenges and opportunities abound. Unfortunately, the number of experienced personnel fall short of the demand. The experience level of the average hazardous waste professional is low. The older, more experienced personnel are few and far between.

Design standards do not exist or are very subjective. The work is often poorly defined. As a profession we have forgotten, or have never learned, a lot of the basics associated with sound design and construction. We have become enamored with powerful analytical tools, voluminous reports, endless studies, and detailed schedules at the expense of appropriate design methodologies and sound engineering judgement. Designers should not forget that it is the basics, such as soil properties or groundwater elevations, that can drastically impact construction methods and efficiencies.

Construction experience is a must for designers and for managers. Designers must be learning from their mistakes. One of the best means for a designer to observe problems with a design is to follow its progress in the field and talk to the people administering or performing the work. No matter how thoroughly one reviews documents a continuing presence on the site will be revealing to the designer. It is important for project engineers and managers to be involved during construction. If designers sit in offices and never see the problems being encountered in the real construction world, many valuable lessons will not be learned.

Interaction of Designers

The Superfund program is challenging in that a wide variety of disciplines such as geologists, geotechnical engineers, mechanical engineers, project managers, chemists, industrial hygienists, chemical engineers, environmental engineers, toxicologists, civil engineers, and electrical engineers are involved. On any given project each discipline will have to interface with many of the other disciplines. Each participant in the design process needs to have an understanding of what functions the various disciplines perform. Failure to communicate with the other participants deprives the project of a fully functional design team. The most dangerous person on any project is the "lone ranger" who either believes he knows everything or is not willing to communicate with the other members.

Level of Design Effort

There seems to be a concept held by some people that design is little more than photocopying a previous project, changing the names, and sending it out for a contractor to perform. This may be true on some jobs, such as small underground storage tanks, where the work is repetitive. As projects become larger, more complex, and less standard the concept of photocopy design becomes less realistic.

Design takes time. Most Superfund projects spend years in the RI, FS, and ROD stage; then design is stipulated to be performed within a nine month schedule. Design schedules need to be carefully considered and must take into account project complexities and the number of unknowns. Setting design schedules solely to meet administrative needs with little consideration of actual design concerns will generally create problems later in the design process.

Types of Specifications

Specifications are generally written as either a performance based specification or as a detailed specification, or some combination thereof. In very simple terms, performance based specifications state the end product desired and give the contractor flexibility on how to achieve those results. A detailed specification gives the contractor clear instructions on what is wanted, how it will be built, what it will look like, etc.

There are advantages and disadvantages to both. With the performance spec the contractor must be provided sufficient information and direction that the job can be adequately evaluated. The contractor has much greater latitude in determining his strategy, equipment, and personnel. If the contractor's method doesn't work then the contractor is responsible for finding an alternative. With a detailed specification, sufficient design information must be available for the designer to assure that the project is constructable. If the contractor builds the design as specified and it doesn't work, it is the designers responsibility, not the contractors. Detailed specifications will provide a specific product; however, a greater responsibility is borne by the designer.

Construction claims are sure to follow when the design fails to adequately address the site conditions and the remediation technology. Because of the complexities in hazardous waste work, and the expense of obtaining information, even the less complicated jobs can have many unknowns. However, matters are often made worse by not providing adequate information on basic site conditions such as soil densities, moisture contents, or water table elevations. It is very possible that a $1,000 saved during the design by not performing moisture contents on soil samples may cost the project millions of dollars during construction because the contractor can prove he had no reason to anticipate a moisture problem. Change orders, changed site conditions, and construction claims can send the best scheduled and budgeted project into a tailspin that will lead to failure in terms of budget and schedule.

It is also important for projects to be technically evaluated after completion by the designers as well as independent reviewers. Many of the remedies being installed on these projects are complex. Failure to evaluate the performance of the system is shortsighted and hampers our ability as designers to learn from previous projects.

DESIGN AND CONSTRUCTION EXAMPLES

Superfund Remedial Design

The project involves the excavation of metals contaminated sediments from a marsh with stabilization and disposal of the contaminated sediments and restoration of the marsh. The ROD specified the construction of a dike around the perimeter of the contaminated marsh. The diked area was to be flooded with several feet of water and a small floating dredge used for removal of the contaminated sediments.

During technical review of the ROD it was pointed out that construction of the dike could be difficult due to stability concerns with the weak sediments and that the RI did not support the assumed thickness of underlying soft sediment. Comments were also generated by technical reviewers that dredging may not be the best alternative due to the material properties of the sediment and the dense root mat which overlies the marsh sediments. Also, very large quantities of water would require treatment if the sediments were dredged.

During the design investigation it became apparent that sediments were much thicker, and much weaker, than assumed by the RI/FS. Based on this the designers, early in the design, suggested an alternative that would have reduced the size of the dike by dewatering the marsh instead of flooding. Excavation of the marsh could then be performed using mechanical equipment instead of a dredge thereby accounting for the sediment and root mat concerns and eliminating a substantial quantity of water treatment.

EPA's initial position was that this did not conform to the remedy described in the ROD; therefore, the design was directed to proceed as originally conceived. Early construction estimates began to show that construction costs were going to be substantially higher than planned. A value engineering (VE) study was performed and the resulting recommendations were the same as those previously suggested by the designers. Due to the potential cost savings, EPA then re-evaluated the ROD and determined these changes could be allowed. This is a case were administrative concerns initially overshadowed technical realities and resulted in time delays.

Superfund Project During Construction

The project is a former landfill that is being remediated by capping and installation of a slurry wall and an internal drainage system for containment and hydraulic gradient control. During design a VE study was conducted which suggested several changes to various components of the design, one being the use of a roller compacted concrete (RCC) wall along the side of the landfill bordering a stream. Because of schedule commitments, no design investigations were performed for the foundation of the RCC wall.

Initial preparatory work by the construction contractor suggested that the RCC wall may be more difficult to construct than originally envisioned due to poor subsurface conditions. It appeared that deeper excavations may be required to find a suitable subgrade material. Substantial drilling efforts were initiated to better define the existing foundation conditions. Evaluations are currently underway to determine the impact on the design. Construction is being held up during this investigation and evaluation. If an adequate site investigation had been performed during design the construction delays arising from this problem, and the construction costs associated with the delays, might have been avoided.

Department of Defense Construction

The project consisted of the cleanup of an explosives contaminated lagoon at a military ammunition plant. Design was fast-tracked to meet a funding deadline. Time and funding for site investigations was not provided. Early in construction a high groundwater table was encountered resulting in dewatering and drainage features having to be added to the project. The specifications stated that the contractor is responsible for handling all water; however, no information was provided to the contractor that water may have been that near the surface. The contractor is claiming a cost due to project delay attributed to defective specifications because the water table was not shown; therefore, there was no reason to suspect this problem would occur. This problem could have been avoided by the installation of a few piezometers during design, at a minimal cost.

Superfund Design Investigation

This project consists of a former creosote plant and nearby bayou containing creosote contaminated sediments. Part of the remedial alternative for this site consists of the excavation of contaminated sediments from the bayou and incineration on-site. At the start of design it was assumed that the contaminated length of bayou had been adequately characterized during the RI.
During the initial design investigation minimal confirmatory borings were conducted which revealed substantially different conditions. Subsequent boring programs have delineated a greater lateral and vertical extent of contamination with a resulting large increase in the quantity of material to be incinerated. Each time a drill rig has been mobilized to the site additional design needs have been identified; unfortunately, budget limitations always seemed to preclude doing all the required investigations. This resulted in increased mobilization costs and probably hampered design efforts. However, the fact remains that several investigations were performed and the scheduling and funding were provided to accommodate most the designer's needs.

Superfund Project Construction Delay

This is a project where a former gravel pit has been contaminated with a variety of organic compounds, including PCBs. The chosen remedial alternative provided for excavation of the contaminated sediments with on-site incineration. The specifications forbid the excavation of any sediments from the lagoon until a trial burn is completed utilizing PCB waste; therefore, it was necessary for the contractor to import PCB waste from another source to spike a trial burn sample. Even though the State was an active participant during both pre-design and design, the State would not let the contractor bring PCB waste to the site because the incinerator was not a permitted facility.

Resolution of this issue has caused a one year delay and a claim for many millions of dollars. This is the type of issue that should have been resolved during design by the regulators, not after the contractor has set up a very expensive piece of equipment that is forced to sit idle while the issue is resolved. Ironically, if the claim is paid, the State will be funding ten percent of the cost of the delay.

Department of Defense Petroleum Cleanup

The project consists of the excavation of soil contaminated by low levels of PCB. The extent and level of contamination were poorly defined. Additional investigations were very limited due to budget and schedule considerations. The specifications were written requiring the contractor to obtain state permits for disposal of low level PCB contaminated soils based on the assumption that any of several nearby landfills would accept the waste.

Permits were granted by the state for disposal of the contaminated soils; however, the disposal facilities refused to accept the waste because of concerns regarding liability associated with the PCBs. Disposal of the soils was ultimately accomplished at a hazardous waste disposal facility at much greater expense. The lesson to be learned from this is that assumptions about the availability of disposal facilities should have been verified during design, based on discussion with the facilities, and not on an assumption that a permit issued by a regulatory agency will make it automatically acceptable to a disposal facility.

CONCLUSION

How will the next generation view our efforts in the hazardous waste cleanup arena. Will they measure success by the schedules that were met? By all the bean counts having been counted? By the amount of money that was spent? Or by the efficiency and quality with which sites were remediated that posed a threat to the environment?

The one goal that everyone should have in the Superfund process is that of cleaning up the environment. The purpose of this entire program is not to generate reports or create employment opportunities, it is to remediate sites which pose hazards to our environment. These remediations can be accomplished better by maintaining the quality of designs as we push to meet schedules and budgets.

Better designs can be provided by:

(1) Establishing schedules and budgets consistent with the needs of the project. Often it seems the primary emphasis in this program is placed on schedules and budgets. Quality seems to have become a distant third. Quality, budget, and schedule all need to be weighted equally if the best possible remedial action is to occur. Schedules have to be established based on site conditions and adjusted, when needed, to address the realities of the site.

(2) Improving the communication between disciplines and organizations. Projects are lacking in quality not because of a lack of technical or managerial input but because the variety of

disciplines and organizations involved in the design are not communicating. Team efforts are required on these projects.

(3) Adequate designs need to be prepared based on realistic data. On almost every site it is imperative that we provide the contractors with a reasonable amount of pertinent information so that the contractor can competitively bid and reliably construct a project. This information may be basic, such as groundwater elevations over a period of time or a more comprehensive soil classification program, yet such information may be essential to the contractor in determining the construction methods. How can we expect a contractor to develop an understanding of a site in a few short weeks during bid preparation that the designers may have had years to attain?

(4) Increase the design experience of the industry by learning from projects during and after construction.

Ultimately, personnel are the most important key to a successful design. Without the right people, and the right amount of communication, the project will not achieve the maximum level of success possible.

CONSTRUCTABILITY INPUT TO THE HTRW PROCESS

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INTRODUCTION:

Constructability has historically been viewed as the process of involving those agencies and persons who supervise and administer construction contracts in the latter portions of a projects' design stage. Such involvement normally occurs at a time when all of the actual design work and technical specifications are complete, and the final contracting package, including general and administrative conditions, is being assembled. Little time, attention, or money was allocated to this phase, and the potential benefits of an expanded role for constructability were seldom realized. Fortunately, the definition, role, and relative importance of constructability input has changed.

We currently think of "constructability" as generically consisting of three elements:

a. Biddability - the ease with which the contract documents can be understood, bid, administered, and enforced.

b. Constructability - the ease with which a designed project can be built.

c. Operability - the ease with which the resultant facility can be operated and maintained.

For the purpose of this discussion, I will consider two additional elements which fall under the "constructability" umbrella:

d. Feedback - providing data on the efficacy of the selected remedy, during the remedial action, to the designer and to the cognizant regulatory agencies.

e. Lessons Learned - a formalized process of reporting problems encountered, and solutions found, for various remedial action alternatives, for the purpose of assisting others in future selections.

Note that in all cases, the purpose of constructability input is to facilitate or make planning, design, construction, or operations easier.

In the Corps of Engineers, we have made numerous attempts to capitalize on the benefits of constructability, for both our military and civil works programs. We also seek to adapt these efforts to the missions and projects which we execute. In Superfund, we found a civil works program which has all of the essential ingredients for optimizing these benefits for us and for our customer, the Environmental Protection Agency (EPA). Further enhancement of the constructability process is essential to the continued success of Superfund and other Hazardous, Toxic, and Radioactive Waste (HTRW) Programs; that expanded role should also benefit our more traditional design and construction missions.

BACKGROUND:

The Corps has been involved in the EPA's Superfund Process since 1981. Our Baltimore District performed the very first Superfund Cleanup at Lehigh Electric, a PCB site in NE Pennsylvania, utilizing a design prepared by the Omaha District. Since that time, our role has expanded on a national scale, and we have developed entire organizations, procedures, and reporting requirements to support this mission. In the meantime, our traditional military construction role is changing, as we in the Department of Defense move to clean up our own environmental problems under the DERP Program.

Our efforts in these HTW programs, especially in Superfund, have taught us some valuable lessons about constructability review and input.

The first of those lessons is timing. When we began working in Superfund, our standard procedure, adopted from our military construction program, was to allow for BCO (Biddability, Constructability, and Operability Review) at the concept (30%) and final (90/100%) stages of design. With Superfund, BCO is most beneficial when it begins at the very outset of planning or design. In our role as EPA's design/construction agent, this usually begins with a design assignment; the Record of Decision (ROD) and all previous investigatory data, such as the Remedial Investigation/ Feasibility Study (RI/FS), are usually provided as guidance documents. At this point, our design and project managers have found it is most beneficial to make preliminary contact with the cognizant construction personnel, and solicit their input throughout the entire process. Depending on the phasing of a particular remedial design/action, we have even been able to provide input at the EPA Regional level, when subsequent RI/FS or ROD work is underway. Furthermore, by providing Corps services in the more preliminary stages of EPA's Superfund Process, and by writing/publishing comprehensive closeout and "lessons learned" reports, we hope to provide even more effective and economical remedies to environmental problems in the future.

In the traditional BCO Process, both funding and scope were necessarily limited. It generally consisted of sending the proposed plans and specifications to the cognizant Resident or Area Office, where someone familiar with the post or facility in question would check them for major conflicts with existing conditions. Design assumptions and parameters, codes and procedures used, and even the content of the technical and administrative specifications were usually not reviewed, as they were dictated by some previously established guidelines. Furthermore, we held to our traditional "turf" as construction managers, and did not attempt to question or challenge any design assumptions, fearing that this was beyond our areas of responsibility and expertise.

Because of the unique nature of Superfund, these traditional barriers to comprehensive BCO Reviews are removed. Our agreement with the EPA provides for reimbursement of the costs we actually incur in performing all of our activities, including BCO reviews. This gives us the flexibility to perform detailed analyses, when required, to achieve the most practicable and economical remedial action package. It also allows us to adapt our review for phased remedial action projects, or for those on which we have less than full assignment for remedial design and remedial action. In fact, under a Technical Assistance Assignment, we can be tasked to perform only BCO functions. In other words, reimbursable funding allows us to expend the appropriate level of BCO effort, without undue cost to our customer.

The second unique feature of Superfund is the nature of the process itself, and the expansion of BCO scope which that provides. Our normal projects follow predetermined time lines, where planning, design, funding, and construction are accomplished in accordance with well established regulations and codes. They traditionally utilize existing systems, proven technology, and standard contracting methods. The Superfund Process does not fit into any of these traditional categories, as the projects are not tied to any predetermined time lines and methods; in fact, most Superfund Projects are constantly being reevaluated and reprioritized for funding and action by the EPA. The very act of performing remedial design and clean up efforts often produces the need to perform such reevaluation, as many of the current RA technologies and decisions are emperically based. Within this framework, the concepts of BCO must always be at work. Furthermore, because there are often no easily defined lines between the activities which we historically classify as planning, design, or construction, Superfund permits those of us in the traditional construction management role to expand our BCO input into all phases of a project. This type of continuum is consistent with recent efforts within the Corps of Engineers to provide "cradle to grave" project management, thereby providing our customers with better, more economical, and timely products.

DISCUSSION:

To illustrate constructability input, we can use the following hypothetical situation:

Project: Blue Moondog Chemical

Description: 100 acre site, containing a 5 acre lagoon, a 20 acre land disposal area, 15 treatment buildings, and miscellaneous storage and operating areas

Principal Contaminants: The lagoon sediments contain PCB and heavy metals; the liquids contain TCE, DCE, and benzene. The land disposal area soils exhibit metals, PCB, and VOC contamination. The treatment and storage buildings contain vats, drums and sumps containing uncharacterized liquids, solids and sludges. During the first Building RA, it was discovered that there was asbestos pipe and boiler insulation, and that it was contaminated with UDMH (unsymmetrical dimethylhydrazine).

Remedial Action Status:

In 1985, the EPA conducted emergency removal of 150 drums, some of which had spontaneously erupted and burned. Between 1986 and 1987, a Group of Potentially Responsible Parties (PRP's) pumped the lagoon liquids and arranged for their off-site disposal. A previous Corps Fund-Lead contract, in 1987, resulted in the characterization and disposal of the residual contaminants in 7 of the 15 buildings; those 7 buildings were also dismantled and the rubble was placed in an on-site landfill cell for future action. The Corps contract was suspended and ultimately terminated when it was discovered that the remaining buildings contained asbestos pipe and boiler insulation, most of which was also heavily contaminated by the chemical treatment process previously performed at Moondog, and with UDMH, a previously unidentified contaminant.

Regulatory Status:

The EPA and state regulators are presently discussing a ROD for the lagoon sediments and land disposal area soils. Future operable units will address potential groundwater contamination, both on and off the site. The PRP Group has disbanded, and no viable PRP's are anticipated for future actions. The Corps is reevaluating the ROD requirements and design criteria to finish the building remedies and dismantlement; they have also received a design assignment to perform predesign activities for low temperature thermal treatment of the soils and building rubble. The EPA and state regulators are also concerned about the long term operation and maintenance of any groundwater treatment systems which may be required, and about recent and proposed changes in ARARS affecting air emissions and landfill requirements.

Miscellaneous: While the original PRP Group has dissolved, several other PRP's have hired a consultant firm to monitor the site investigation and cleanup activities. The local citizen group is extremely active and anxious for a final remedy. Local, State and Congressional interest is high, as the remediation of Moondog will clear the way for the development of an industrial park on adjacent lands.

In this scenario, one can obviously see the need and opportunity for constructability input. What is not so apparent is that all of the site participants, ranging from the EPA and State representatives to the PRP Group, can and should be considered a part of the constructability process. There are several reasons for this:

a. They may have specialized knowledge about the site, such as past operating practices.

b. They may have some chemical and physical data, developed during previous studies or remedial actions, which can benefit ongoing work.

c. They may be direct participants, advisors, protagonists, or antagonists in the ROD or Consent Decree processes.

d. They may be providing funds or technical support for the project.

e. They may be the ultimate decision-maker.

f. They may be the ultimate operator of any long-term cleanup facility and/or assume caretaker status on the project.

g. They may simply have some good ideas about how the site should be remediated.

Having identified the players, let us now consider how they can facilitate or hinder the constructability process. From the EPA's perspective, the most efficient, economical, and expeditious remedies for Moondog will occur if they can advance all of the operable units at the proper time and at the proper pace. In order to maintain this momentum, they will be considering items such as when the Corps will complete their investigations and resume work on the buildings; when the State will promulgate final ARARS for air emissions and landfill requirements; how and when the PRP's might again figure into the remedial action or cost recovery; and, most importantly, how all of these actions will affect the surrounding community. As a participant in the constructability process, the EPA Project Manager has the primary role and the authority to ensure that the database of knowledge about the site, including relevant economic, political, and social concerns is constantly updated and available to all of the other participants. By doing so, the EPA will receive current, clear, and timely recommendations on which to base their decisions.

The State's perspective, while similar to that of the EPA, will involve potentially long term commitments for operation and maintenance at the site; the impacts of their proposed air and landfill regulations on Moondog and on other sites within the State; and the precedents which their actions, decisions, and agreement might set for future Superfund Sites and for their own HTW Programs. Timely and comprehensive answers, and review/approval actions, for all state related items are the most important constructability input they will provide. These include anything from water quality certifications, to hauling permits for oversize loads, to air emissions permits for the proposed thermal process. Coordination among the various State agencies; with local governments, emergency responders, other regulators, and potential disposal facilities, are also essential contributions by the State. All of these inputs have a direct and substantial impact on how the remedial action will be performed, thereby touching on all three elements of "BCO" previously discussed. Perhaps the most important of these from the State's perspective (at least for Moondog) is the "O" for operability. One can easily envision that the design of a sophisticated groundwater treatment system may initially be justified, based on the cleanup levels which can be achieved. However, if the State is not willing or able to provide the funding and staffing for long term operation of such a facility, a less sophisticated system may be in order. Given our present bias for "best available technology", and our relatively limited experience with many of these treatment systems, this may be one of the single largest constructability issues for the next decade.

The PRP groups have an obvious interest in the cost and efficacy of the site cleanup. However, they also have concerns about the residual liability which may be incurred by their participation (or their refusal to participate) in the process. Those of us in the Government's service sometimes overlook or fail to fully appreciate what motivates PRP's actions, especially their potential role in constructability. By recognizing that the technical and financial concerns expressed by PRP's during remedial design/action may be the same tests by which cost recovery is ultimately adjudicated, we can make more intelligent economic choices. Furthermore, with an increase in projects where PRP groups actively perform some or all of the remedial actions, like Moondog, a higher degree of cooperation and sharing of information is essential. Our BCO Review of their proposed remedial action documents should be as thorough as if we are doing the work as a Fund-Lead Project, but should recognize and respect those areas where they are entitled to latitude.

Finally, let us examine the role which the Corps of Engineers plays in this scenario. As EPA's design and construction agent, and in our role as the Federal Engineer, we have a responsibility to provide our customer with quality products; delivered on time and within budget; and to perform this work in a manner which protects the remedial action workers and the surrounding community. To those ends, our constructability actions involve the collection and consideration of as much information as we can possibly obtain, as early as we can get it. In our hypothetical example, we would read all of the relevant documents generated by the EPA's emergency removal action and the PRP's lagoon work. Data on the processes used at Moondog would also be important to us, especially as we designed and executed the building and process dismantlement/removal. By reviewing all of this data, and considering what we learned during our first attempt on the building/process contract, we would have a better handle on the scope of work for a second dismantlement contract, and a more focused pre-design for the thermal process. In the interim, we would also be generating and distributing our own information to the EPA and the State, for their use in providing future direction to us, and in formulating future ROD's, Work Plans, etc. With due consideration for any legal implications, we would also share information with PRP's and their consultants. Chronologically, our involvement at Moondog might have been as follows:

a. EPA signed an agreement with the Corps to provide document review and oversight of the PRP's lagoon closure. The Corps was involved prior to the signing/lodging of the EPA/PRP Consent Decree. Although not a party to the Consent Decree, the Corps/EPA Agency status was made known to the PRP's prior to their signing the Consent Decree. The Corps performed BCO reviews of the PRP's design, work plan, contract plans/specifications, health and safety plans and other pre-work documents. The scope of these reviews was decided between the EPA's Regional Project Manager and the Corps Design and Construction District Representatives.

b. The Corps performed on-site inspections and oversight of PRP remedial actions. The scope of Corps involvement, and reporting requirements, were contained in a Work Plan, Budget Estimate, and MOU between the cognizant Corps District and EPA Region. The Corps provided full-time on-site inspection, and split/analyzed field samples with the PRP's contractor(s). Documents and data generated by this involvement, save those which were designated as proprietary by the PRP or their contractors/consultants, were used in future Corps design/construction decisions.

c. After the EPA assigned the Building Operable Unit to the cognizant Corps Design District, the appropriate Construction District was consulted and involved with the scope of work development for the design (Architect-Engineer) contract and with the Acquisition Planning for both the design and construction processes. The design assignment was made under one of the Design District's Indefinite Delivery-Type Contracts (IDTC); the remedial action contract was a fixed price, competitively negotiated instrument. The IDTC Design Engineer was furnished with all of the relevant pre-design information, including the ROD, RI/FS, documents from the Lagoon RA, etc. The design work consisted of developing a set of Request for Proposal (RFP) documents, consisting of Plans, Specifications, and a Solicitation package. On-board reviews of the design work were coordinated at the 30, 60 and 90%

levels; Construction District personnel were afforded the opportunity to review documents and provide input at each of these steps. Among the more important considerations were what to ask for in the RFP (i.e. technical factors such as a Work Plan, proposed schedule, health/safety plan, etc.) and how to evaluate and score these factors, along with bid price, in selecting a contractor.

d. With the completed RFP "on the street" Construction District representatives participated as members of the Selection Board. The successful contractor was awarded a $6.2 M fixed price contract, based on his choice of a dismantlement method which promised to minimize air emissions and potential worker exposure; the contractor also had superior (in-house) sampling and analysis capabilities.

e. After the appropriate award and pre-construction submittals/approvals were completed, on-site work began on the Building Operable Unit. Work on the first 7 buildings proceeded on schedule during the first year of the scheduled 2 year contract. Periodic sampling of the sump wastes revealed that they closely approximated those liquids which the PRP's found in the Lagoons. However, upon discovering that Buildings 8 through 15 contained (contaminated) asbestos pipe and boiler insulation, which was not revealed by the previous investigations or by design activities, the contractor was suspended. Because of the contractor's high extended overhead costs and the lack of approved sampling, analytical, and disposal methods for the contaminated asbestos, the contract was terminated for convenience. Construction and Design representatives researched all of the design documents for potential A/E liability by the Corps A/E, and advised the EPA of any similar liability potential for the previous RI/FS contractors. After the technical and regulatory questions are resolved, design of Building Operable Unit, Phase II, will get underway, utilizing yet another IDTC contractor. In drafting the scope of work, Design personnel will rely heavily on input from construction records from Phase I, and on the chemical data generated by the PRP Lagoon RA, to carefully analyze and characterize the remaining structures, debris, and contaminants. Samples of the building rubble, previously placed in on-site landfill cells, will also be analyzed for the presence of friable and/or contaminated asbestos, and for indicia of the contaminants found in the sumps and lagoons.

f. Assuming that the future design and remedial action work proceeds without incident, the Construction District will prepare closeout reports for each of the operable units for which they received design/construction assignments. These reports will chronologically document both the physical remediation activities and the certified chemical data which were generated throughout. "Lessons Learned" reports and input will also be generated and disseminated via electronic data bases, papers and presentations, and briefings.

g. Long term action at Moondog will include State operation of the groundwater treatment system, and the recovery of costs from PRP's. Documents generated during RD and RA will figure heavily in the recovery process, as all alleged costs and actions will be analyzed, in detail, under the most critical of all circumstances: Hindsight!

As described in this hypothetical situation, constructability in the HTRW Process seeks to provide relevant input at all stages of the process, and to facilitate the transition between these phases. For the RA Phase, where construction personnel are the focus of the process, our constructability actions include the feedback of information to cognizant regulators and designers, to ensure that the RA is proceeding as planned. At the conclusion of RA, constructability includes the accurate and complete documentation of the project, to prove that the designed objectives have been accomplished, and to provide a history of the project with a "lessons learned" emphasis.

Unfortunately our experience in achieving these goals for all HTRW Projects has been less than perfect. This is especially true for projects like the Moondog example, where many phases and parties are involved. Among the problems which we find inhibit constructability input, or decrease its effectiveness are:

a. All of the site historical data is seldom available to construction personnel.

b. There is seldom any complete institutional knowledge of a site, either from a historical or regulatory standpoint.

c. We are seldom asked to participate in any portion of the RI/FS or ROD development.

d. We are not usually staffed or funded to fully participate in all aspects of the RD.

e. The RA phase has historically uncovered additional quantities and types of contaminants, thereby resulting in delays, cost increases, claims, changes, and incomplete RA's.

f. We have not placed enough emphasis on providing timely feedback, or to preparing and disseminating our "lessons learned" reports.

However, the Superfund Program, by virtue of the way it is funded, and because the workload has somewhat stabilized, provides us with an opportunity to overcome some of these problems. We have noted an increased constructability awareness on the part of the scientists and regulators who normally control the RI/FS and ROD phases of these projects, and a mutual understanding among all of the players about their roles and interactions. Most people now realize that the best RI/FS, ROD, or RD is worthless if the resultant RA cannot be bid, constructed, and/or operated in the fashion which it was intended. For our part, those of us in construction management now realize that unless we make a conscious effort to track and participate in upcoming project development, and unless we keep our regulators and designers intimately involved during the RA phase, we cannot hope to improve the end product. We also recognize our duty to tell the design and construction community about our experiences, especially those procedures and processes which do not work, so that others can avoid repeating our mistakes.

In order to maximize the benefits of constructability input for HTRW Projects, the following are suggested:

a. Regulations/standard practices should require a BCO review at least at the draft stage of every phase of a project (i.e. draft RI/FS, ROD, RD, etc.). As the proposed action becomes more definitized, construction involvement should increase, with BCO review effort ranging from one week for small RI/FS documents to one year (equivalent) for BCO on a large RD effort.

b. Funding and staffing should be programmed in advance, for BCO input at each phase of the project.

c. BCO comment format and reporting times should be agreed to with the agency and person who will draft the document(s) in question. A time frame for review and comment should be agreed and adhered to. The process must also include written responses to the comments; an "on-board" session to discuss questions/disagreements; and a corporate approach to resolving any remaining problems.

d. When site characterization nears completion and cleanup alternatives are being evaluated, an active search for "lessons learned" should be conducted. Any findings, both pro and con, should be included in the subsequent report. The ROD should also reflect and account for these efforts.

e. All selection and design decisions for long-term remedies (groundwater pump/treat, etc.) should consider the element of operability. Technical difficulty, cost, staffing, and decommissioning of the systems should be addressed.

f. Ongoing efforts by EPA, the Corps, States, and other Government agencies and private firms, to share available data, and to enhance discourse between various HTRW elements, should be encouraged. EPA's SITE Program is a good example of this.

g. Guidance documents for the HTRW process should address the creation of project milestones for constructability input, feedback, and "lessons learned".

h. Innovative contracting strategies should be developed based on site specific criteria and timing. For instance, if site knowledge is limited and some type of immediate RA is necessary prior to the completion of RD, a cost reimbursable form of contract might be required. This allows the construction manager to better handle the unknowns and to provide feedback to the ongoing design process. It also helps us to be more responsive to customer requests and criteria changes.

i. Construction personnel should be required to periodically brief and/or report to regulators and design personnel on the status of all ongoing RA's.

j. Closeout reporting formats should be standardized to facilitate use by regulators in "delisting" NPL sites, and to feed existing data bases on HTRW remedial alternatives. Any "lessons learned" should receive the widest possible dissemination, perhaps via programs like SITE.

CASE HISTORIES:

The following are examples of HTRW projects where constructability input, or the lack thereof, has been a factor in our ability to implement the selected remedy:

a. Lackawanna Refuse Site: This $25M RA, conducted in 1987-88, consisted of the excavation, sampling, on-site analysis, and disposal (or backfill) of 114,000 CY of potentially contaminated refuse and 8,500 drums. In performing this remedy, we utilized a unit-price competitively bid contract format to allow us some flexibility in quantity variation. Because of this, and by using a special form of the variations clause, we were able to hold the bid price for disposal, despite a six-fold increase in the estimate of contaminated refuse encountered. More importantly, this allowed us to continue work without any suspension or interruption; we were therefore able to meet the required "Land Ban" Disposal Date on 8 November 1988. This project also included many ideas, generated by the EPA, Corps, State, and Design A/E personnel which have become "constructability" input standards for other large HTRW projects in the Baltimore

District: Time lapse video surveillance of work activities; selection and periodic verification of Key Indicator Compounds as indicia of contamination; and the use of on-site laboratories for clean/dirty determinations. One item which remains at this site is the long-term collection and treatment of leachate. The original RA contract contained provisions for the design and construction of an on-site treatment plant. This requirement was subsequently deleted when it became apparent that it would not be cost effective or practical for the State to operate and maintain the plant. The EPA and the state are currently negotiating with a publicly owned treatment works.

b. Lansdowne Radiation Site: This site was a duplex residential structure and surrounding grounds which were contaminated by Radium 226. In order to advance the RA and obtain the most technically and cost effective remedy, we advertised this as a "Request for Proposal" contract with unit-prices. The successful contractor proposed an innovative method of dismantling the contaminated structure without having to use a secondary containment. Other constructability inputs were: a payment item based on the weight of contaminated rubble and soil, coupled with the contractor's arrangement with the disposal facility to pay based on volume, ensured the most economical and compact handling and transport system; on-site contractor and Government quality assurance (QA) laboratories allowed for quick turn-around of analyses and clean/dirty determinations; the presence of QA personnel, and their development of a real-time method for determining/predicting soil contamination, allowed for continued funding and execution of the project despite a four-fold increase in the amount of contaminated soil.

c. Bruin Lagoon Site: Our first attempt at remediating this site, an acidic sludge lagoon (approx. 73,000 CY) was suspended when an uncontrolled and uncharacterized release occurred. During the redesign of the project, construction personnel provided input on methods to predict and control any future releases, and to provide real-time acceptance criteria for the neutralized and stabilized sludge.

d. Heleva Landfill Site: This site was originally envisioned as being 22 acres in size and contained by the existing physical boundaries. Although we did place test pit provisions in the contract to accurately define the landfill limits after the contract was awarded, we were forced to make other adjustments in grading, drainage, and fencing when we discovered that the actual limits were 25% larger, and not constrained by the obvious physical limits of the site. More extensive investigation prior to the advertisement and award of this contract may have been useful. Heleva was also one of our first attempts at using a fully synthetic cap and flow zone system, coupled with a minimum vegetative soil cover, to limit settlement. To date, this system has proven to be very effective and required minimal maintenance.

e. Tyson's Dump Site: This PRP-lead project used vacuum extraction for the removal of volatile organics from soils and sludges in previously closed lagoons. Incomplete and untimely coordination between the Corps, the EPA, and the PRP led to a number of disagreements about the Corps' role and authorities on this site. Corps involvement prior to and during the negotiation of the Consent Decree may have mitigated these problems. On the positive side, constructability input at this site did produce a method for baselining and subsequently measuring the efficacy of this alternative technology at various points in time, as opposed to waiting until the soil long-term cleanup levels were projected to be achieved, some 2 years after the start of RA.

CONCLUSIONS:

The role of constructability input, especially on HTRW projects, is expanding. There are a number of reasons for this, principally: remedial action is generally the most expensive phase of the remediation process; and many remedial designs are emergent technology which are emperically based on limited data from other remedial actions.

To maximize the benefits of constructability, opportunity, funding, and staffing are required. Programs like Superfund provide many of these essential elements and, because of their unique nature, are not burdened by some of the traditional barriers to the constructability process. Personnel involved in HTRW programs, in general, are coming to the realization that a continuum of involvement by scientific, design, and construction personnel, from the RI/FS through project closeout/O&M, is essential. In the Corps of Engineers we hope to continue that trend in our Superfund work, and in our other HTRW missions.

ACKNOWLEDGEMENTS:

I would like to thank the EPA Headquarters Staff for this opportunity to present my views on constructability. I would also like to thank the staff at EPA Region III, the Pennsylvania Department of Environmental Resources, and the Corps Missouri River Division and Omaha District, for allowing those of us in construction management to fully participate in the remediation process.

Applications of a Design/Build Advisor Expert System to Environmental Remediation Projects.

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INTRODUCTION

The U.S. Army Corps of Engineers Construction Engineering Research Laboratory (USACERL) is currently developing a knowledge-based expert system for Design/Build construction -- a non-traditional approach to the design, contracting, and construction of facilities. A "DESIGN/BUILD ADVISOR" will provide expert-based guidance to support project planning and execution by those who may not have a great deal of first-hand personal experience. The DESIGN/BUILD ADVISOR provides step-by-step procedural guidance and advice in an interactive menu-driven environment.

The relative newness of environmental remediation construction and limited expertise in this field strongly suggests that similar type of advisory system would be applicable to environmental remediation projects. Significant benefits may be achieved. The overall system architecture of the DESIGN/BUILD ADVISOR would be compatible to environmental construction applications.

The DESIGN/BUILD ADVISOR was developed for application to facility design and construction. However, this paper focuses on the overall system architecture and its decision support capability for construction-related issues. Those expert in environmental and hazardous and toxic waste fields can then visualize the applications of a similar "advisor-type" system to environmental remediation projects.

BACKGROUND

The Design/Build approach is by no means a new method of constructing facilities. However, it is not universally practiced within the design and construction community, and project execution differs widely among facility owners and contractors. Federal agencies' practice of Design/Build construction also differs from private practice. While the Design/Build approach is used within the U.S. Army Corps of Engineers (USACE), it is by far the exception rather than the rule. USACE personnel are not nearly as well versed in Design/Build as they are in the conventional design-bid-build practice. Design/Build practices within USACE differ, as do project results.

Congress has instructed the Defense services to explore "Alternative Construction Methods" (including the Design/Build approach), which means that Design/Build will be applied more widely within USACE. It became clear that further guidance was necessary to support USACE Districts in conducting Design/Build projects.

USACERL had previously developed a guidance document for Headquarters, USACE (HQUSACE) on the Design/Build approach applied to Army facilities. This Architectural and Engineering Instructions (AEI) provides general guidance and in that regard is quite useful[1]. By necessity, however, it could not always address specific conditions surrounding any given project. Interpretation by project personnel is still necessary. It became evident that an additional "advisory" capability was still necessary to provide guidance more specifically tailored to a given Design/Build project.

The DESIGN/BUILD ADVISOR was initiated to support the planning and execution of a design/build project through experiences, guidance, and advice collected from knowledgeable sources, i.e. experts. It will provide a step-by-step "roadmap" of the process, generalized advice for each step, and project-specific advice for decisions which require design/build expertise. The DESIGN/BUILD ADVISOR will not substitute for expertise, nor would it usurp an individual's professional judgement. The DESIGN/BUILD ADVISOR will provide advice which project personnel can then incorporate into their decision-making process.

DISCUSSION

Application of Knowledge-Based Expert Systems.

Under contract with USACERL, the University of Illinois Department of Civil Engineering, with support from the University of California Department of Civil Engineering, developed a prototype DESIGN/BUILD ADVISOR[2]. USACERL personnel provided expert knowledge and directed university personnel to other expert sources. USACERL personnel completed the substantive content of this system. The following describes the application of knowledge-based expert system technology to this project.

Three major elements should be recognized in the DESIGN/BUILD ADVISOR's development: a Process Model of the Design/Build approach, Activity Performance Descriptions, and Knowledge Representation.

A Process Model was created to formalize representation of phases, activities, sub-activities, and decisions involved with a Design/Build project. The model presents a chronological sequence of steps in a hierarchical structure. The process consists of a number of phases. Each phase consists of a number of activities. Each activity is dependent upon sub-activities. Sub-activities are defined to the lowest, most detailed level useful to accomplishing the activity. The process model also identifies the relationships and dependencies among activities. These include activities contributing to the performance of a higher level activity, activities affecting the subject activity, and activities affected by the subject activity. The process model identifies points where domain-specific expert knowledge will contribute to decision making.

An Activity Performance Description provides a definition, description, and information on accomplishing each activity. This information is drawn from facts, experiences, and advice compiled from expert sources in the Design/Build knowledge domain. The Activity Performance Description for each activity portrayed in the DESIGN/BUILD ADVISOR Process Model includes the following:

Activity description.
Purpose or objective of the activity.
Sub-steps.
Super-steps.
Steps upon which the activity is dependent.
Steps impacted by the activity.
Activities or decisions upon which the subject decision is dependent.
Input required to perform the activity.
Production or output of the activity.
Schedules, deadlines, or routing.
Forms used during the activity.

General suggestions.
Cautions.

Knowledge Representation is achieved through an object-oriented approach. Each activity or decision is represents an object, with which attributes are associated. Data, information, and heuristics gathered from expert input are codified and entered in a knowledge base. Rulesets are then developed for each activity. The following information was obtained for the DESIGN/BUILD ADVISOR.

Requirement for expert knowledge.
Description of the results or outputs of the decision.
Factors considered when making the decision.
Inputs required for each factor.
Determination of how decisions are made.
Hierarchy or criticality among factors and inputs.

The three elements described above are fundamental to knowledge-based expert system planning. A similar approach would seem to be equally appropriate for environmental remediation projects.

Functional Description of the DESIGN/BUILD ADVISOR.

There were several fundamental requirements that had to be addressed when developing the DESIGN/BUILD ADVISOR. These involve the contents of the system, users of the system, and mechanics of implementing the system within USACE.

Requirements for the system's contents and advice were gathered through experience and exposure to USACE Design/Build projects. This included input from HQUSACE, USACE District, and USACE field personnel involved with Design/Build projects, as well as first-hand experience by USACERL personnel. Recurring issues, questions, and problems involved the following general topics.

General USACE policy and procedures relative to Design/Build projects.

Selection of projects suitable for a Design/Build approach.

Development Scope and Statement of Work descriptions for contracted Architects/Engineers (A/Es) and other services.

Contents and development of solicitation documents (Request for Proposal) for Design/Build projects; technical specifications, instructions to offerors, proposal submittal requirements, and other provisions.

Certain features of the contract award process (proposal evaluation and source selection procedures).

Certain features of construction contract administration.

It was also determined that a representation of the complete military facilities' design and construction process was unnecessary. The system should focus only on those areas which the Design/Build approach presented considerations and problems not normally encountered in conventional practices.

The primary users of this system would be USACE project managers at the District level; those directly responsible for managing facility design, contracting, and construction activities. Project management personnel would apply the system to all phases of a Design/Build project. Similar use could be in a review and oversight capacity at the USACE Division level. Technical personnel (i.e. the engineering disciplines) may also apply the system to the development of specifications and other engineering criteria. However, the system would not be a rigorous engineering design or analysis tool. HQUSACE personnel may use the system when selecting projects for a Design/Build approach.

The system had to be compatible with the USACE automation environment. A 286 DOS-based microcomputer was determined to be the appropriate platform for the system, although a 386 DOS delivery environment is preferable. Software would have to to run at multiple sites at a reasonable cost for each site.

Finally, it was decided that knowledge would have to be represented in a object-based environment. This approach allows the development of logical knowledge packages (nodes) that can resemble the natural logic of experts in the field. An object-oriented approach also expedites updates to the resident knowledge. Objects and their associate attributes can be amended independently, without necessitating the reprogramming of all rulesets associated with interrelated objects.

The DESIGN/BUILD ADVISOR is designed to allow the user to navigate through the system and seek advice selectively. Information is displayed in a two-tiered system architecture.

The Interactive Index (first tier) uses a multi-level mapping concept. The user may enter the system at any of the five phases described for Design/Build projects. Activities involved with each of the phases are displayed in menu format. The user then selects the activity for which information or advice is sought. Information on the selected activity appears in menu format. It is generally procedural in nature and includes the following, as applicable to the subject activity.

Description of the activity.
Cautions about the activity.
General suggestions for performing the activity.
Steps immediately preceding the activity.
Steps immediately following the activity.
Schedule and routing information.
Other activities affecting the activity.
Other activities affected by the activity.
Forms, reports, and other documentation involved.
List sub-activities.
Decision Advice.

The user may select any of the options listed, upon which the relevant information appears in text. Selection of the "List Sub-Activities" option invokes and additional menu of more detailed activities. The user then repeats the sequence, selecting the desired sub-activity, then the desired information, as described above. In some cases, Hypertext™ explanations are imbedded in the system for selected items. When selected, these provide additional explanations, references, or information that must be considered when performing the subject activity.

There are 186 activities and sub-activities defined within the five phases of the Design/Build process. The user selects the information he/she requires directly. It is not necessary to progress through a lengthy sequence of activities or the finest level of detail.

Project-Specific Advice (the second tier) is provided for those decision points which require an expertise in Design/Build that may not ordinarily be present in a USACE office. A "Specific Advice" option appears in the information menu for those decision points. Heuristics and rulesets are maintained in this tier. The system obtains input interactively from the user by requesting information appropriate to the activity or decision. Given the users input, the inference engine (the expert system) triggers rulesets for that activity based on the combination of attributes represented by the user's input. This second level of information provides guidance that is not possible in static media such as guidance documents.

Once again, it seems reasonable to assume that a similar approach could be applied to an advisory system on environmental remediation projects.

Example Application of the DESIGN/BUILD ADVISOR.

The following example describes the logic, sequence, and information involved when consulting the DESIGN/BUILD ADVISOR. This example involves selecting a facility acquisition approach for a military construction project. This example may also have parallels in the environmental remediation field.

HQUSACE or a USACE District (a USACE construction agent, also referred to as Field Operating Activity (FOA)) may consider whether or not it would be advantageous to construct a facility using the Design/Build Approach. USACE personnel may apply the DESIGN/BUILD ADVISOR in the following manner. This example focuses on a sub-activity entitled "Decision: Select Procurement Approach".

For the purposes of this paper, all information is presented in text format for clarity and brevity, and to facilitate explanations. Text was also edited for clarity and is not necessarily verbatim as it appears on the screen. Menus appear in *italics*. The user's selection from the menu then appears in **bold** and are highlighted with an asterisk (*).

Upon entering the system, five Design/Build project phases are displayed to the user. These are:

* **Phase 1: Identify Facilities for Design/Build Approach.**
Phase 2: Conduct Pre-Design Activities.
Phase 3: Develop and Administer Request for Proposal (RFP).
Phase 4: Perform Proposal Evaluation.
Phase 5: Administer Construction Contract.

Two activities are displayed under Phase 1.

Identify Facility Requirements.
* **Determine Facility Procurement Approach.**

Two sub-activities appear:

Review Directive.
* **Decision: Select Procurement Approach.**

The advice for the *"Review Directive"* option, in summary, instructs the user to consult the project's design authorization directive (transmitted from HQUSACE) for 1) explicit instruction to implement a Design/Build approach, or 2) other project instructions, special objectives, or other unusual conditions that would necessitate or strongly suggest using Design/Build as a means of achieving the stated objectives. Finding no explicit or implicit instructions contained in the directive, the user would then judge the most advantageous approach for completing the project; conventional design-bid-build approach, or a Design/Build approach.

The following menu would appears for the *"Decision: Select Procurement Approach"* option.

Description of the activity.
Cautions about the activity.
General suggestions for performing the activity.
Steps immediately preceding the activity.
Steps immediately following the activity.
Schedule and routing information.
Other activities affecting the activity.
Other activities affected by the activity.
Forms, reports, and other documentation involved.
List sub-activities.
Decision advice.

The user may select any of these options for further information. The information contained for each of these options is as follows.

Description of the activity. *The conventional design-bid-build or Source-Selection Design/Build procurement approaches are considered at the outset of the project; one approach must be selected prior to initiating design work. This activity presents decision rationale for considering the factors critical to selecting the procurement approach. The decision rationale applies to both HQUSACE and FOA levels.*

Cautions about the activity. *The design and construction community must be capable and willing to enter into a competitive Design/Build arrangement. The USACE construction agent should have a reasonable level of confidence that an acceptable number of offerors will participate. The project must be of sufficient scope and contract amount to attract offerors. Project requirements must not be so cumbersome or restrictive that potential offerors are discouraged from participating. However, project requirements cannot be so ill-defined that offerors will be uncertain as to the Government's requirements, or the Government is vulnerable to receiving an unsatisfactory facility. Specification development, proposal evaluation, and design review/approval are activities conducted in a different fashion than traditional USACE practices; the USACE construction agent must be adaptable to these practices. Approval to initiate a negotiated Source Selection procurement must be pursued per FAR part 15 and other established procurement regulations.*

General suggestions for performing the activity. *The USACE construction agent or contracted A/E services should be familiar with the availability of design and construction services and Design/Build activity in the project's locale. Facilities that more closely resemble facilities in the commercial construction market are generally better candidates for a Design/Build approach. Consider the suitability of design, engineering, and construction criteria normally observed in the commercial market. Facilities that are unique within the Army may be less appropriate candidates. Severe time constraints generally favor a Design/Build approach over the conventional design-bid-build process, and may sometimes be the only feasible option.*

Steps immediately preceding the subject activity. *"Review Directive"; identify any explicit directive or implied or indirect project requirements necessitating or strongly suggesting preference toward a Design/Build approach.*

Steps immediately following the subject activity. *Phase 2, "Conduct PreDesign Activities".*

Schedule and routing information. *There are no specific schedule requirements. This decision should be concluded as quickly as possible to maintain progress relative to a conventional project.*

Other activities affecting the subject activity. *"Review Directive"; identify any explicit directive or implied or indirect requirements necessitating or strongly suggesting preference toward a Design/Build approach.*

Other activities affected by the subject activity. *Phases 2 through 5, in their entirety.*

Forms, reports, and other documentation involved. *Approval to initiate a negotiated Source Selection procurement must be pursued per FAR part 15 and other established procurement regulations. Submit request in memorandum format through USACE Division, Construction Division, to HQUSACE, CEMP-C.*

List Sub-Activities. *Initiate Design/Build procedures.*
Initiate conventional procedures.

Decision advice. *Yes.*
No.

"Decision advice" only appears if there is conditional advice resident in the knowledge base. If the user selects the "yes" option, the system invokes rules and heuristics resident in the knowledge base for this phase. The user is queried for information that reflects specific project conditions. In the case of "Decision: Select Procurement Approach", three groups of questions are asked. The system analyzes the user's inputs for each group, provides advice, then proceeds to the next group. A conclusion statement aggregates the advice synthesized from each of the three groups. This query is as follows:

Are there any site or security requirements that would prevent the general design and construction community from participating in this project ?

* **1) No.**
2) Yes.

What are the current conditions of the local/regional construction economy ?

* **1) Relatively inactive; favorable to owners.**
2) Average.
3) Very active; favorable to contractors.

What level of capability and interest can be anticipated for this project; how evident is Design/Build practice in the local/regional design and construction market ?

1) Design/Build is practiced and evident.
* **2) Design/Build is practiced on occasion.**
3) Design/Build is rarely practiced.

How capable and receptive is the FOA to adjust practices to a Design/Build approach ?

1) Very capable/receptive, experienced and well versed in Design/Build.
*** 2) Moderately capable/receptive, some experience in Design/Build.**
3) Limited capability or experience.

Given this input, the following advice is offered.

Project conditions appear favorable to a Design/Build approach. A soft construction economy suggests designers and contractors are seeking additional avenues for business. Evidence of Design/Build practice suggests interest, presence of necessary design and construction services, and local/regional Design/Build experience. Moderate FOA receptiveness/experience enhances chances of successful project execution, but proper execution must be ensured throughout the project's progress. A conventional design-bid-build approach would also be appropriate.

If the response to the first question would have been "yes", the system would have advised that the Design/Build option not be pursued and would not continue any further. If the responses to all of the other three questions would have indicated unfavorable conditions, the system would have advised against further consideration of the Design/Build option, and would not continue any further. This first group of questions is the only group where negative responses would be "fatal" to the Design/Build option.

The second group of questions is as follows:

What is the facility type; how common is this facility type in the commercial construction market ?

1) Very common facility type.
*** 2) Both common and Army-unique features are present.**
3) Unique facility to the Army; no commercial counterpart.

What is the scope of the project (in contract amount) ?

1) Large (roughly $20M or more)
*** 2) Moderate (roughly $5-20M)**
3) Small (roughly $5M or less)

To what extent can commercial design, engineering, and construction criteria, specifications, and detailing be used for this facility in leu of standard USACE or Army-specific criteria ?

1) Commercial/industry criteria will be suitable for the project.
*** 2) Commercial/industry criteria may be suitable for the project; some Army-specific criteria may be necessary.**
3) Only Army-specific criteria is suitable for the project.

Given this input, the following advice is offered.

Project conditions are very favorable to a Design/Build approach. A common facility type suggests that there is sufficient familiarity and expertise with the facility type present in the commercial construction market. The project scope is adequate to attract participation in the project, although care must be taken not to discourage potential offers by inadvertently *imposing cumbersome or restrictive project conditions. The use of commercial/industry criteria is more consistent with private commercial practices and enhances participation by potential offerers; the application of Army-specific criteria should be reviewed as the project progresses. A conventional design-bid-build approach would also be appropriate.*

The third group of questions is as follows.

What are the time constraints for design and construction (time to Beneficial Occupancy Date) relative to a conventional military construction project ?

1) Less time to BOD than a conventional project; 24-30 months or less.
* **2) Comparable to a conventional project; 30-36 months.**
3) More time to BOD as a conventional project; 36 months or more.

Are there any existing design/construction documents readily available for this facility type?

* **1) Yes.**
2) No.

Given this input, the following advice is offered.

Project conditions are favorable to a Design/Build approach. The time available is ample for a Design/Build approach, but gives it no particular advantage over conventional design and construction practices. Existing documents may be helpful to either a Design/Build or a conventional design approach. A conventional design-bid-build approach would also be appropriate.

Summary advice on **"Decision: Select Procurement Approach"** is as follows:

Project conditions are favorable to a Design/Build approach. There may be a potential advantage over the conventional design-bid-build process. Capability, interest, and Design/Build experience appear to be present in the local/regional construction community. This must be verified as the project progresses. The project description appears to be consistent with commercial/industry design, engineering, and construction practices, which enhances the chance for successful project execution. This must be verified as the project progresses. The time available to BOD is ample for a Design/Build approach, but gives it no particular advantage over conventional design and construction practices. A conventional design-bid-build approach would also be appropriate.

The user would consider this advice and act according his/her own best judgement. Given this advice, the user should have a fairly high level of confidence that a Design/Build approach can successfully be implemented to the advantage of the project. The system provides information that the user may not ordinarily have at his/her disposal. If, for whatever reasons, however, the user is still reluctant to commit to a Design/Build approach, he/she can also feel comfortable that conventional design-bid-build practices would be appropriate.

The example illustrated above represents the typical case in facility design and construction. Either a Design/Build approach or conventional design-bid-build practices could result in a successfully completed project. However, unfamiliarity with Design/Build practices and absence of project-specific guidance would generally steer project management personnel away from non-traditional practices. As a result, the opportunity to achieve positive results is frequently lost. Reinforcement from the DESIGN/BUILD ADVISOR should enable USACE to take advantage of more of these opportunities.

The DESIGN/BUILD ADVISOR provides advise in a similar fashion for the remaining four project phases. *Phase 2: Pre-Design Activities* provides advise on activities and procedures encountered prior to the development of construction documents (design drawings and specifications). As these activities are generally similar to conventional design and construction practices, the majority of the advice is procedural and non-conditional.

Phase 3: Request for Proposal (RFP) Development and Administration provides advice on the development of the solicitation documents for a Design/Build project. The content and composition of the RFP differs considerably from conventional construction documents. Therefore, more project conditional advice is provided. Project conditions dictate the preferred composition of drawings, sources of criteria, and content of specifications, as well as various procurement and contract award provisions.

Phase 4: Preform Proposal Evaluation provides advice on Design/Build contractor selection, i.e. Source Selection procedures. Much of this advice is procedural and can be conveyed in a general, non-conditional fashion. Development of contractor selection criteria depends upon project conditions and must be addressed by project-conditional advice. However, as the development of this material must actually take place during RFP development, advice for certain *Phase 4* activities is contained in *Phase 3* for consideration at that time. Advice provided under *Phase 3* and *Phase 4* activities clarifies these relationships to the system's user.

Phase 5: Administer Construction Contract provides advice on the completion of construction documents by the contractor. Although this activity differs in sequence from conventional design practices, it is executed in similar fashion to a conventional project. Non-conditional advice is appropriate. Once construction documents are approved for construction, the remainder of the construction process is administered in a similar fashion to a conventional project where non-conditional advice is likewise appropriate.

Applicability to Environmental Remediation Projects.

There are parallels between Design/Build construction and environmental remediation projects that suggest a similar advisory-type would be applicable. Environmental remediation is a "non-traditional" field in that the state of knowledge has not yet matured into standard or widely accepted practice. There is not yet extensive first-hand experience or a widespread base of expertise. Experiences are not widely disseminated. Yet, remediation projects must still be conducted with a high levels of skill, quality, and performance. Process information will be necessary for project planning and strategic decision making. Generalized information, guidance, and advice will be necessary for procedural and technical issues. Conditions encountered on a case-by-case basis will necessitate project-specific advice.

A "strategic planning" phase for remediation projects may parallel the project selection phase of the DESIGN/BUILD ADVISOR. In a facility construction context, this issue is not overly complex. Initial planning decisions for remediation projects, however, will be considerably more complex.

Selection of a contract method, for example, will have profound affects on the remainder of the project. Some project requirements may be well enough defined that a firm-fixed contract will be appropriate. Most often, at least in facility construction, this approach is selected by default rather than through consideration of the circumstances. If the scope of services cannot be accurately defined, or if there are unknown conditions to the project, a deluge of costly and time consuming contract modifications will be forthcoming. Perhaps a cost-plus type of contract would be better suited -- but at a price of considerably more intense contract monitoring. Project planning personnel must be able to identify the relevant conditions present for the project, associate project conditions with advantages and disadvantages of alternative contracting methods, predict the affects the selected method will have on the remainder of the project's duration, and select the method best suited the project at hand.

An advisory-type system similar to the DESIGN/BUILD ADVISOR would be able to provide advice on based on project-specific conditions. The different contracting options would be defined. Conditions that would suggest advantages and disadvantages of each option would be defined. Rules would be developed for each combination of conditions. Advice statements would be crafted accordingly. User input would be solicited to identify the conditions present at any specific project. The expert system would then invoke the rules and advice consistent with the conditions described by the system's user. Although the numbers of options, conditions, and combinations are likely to be many times those involved with the example above, the principles and basic structure will be the same.

The process model for the DESIGN/BUILD ADVISOR was created as a frame for the expert system. A secondary use, though one more visible to the system's user, is as a process guide and "roadmap" through the Design/Build process. Although procedures for remediation projects may be well established, a consistent process guide may enhance training and familiarization among project management personnel.

Another possible application of an advisory-type system would be for the development of engineering requirements, criteria, and specifications for project contract documents. Where a precise description of methods, materials, or techniques can be made, these may be included in project specifications. However, if such descriptions cannot be made, methods are as of yet unknown, or a number of alternative methods may achieve the same results, a performance approach to specifying input and output requirements may be more advantageous. The nature of the project, existence of criteria, sources of criteria, and required results contribute to the specifier's decisions. Once again, the complexities of environmental-related criteria will likely exceed those of building construction. However the principles and applications could be the same. Decision factors, inputs, rules, and advice can be created to assist in the composition of criteria and specifications.

Finally, this paper recommends consideration of an additional feature not currently part of the DESIGN/BUILD ADVISOR. Building design and construction professionals struggle with the problem of contract modifications necessitated by unknown conditions, inaccuracies or ambiguities in project scope, criteria changes during the project, and other change conditions. The nature of environmental remediation projects exacerbates this problem severely. Expert system technology <u>may</u> facilitate management of this problem area. The potential for changes may be so great, and the number of conditions and possible resolutions may be so numerous that comprehensive and meaningful rules and advice may be difficult to develop. However, as experience is gained and documented over time, and change conditions can be anticipated and modeled with greater confidence, an advisory-type system may contribute significantly to the management of this problem.

CONCLUSION

In summary, an advisory-type system is being developed to support project management personnel in the planning and execution of the Design/Build method of facility acquisition. A prototype DESIGN/BUILD ADVISOR has proven that the system works, is useable for the intended purposes, and provides valid advice. Current work involves reinforcing the material presently in the system, i.e. text revisions and editing, and addition of expert-based knowledge. Inclusion of a database to store project information and document decisions as a project progresses is being incorporated into the system.

The overall system architecture of the DESIGN/BUILD ADVISOR would be compatible with environmental remediation projects. Project phases and steps would be formalized in a process model. Rules would be synthesized from domain-specific expert input into general and project-specific advice. An interactive menu-driven environment would generate advice based on input from the system's user.

Significant benefits can be achieved with the application of an advisory-type expert system to environmental remediation projects. Individuals' capabilities will be enhanced through access to a knowledge base founded on expert input, which will broaden with additional project experience. The primary benefit would be in the improvement of the quality of decision making and, therefore, the probability of successful project execution.

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2. Draft Final Report "Knowledge Based Expert System for Design/Build Project Planning", James H. Garrett, Department of Civil Engineering, University of Illinois at Urbana/Champaign, Anthony D. Songer and C. William Ibbs, Department of Civil Engineering, University of California, Berkeley, CA, February, 1990.

"CONFORMING STORAGE FACILITIES" REMEDIAL CONSTRUCTION ACTIVITIES

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INTRODUCTION:

Hazardous waste (HW) remediation has become an increasing complex issue. In 1980 the Department of Defense (DoD) consolidated the responsibility for disposal of HW generated by DoD activities under one agency *Defense Logistics Agency (DLA)*.[1] DLA recognized the importance of studying and developing safe disposal methods for HW however, the problem of safe storage of HW generated on a daily basis remained. The ***Conforming Storage Facility (CSF)*** program came into existence as a result of this need. This program constructs storage facilities which allow temporary storage of HW until proper disposal is possible.

BACKGROUND:

In 1981 DLA, thru the Defense Reutilization and Marketing Service (DRMS), embarked on an ambitious program to construct CSF's are most Defense Reutilization and Marketing Office (DRMO) locations worldwide. These facilities are *"conforming"* because they are designated to conform with the Resource Conservation and Recovery Act (RCRA)[2] requirements of cradle to grave management of HW.[3] Each CSF requires a RCRA Part B permit before they may be built and operated. CSF are facilities for the temporary storage[4] of HW until proper disposal is possible. The host installation (owner) of the CSF

(1) Defense Environmental Quality Program Policy Memorandum: DLA is designated the responsible agency within DoD for worldwide disposal of hazardous materials, except for those categories of material specifically designated for DoD component disposal.

(2) RCRA is an Act to provide technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials, and to regulate the management of hazardous sites.

(3) RCRA defines *"hazardous waste"* as solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious character are harmful to the environment.

(4) 40 CFR 270.2: *"Storage"* means the holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed or stored elsewhere.

submits a RCRA Part B permit application or modification which provides all the information requirements necessary in order to determine compliance. The CSF's comply with the Environmental Protection Agency (EPA) permitting regulations outlined in the Code of Federal Regulations Title 40, Part 270 (40CFR 270). These regulations establish the provisions for the Hazardous Waste Permit Program under Subtitle C of the Solid waste Disposal Act (42 USC 3551), as amended by RCRA. These regulations cover basic EPA permitting requirements such as application, standard permit conditions, monitoring, and reporting requirements.[5] The RCRA permit program has separate additional regulations that contain technical requirements 40 CFR 264, 266, and 267. These regulations are used by permit issuing authorities to determine what requirements must be in place in the permit if they are issued. The CSF design incorporates the applicable technical requirements.

CSF Design:

CSF's store almost all hazardous property generated by the military services.[6] The CSF design adopts a modular concept to provide flexibility in adjusting the size to meet site specific storage needs, separation of flammable and nonflammable areas, and an interior spill containment system.[7] Inside the CSF there is a staging area, storage modules, and a covered load/unload area. HW are off-loaded from the delivery carrier and inspected within the staging area. After inspection the HW are placed in the storage modules according to its classification. The spill containment system consists of a leveled floor within the storage modules accessed by a ramp from the higher elevation of the staging area and central corridor. If a leak were to occur it will be confined to the immediate storage area. The storage containers are maintained elevated from the floor by placing them on pallet racks or shelves to facilitate the clean up of spills. The building has a perimeter curbs, entrance ramps, and raised thresholds for all emergency personnel door exits to prevent the escape of interior spills to the outside. CSF's are located within a fenced compound which does not allow for the unknowing or unauthorized entry. Each facility is equipped with spill and fire alarm systems, telephones, fire protection system, emergency showers and eye washes.

CSF Operating Procedures:

DoD and DLA installations are responsible for compliance with environmental and other pertinent laws and regulations. To ensure environmental compliance the DRMO's and generators carry out the

(5) Appendix A is a simplified permit process flowchart.

(6) There are eight categories of hazardous property for which the military services retain disposal responsibility, see Appendix B.

(7) Appendix C is an excerpt of the basis of design of the CSF standard design.

following turn-in procedures:

1. Preplan, schedule, and coordinate hazardous property turn-ins.

2. Process turn-ins of hazardous property as follows:

a. Identification - of hazardous property.

b. Packaging - nonleaking and safe containers.

c. Labeling - to comply with established environmental, safety and transportation laws and regulations.

d. Disposal turn-in document.

Hazardous waste is disposed of by the use of commercial disposal service contracts. Contracts are awarded to contractors which are considered responsive and responsible as outlined in the Federal Acquisition Regulations and who are licensed by EPA. Licensing also includes permits of the contractors' disposal facilities.

CSF Design and Construction Program Management:

DLA delegated the specific design and construction management responsibility if all CSF project to DRMS. DLA continues to oversee the entire CSF program and provides the planning and programming guidance and policies.

CSF Construction Funding:

Due to uncertainties associated with obtaining site approval, design completion, and receipt of the RCRA permit, Congress has approved a single-line-item (block) funding for CSF's construction projects in fiscal year (FY) 87. This approach means that the funds are not earmarked for a specific project but can be utilized where needed. The fiscal year assigned to CSF project represents the funds we propose to use for construction. Projects are funded for construction as they receive the RCRA Part B permit, but not to exceed the appropriated amount. DLA has received $40.3 million between FY 87 and FY 91 for the construction of CSF projects. DLA estimated an additional $75 million is required to complete this program.

DISCUSSION:

Even with the best intensions in mind the construction of CSF's has been a slow process and has suffered several setbacks. This program has (and still is) been under close scrutiny by Congress, DoD IG, EPA and the general public.

Congress has imposed the following restrictions on the CSF program:

1. All CSF construction projects require their RCRA Part B

permit prior to authorizing construction funding.

2. Congress requires a notification of intention to proceed with construction. There is a 21 day waiting period for this notification.

The DoD IG was concerned with the quality of the requirements data initially used to justify the need and size of the CSFs and the exorbitant cost to construct these facilities. The DoD IG recommended DRMS revalidate the need for and size of all CSFs and reevaluate the standard design. The revalidation and redesign efforts were initiated to reduce the construction costs and avoid duplicity and unnecessary construction of storage facilities. The revalidation effort[8] evaluates the need and size of existing CSF projects. This is a three phase effort:

Phase I: DRMS reviews the generation data and determines the sizing and type of facility required. A revalidation package and questionnaire is prepared and submitted to the User and Host for review and comment.

Phase II: The User and Host review the revalidation package and answer the questionnaire.

Phase III: DRMS reviews the User and Host response and determines if the CSF is properly sized and make the final determination on size and facility type.

This process is now a standard operating procedure in evaluating existing requirements and developing and sizing new requirements. The monetary benefits attributable to the revalidation effort are anticipated cost reductions in the amount of $26.5 million.

The redesign effort[9] evaluates the CSF standard design in an effort to reduce project costs and eliminate excessive systems safety criteria. This effort was divided into four phases:

Phase I: Review of proposed changes to the CSF standard design.

Phase II: Cost comparison between the CSF standard design and the revised CSF standard design.

Phase III: Incorporate the approved changes which are economically feasible to the CSF standard design.

The monetary benefits attributable to the redesign effort are anticipated cost reductions in the amount of $16.5 million.

(8) Appendix D is a simplified *revalidation* process flow chart.

(9) Appendix E is a simplified *redesign* process flow chart.

The EPA permit approval process takes 2 - 3 years. In addition, permit review and approval has a low priority with the regulatory agencies.

Another complication is the "NIMBY" syndrome (Not In My Back Yard). The public, has a misconception of the purpose of a CSF. Great alarm is sounded during public hearings, near by neighbors of the CSFs often believe that the CSFs process or hold controlled substances or fear massive contamination of one kind or another. This causes CSF relocation or design changes beyond anything anticipated or required by law.

CONCLUSION:

Conforming storage facilities are an effective and safe solution for the temporary storage of hazardous wastes until they can eliminated properly and permanently. Effective use of CSFs will

require the education of the public.

REFERENCES:

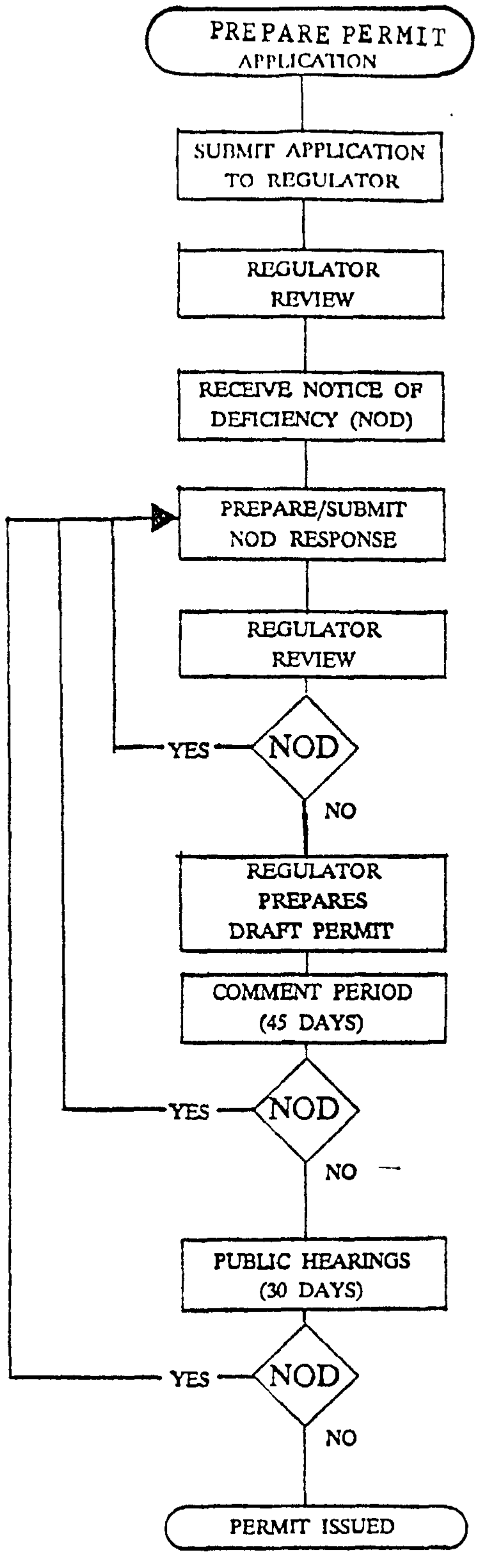
Defense Environmental Quality Program Policy Memorandum (DEQPPM) 80-5 dated 13 May 80.

Resource Conservation and Recovery Act - USC Title 42 Section 6901.

Code of Federal Regulations:
40 CFR 264
40 CFR 267
40 CFR 266
40 CFR 270

Solid Waste Disposal Act - USC Title 42 Section 3551

Defense Reutilization and Marketing Manual - DoD 4160.21-M Mar 1990



PERMIT PROCESS FLOWCHART

APPENDIX A

MATERIALS ASSIGNED TO DOD COMPONENTS FOR DISPOSAL

DoD components shall be responsible for disposal of the following categories of hazardous materials which have not been assigned to DLA:

1. Toxicological, biological, and lethal chemical warfare materials which, by U.S. law, must be destroyed. Disposal of the by-products of such material is the responsibility of the DoD component with the assistance from DLA.

2. Material which cannot be disposed of in its present form due to military regulations, e.g., consecrated religious items and cryptographic equipment.

3. Municipal type garbage, trash, and refuse resulting from residential, institutional, commercial, agricultural, and community activities, which the facility engineer or public works office routinely collect.

4. Contractor generated materials which are the contractor's responsibility for disposal under the terms of the contract.

5. Sludges resulting from municipal type wastewater treatment facilities.

6. Sludges and residues generated as a result of industrial plant processes or operations.

7. Refuse and other discarded materials which result from mining, dredging, construction, and demolition operations.

8. Unique wastes and residues of a non-recurring nature which research and development experimental programs generate.

APPENDIX B

CONFORMING STORAGE FACILITY
BASIS OF DESIGN

1.0 INTRODUCTION

1.1 Purpose: To provide site adapted design drawings and specifications for the Defense Reutilization and Marketing Service (DRMS) Conforming Storage Facilities (CSF).

1.2 Directive Authorization: The standard design was in accordance with the following:

1. Letter, DPDS-L, 2 April 1984, subject: Engineering Services Assistance.

2. Memorandum of Understanding between the U.S. Army Corps of Engineers and the Defense Logistics Agency (DLA), 16 July 1985, subject: Support of the DLA Environmental Protection Program.

1.3 Criteria: Project Development Brochure I, I revised 5 February 1987.

1.4 Project Description: The function of the CSF is to provide for a safe, long term (in excess of 90 days) storage of hazardous waste and excess hazardous materials in accordance with the Resource Conservation and Recovery Act, Toxics Substance Control Act and applicable design criteria.

A modular concept for the facility was adopted to provide for:

a. Expansion as required to meet site specific storage needs.

b. Two-hour fire rated separation of flammable materials.

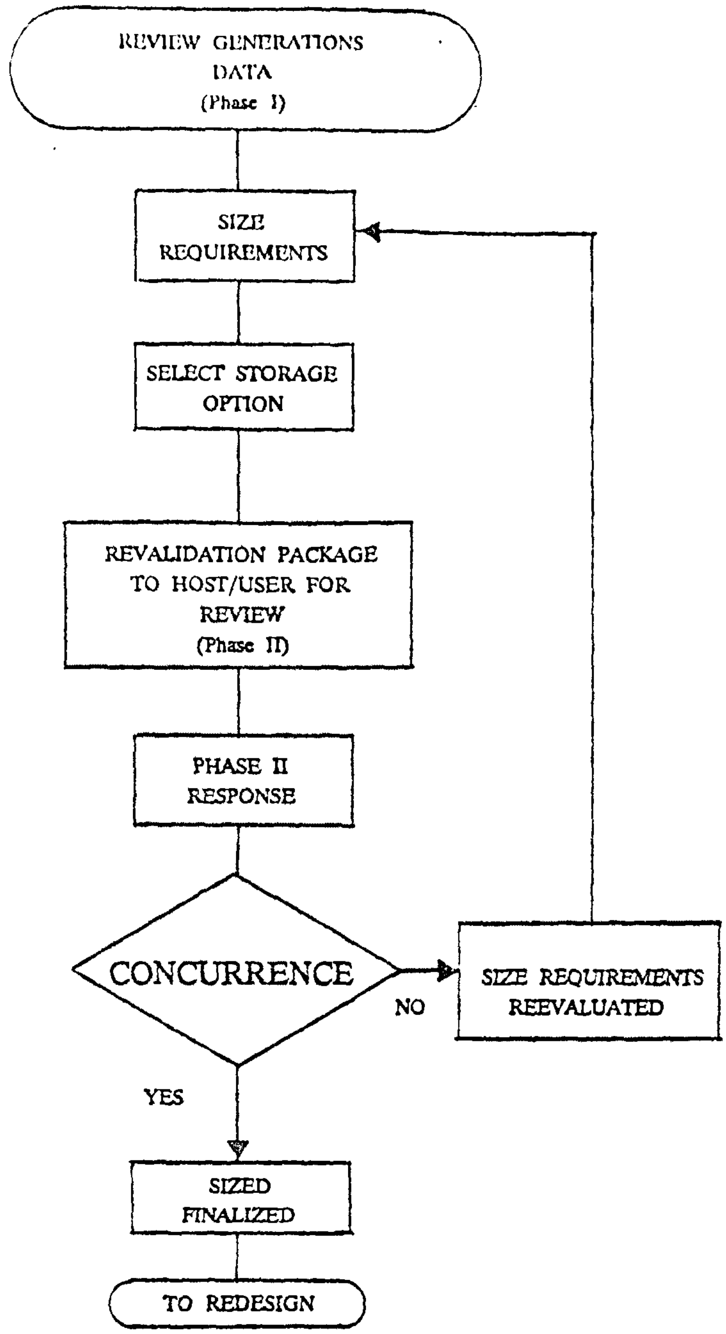
c. Segregated containment of accidental spills and leakages of hazardous materials in accordance with state and federal requirements.

Staging Area: The staging area consists of the material handling area inside the CSF. Hazardous materials are off loaded from the delivery carrier, inspected within the staging area and then placed in the proper storage module or closet. Hazardous material is ot to be stored overnight in the staging area. Containment within the staging area is achieved by perimeter curb and ramp loading down from the exterior cargo door and personnel door. The emergency eyewash/shower and other equipment necessary in handling hazardous materials are stored in this area.

Covered Load/Unload Area: The covered load/unload area is a pre-engineered metal building. It will have an open front to allow vehicles to back up to the exterior overhead door of the facility for delivery and pick up.

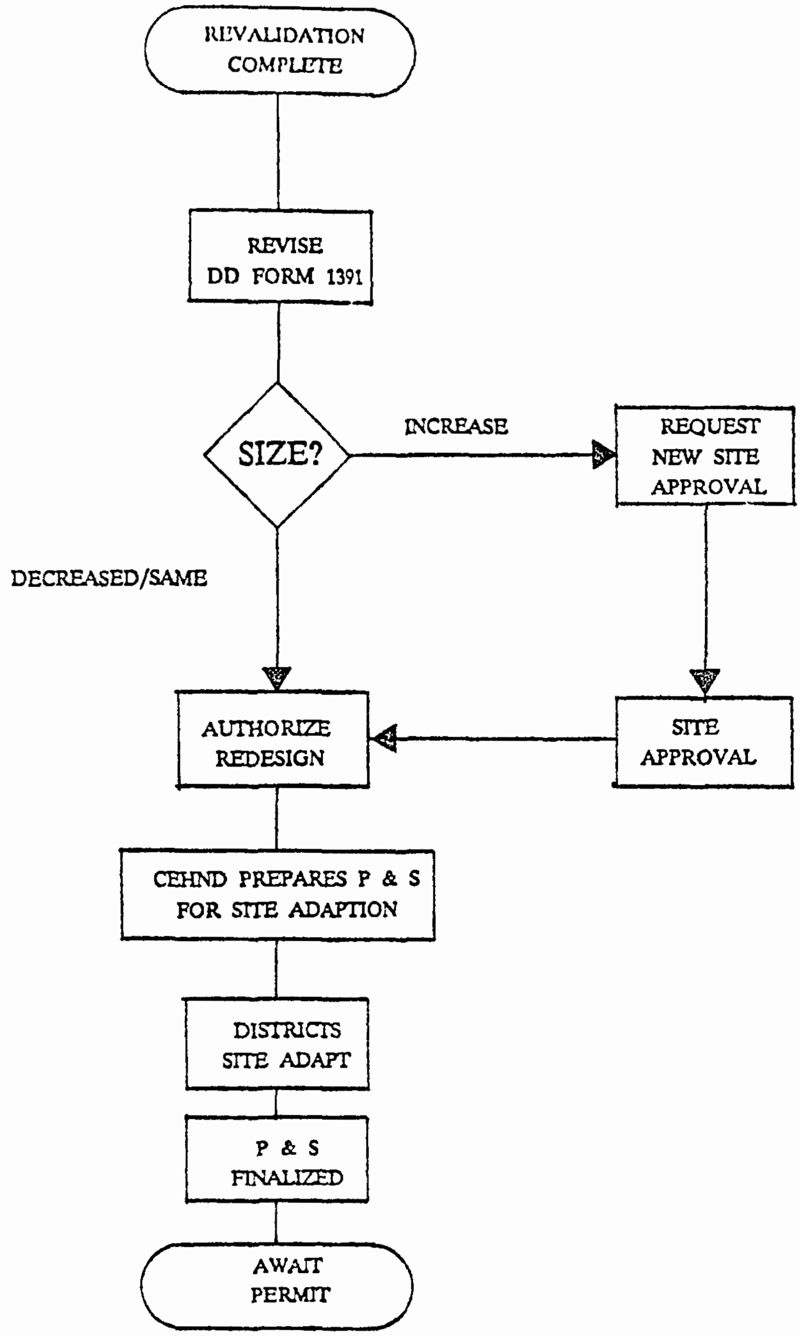
Fire Suppression Systems: The standard design provides for automatic sprinkler system protection of all areas of the building except the electrical room.

APPENDIX C



REVALIDATION FLOWCHART

APPENDIX D



REDESIGN FLOWCHART

APPENDIX E

IX. TREATMENT TECHNOLOGIES

A New Horizontal Wellbore System For Soil and Groundwater Remediation

by

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Introduction

This paper will describe the development of an innovative drilling system for installing horizontal wells for soil and groundwater remediation. The paper will suggest specific applications for the system. Detailed technical specifications and a summary of a four-well field testing program also will be presented.

Background: Potential Applications

Over the last decade, horizontal drilling technology has been developed and applied in the petroleum industry for oil and gas production and in civil engineering projects for utility and pipeline installation. The oil industry has drilled more than 2,000 horizontal wellbores since 1980. This experience has helped service companies develop new drilling technology and has helped oil companies gain a better understanding of how to use horizontal wells for petroleum production.[1]

In 1989, the authors initiated a research project to identify potential applications for horizontal drilling in the environmental industry. This study indicated that many environmental problems can be solved more efficiently with horizontal wells than with traditional vertical wells.

For example, there are numerous "common sense" applications for horizontal drilling, including capture of contaminated groundwater or leachate from beneath lagoons, landfills, buildings, storage tanks, refineries, and chemical plants. (Figure 1). Similarly, horizontal wells may be used to recover spilled product which has pooled under tanks and processing facilities. In these cases it is difficult to place vertical wells to perform sampling or remediation.

In other situations, where vertical wells now are used to extract polluted groundwater for treatment, horizontal wells can offer significant advantages. (Figure 2). By placing a long horizontal section through the contaminant plume, a single horizontal well may replace many vertical wells, while also reducing clean-up time.[2]

Soil gas extraction is another important potential application for horizontal wells. Figure 3 shows how pairs of horizontal wells can be drilled at different depths. The lower well could be used to injecti air, while the upper well could be used to extract the air stream along with volatile organic compounds that have been stripped from the soil.[3]

A similar well configuration could be employed with the lower air in the saturated zone. Air forced into the lower well would bubble through the aquifer, and help remove volatile organic compounds in a sparging effect that acts like an in-situ air stripper.

Other forms of in-situ remediation also may benefit from horizontal drilling technology. For example, horizontal wells might be used to convey microbes and/or nutrients for bioremediation of underground contaminants. (See Figure 4). Likewise, horizontal wells might make it possible to chemically treat heavy metals in place without incurring the expense and hazards of digging up contaminated soils.

Horizontal wells also could be applied at landfills and other areas where a barrier must be installed to keep pollutants from migrating into the groundwater (Figure 5). A series of horizontal wells beneath a landfill or a lagoon, for example, could be used to place a pressure curtain of pumped air or water, or a floor of grout, epoxy or cement to contain the potentially harmful leachate.

Another potential application for horizontal wells is remediation of contamination in fractured bedrock. Petroleum production in vertically fractured reservoirs has been enhanced significantly by the installation of horizontal wells which intersect several fracture planes. Likewise, horizontal wells drilled to cross multiple bedrock fractures at a high angle could improve product or contaminant recovery where vertical wells have proven ineffective.

Horizontal wells also have the potential of providing improved recovery of dense, non-aqueous phase liquids (DNAPLs) from aquifers. DNAPLs tend to sink through porous media until they encounter a low-porosity layer. At this point, the DNAPLs pool along the horizontal boundary. Because horizontal wells can be installed parallel to bedding planes, the cleanup can be accomplished more effectively than with vertical extraction wells.

During our technical review, many potential users requested the capability to take samples of soil gas, soil, and bedrock from beneath landfills , lagoons, tanks, and buildings. In these situations vertical methods are either impossible, inconvenient, or pose a threat to the environment by providing contaminants a pathway into the aquifer. Horizontal wells can be applied to handle the majority of these sampling needs.

Major Design Considerations

Our technical study also determined the industry's preferences for horizontal well construction and the geologic strata to be drilled, as well as requirements for well depth, overall length and borehole directional accuracy. Other considerations such as availability of suitable drilling rigs, site space limitations, and the acceptable operating schedules also were investigated. These efforts resulted in the general systems specifications listed in Table 1.

Major considerations in designing the drilling system included:

--Placement of horizontal sections at depths ranging from 20 ft. to more than 500 ft.

--Installation of horizontal lengths of more than 500 ft.

--Drilling in very unconsolidated formations

--Effective completion of the wells with a minimum 4-inch OD screen

--Operation with a minimum rig crew

--Use of non-contaminating drilling fluids

--Personnel safety and protection of surface environment from contamination

Custom Drilling System

After reviewing the available contract drilling service and hardware, the project team concluded that technology is not available within the water well and monitoring well industry to conduct horizontal drilling operations. In addition, mining and civil engineering technology also does not meet the specific requirements of horizontal drilling in environmental applications. Because of these factors, an entirely new drilling system, including downhole technology and a custom slant drilling rig would have to be designed and built for horizontal drilling in the environmental industry. The project team developed the concept by adapting advanced oilfield technology. The rig and downhole tools were designed to work as a system to drill to horizontal on a 100-ft. radius (Figures 6 and 7).

Important features of the drilling rig that resulted from this effort include:

--Capability to slant the rig mast from vertical to 60 degrees in 15-degree increments. Figure 8 shows how this capability enables the drilling system to place the horizontal section at any depth in this range.

--The rig is hydraulically operated for precise, automated control from a single driller's console. Rated at 2,000 ft. for vertical drilling, the unit has a hoisting capacity of 70,000 lb. and 30,000 lb. of push down capability. This gives it ample power for handling the system's dual drill string which may encounter significant torque and drag during horizontal drilling.

--Pipe handling is accomplished with a hydraulic pipe-handling arm and two hydraulic top drives: one for the casing and one for the drill pipe. In addition, a power tong make-up and break-out unit is incorporated for making/breaking connections. Casing tongs are provided to hold the well casing when required.

--The drilling unit's fluid system -- with mud pumps, fluid tanks, solid control equipment and a grouting machine -- is included in a single trailer. The circulation takes place in a closed loop and requires no earthen mud pits. At the conclusion of the job, drilling fluids and cuttings can be placed in drums for disposal.

--Rig operations requires only a 3-man crew per shift, with a project engineer supervising the job.

--Pipe storage, rig-site office and electrical generator are incorporated in a third trailer. The site office includes a computer and can be used as a laboratory as needed. The generator provides power for lights used for night-time drilling as well as for the solid's control equipment. A small crane, mounted on the trailer, is used to move drill pipe and casing.

--All three trailers that comprise the drilling unit can be transported without special permits on highways in the contiguous 48 states.

Downhole Drilling Equipment

Like the drilling rig, the downhole system also had to be specifically engineered to solve the unique problems associated with horizontal drilling in shallow, unconsolidated formations. The downhole drilling assembly is comprised of a dual drill string; a hydraulic downhole motor; an expanding drill bit; and a toolface indicator/inclination measurement device. (See Figure 9).

The unique drilling assembly was designed to address the problems of drilling horizontally through unconsolidated and heterogeneous formations found near the surface. Such strata make it difficult to maintain hole integrity, even in vertical drilling. In horizontal drilling, there is an even greater risk of hole collapse. This is especially true in environmental drilling applications where most drilling fluid additives are avoided. In such conditions, the horizontal hole could be lost when the assembly is changed or during installation of completion hardware.

A new casing-while-drilling method was developed to solve this problem. An inner string of 2-7/8" drill pipe pushes the high density polyethylene (HDPE) casing/well screen into place. This protects the hole from cave in during drilling and installs the well casing at the same time. (HDPE was chosen because of its unique physical properties including strength, flexibility and resistance to damage from a broad range of chemical contaminants.) The casing is centralized in the hole to permit cementing and effective well completion. Once the well is drilled to total depth, the inner drilling assembly is withdrawn from the hole and the casing is left in place.

Downhole power and the ability to guide the hole are provided by a steerable downhole hydraulic motor. The motor is based on oilfield positive displacement moineau motor concept which converts the hydraulic energy of the pumped drilling fluid into mechanical energy (speed and torque) that rotates the bit. Refinement of this concept resulted in a specially-designed multi-lobed motor that is about one-fifth the length of oilfield tools. Flow rates range from 150 to 300 gpm, generate up to 40 hp at the bit.

Directional drilling is accomplished by placing the motor in an eccentric position in relation to the hole axis by installing stabilizer rings at two points on the motor housing. (Figure 10). These eccentric stabilizers are positionally matched with the concentric stabilizers in the lowest joint of outer casing. By orienting the direction of the bit offset (also called "toolface"), the hole can be steered. The configuration of the drilling assembly is designed to turn the borehole at a constant rate which can be precisely calculated (See Figure 11). The two stabilizers and the bit gauge serve as tangency points that define a constant radius arc along which the assembly will drill. Build rate can be controlled by varying the eccentricity of the inner stabilizers. The system drills a straight course through regularly adjustments of the toolface from side to side. [4]

The downhole drilling system features an expanding bit which drills a hole that is large enough to permit the casing to be installed during drilling. The bit used in the curved section drills a 12-1/4" hole for installation of 10-3/4" OD casing, and the bit used in the horizontal section drills 8-5/8" hole to permit running a 6-5/8" OD casing/well screen, and providing space for gravel packing around the screen. Initial bits used with the system were drag-type bits with hydraulically-spread wings and tungsten carbide cutting surfaces. Other drill bits developed for the system include roller-cone bit technology for drilling harder formations and glacial till.

The toolface indicator system is a mud-pulse telemetry system which measures inclination from vertical and toolface orientation, and transmits the measurements to the surface via pressure pulses in the drilling fluid. These are detected at the surface by a pressure transducer, whose readings are interpreted by a surface control computer. The toolface indicator sensors are located just 12 ft. above the drill bit. The system gives operators the ability to monitor the drill bit's position and wellbore trajectory every 60 seconds. The TFI therefore saves a significant amount of time that would be required for single shot surveys, while eliminating the complication and risk associated with electric wireline steering tool devices commonly used in petroleum drilling and river-crossing applications.

Drilling Process

Before drilling begins, wells are carefully engineered to meet the specific objectives of the project. Site characterization studies, including monitor well data, are reviewed to determine the size and three-dimensional position of the contaminant plume. Groundwater flow and contaminant migration characteristics are analyzed to assure proper well placement. Next, surface location and operational factors are considered. Then, the depth and direction of the horizontal wellbore, screen length, development and pumping methods are determined.

The rig is moved onto location and aligned to drill the horizontal wellbore in the desired direction. The angle of the rig's mast is adjusted to drill the horizontal section at the proper depth.

A 14" hole is augered 5 to 10 ft. into the soil and a 12-3/4" conductor is set and cemented in place to provide a controlled conduit for the drilling fluid.

A straight drilling assembly is lowered in the hole to drill to the required depth so that the 100 ft. radius curve will reach horizontal at the desired vertical depth. Once this depth is reached, the assembly is withdrawn and the curve drilling assembly is picked up and run into the hole.

The curve is drilled in a 12-1/4" hole and cased at the same time with 10-3/4" casing. The assembly is oriented in the proper direction using the toolface indicator and by holding orientation at the surface. The same survey tool is used to track the progress of the assembly. After the 20 ft. lengths of dual drill string are drilled into the hole, both components of the dual drill string are added simultaneously with the mechanized pipe handling system in the rig mast. Once the curve reaches horizontal, the inner assembly is withdrawn leaving the 10-3/4" HDPE in place.

A cementing plug is then run into the hole to seal the end of the casing and to allow the cement grout to be circulated through the drill string to fill the annular space between the casing and the hole wall. Once the desired amount of cement is in place, the drill pipe is withdrawn from the well and the grout is allowed to set. The grout will provide structural support to the casing and will prevent the migration of contaminants from one zone to another along the outside of the casing.

As mentioned above, the system uses an 8-5/8" bit to drill the horizontal section. A 6-5/8" OD HDPE screen is pulled into the lateral wellbore by the drilling assembly as the well is drilled. The system is steerable for course corrections and adjustments to the horizontal section. Steering capability is provided by the hydraulic downhole motor, by stabilizers on the casing, and by survey instrumentation.

Formation evaluation will be accomplished at desired intervals using a core, soil or gas sampler, which are being developed. Drilling is stopped and the inner assembly consisting of the bit, motor, and drill pipe is retrieved from inside the slotted liner. The bit and motor are replaced by the sampling tool and run into the hole. The sampling tool is then drilled into the formation for the required depth and samples are retrieved. Shelby-tube and soil gas sampling devices also are in development.

Drilling continues with the horizontal drilling assembly until the desired displacement is achieved. The inner drilling assembly is then retrieved leaving the 6-inch screen in place.

A combination plug running tool, wash sub is run into the ID of the 6-5/8" casing, and a plug is placed at the bottom of the screen. The screen is then washed by circulating fluid through the inner string and out through the nozzles of the wash sub. These nozzles are aimed radially outward to clean the screen to remove any drill cuttings plugging the screen slots or remaining in the wellbore. Once the hole is clean, the wash sub is removed and the string is run back into the hole for the filter packing procedure, should a filter be required between the screen and the wellbore.

Filter packing is performed using low density materials, placed in a uniform layer around the screen by circulating it through the drill pipe and into the annulus, thus filling the volume between the screen and the wellbore.

Once the filter packing is complete, a submersible pump can be lowered into the well to complete the development. Typical well construction is shown in Figure 12.

An alternative completion method involves using well screen in the horizontal section which has an additional layer of fine mesh well screen to provide san control, in lieu of the gravel packing.

A variety of other completion methods are being investigated. In cases where the horizontal section is placed in bedrock, the well can be drilled without the outer casing string, and the desired production hardware, for example stainless steel or wire-wrapped screens, can then be run.

Field Test Objectives

The prototype horizontal wellbore system underwent its first field trials in the summer and fall of 1990, southeast of Houston, Texas. The objectives of the field test were to:

--Test the functionality of the surface equipment, including rig system components and circulating system.

--Drill a 45 ft. vertical hole to demonstrate casing-while drilling operations; to test the functionality of the expanding drill bit; and to gain experience making hole in the target formation.

--Drill a horizontal hole with approximately 400 ft. of departure from the wellhead. This included drilling from a 45 degree slanted rig position and building the hole's inclination along a 100 ft. radius. This curved section would be drilled in 12-1/4" hole and cased in 10-3/4" HDPE casing, which would then be cemented in place. Then the smaller drilling assembly would be used to drill the horizontal section and install the 6-5/8" liner simultaneously.

--Complete the horizontal section by pumping HDPE gravel packing material into the annulus between the casing and the hole wall.

--Drill a second horizontal well, at a true vertical depth of 30 ft, with a horizontal section exceeding 100 ft.

During test well drilling, project engineers would monitor the performance of system components, noting areas for improvement.

Field Test Preparation

To prepare for the test, a vertical surface hole 12 ft. deep was augered and the 12-3/4" conductor was set and cemented in place. A slanted conductor was installed at 45 degrees, close to the vertical hole and positioned so the rig would not have to be moved to drill through it. Once this slanted conductor was cemented in place, an unstabilized rotary assembly with a roller cone bit was used to drill the cement plug and approximately four feet of the formation.

Vertical Test Well

The vertical hole was drilled with a bottomhole assembly comprised of the 8-5/8" expanding bit, a 4-3/4" drilling motor placed concentrically in the casing; and the 6-5/8" well casing. The hole was drilled to 60 ft. in one hour, at a flow rate of 150 gpm. The casing easily ran into the hole, demonstrating that the motor/expanding bit concept could successfully be applied. Formation was a fine, unconsolidated sand, interspersed with clay stringers. Pockets of gravel also were encountered.

Directional Test Well

The first borehole drilled from a slanted conductor demonstrated the directional drilling capabilities of the downhole system. Drilling parameters and operating procedures were varied to test directional results.

After the vertical hole was drilled, the rig mast was tilted to 45 degrees in preparation for drilling the horizontal hole. Then the 6-3/4" motor assembly was made up and inserted in the plastic casing, and together they were lowered into the conductor.

After orienting toolface to high side (for maximum angle build), drilling circulation was begun at 200 gpm, and the motor stalled almost immediately. It was surmised that this problem was caused by the condition of the conductor pipe, which still contained some cement which had not been drilled out. The assembly was retrieved from the hole along with the casing and a stiff assembly, including a 12-1/4" bit and two stabilizers, was used to drill from the conductor (12 ft. MD) to 16 ft. MD, providing a straight pathway for the curve-drilling assembly to enter the formation.

The curve drilling assembly with casing was run into the hole. The motor was started with a flow rate of 150 gpm, and the assembly was worked up and down until it ran smoothly into the hole. Drilling commenced at 4 ft./minute. Because there was no identifiable torque created by the motor, it is likely that the formation was being jetted away ahead of the bit. The formation was an unconsolidated, very fine sand.

The assembly drilled to 42 ft., but dropped angle at the rate of 0.58 deg./ft. Below 42 ft. MD, the penetration rate increased to 3.5 ft./minute, but the hole continued to drop angle at .27 degrees/ft. over the next joint to 62 ft. MD.

On the next joint, the flow rate was reduced to 150 gpm and penetration rate dropped to 2.5 ft./minute. Over this hole section, the assembly began to build angle at the rate of 0.43 degrees/ft.

Because the reduced flow rate appeared to help regain control over the angle build, it was concluded that the fluid was washing the hole diameter. To reduce these effects, the inner string was tripped out of the hole. The outer-facing bit nozzles were plugged and the forward facing nozzles were replaced with larger nozzles.

The assembly was placed back inside the casing and drilling was commenced with 150 gpm of circulation. ROP of 3-4 ft./minute was achieved. The assembly built angle at 0.36 degrees/ft. (159 ft. radius).

On the next joint (102 to 122 ft. MD), flow rate was increased to 200 gpm, to improve hole cleaning. Penetration rate increased to 4 ft./minute, and build rate increased to 0.54 degrees/ft. (106 ft. radius).

At measured depth of 136 ft (96 ft True Vertical Depth, TVD), the hole had achieved 52.2 degrees of inclination. (See Figure 13).

Changing the bit nozzles had significantly improved the directional performance of the bottomhole assembly. Armed with this knowledge, the project team decided to start a new well with a newly-installed slanted conductor.

Casing from the slanted well would be pulled from the hole for re-use on the second attempt, after installing new HDPE connections using fusion welding techniques.

Horizontal Test Well #1

A second slanted conductor was augered into place approximately 8 ft north of the first one and cemented into place. After moving the rig, the stabilized rotary drilling assembly was used to drill out the cement plug and establish contact with the formation.

The curve-drilling BHA used on this borehole varied from that used on the directional well in that: a) the outside bit nozzles were plugged and two large nozzles were used at the nose of the bit. This would result in no hydraulic horsepower at the bit, and less hole enlargement, and b) an increased bit deflection (caused by greater eccentricity of the stabilizers on the motor body) was used, resulting in an assembly with a theoretical 90-ft turning radius (compared to the 100 ft radius used on the directional well).

As in the slant well, it was difficult to build angle in the soft formation immediately below the conductor. The well dropped angle slightly as the first joint was drilled, then held angle to approximately 63 ft MD. Then the assembly began building angle steadily, reaching 80 degrees of inclination at 150 ft TD (87 ft TVD), the end of the 10-3/4" casing section.

Due to the low flow rate, pulse heights from the TFI tool had been adjusted to improve the strength of the signal. This system performed impeccably while drilling the curved section.

Some hole drag and compressive buckling of the casing were experienced during the drilling of the curve, possibly due to clay and gravel stringers or to some spiraling of the hole. The drilling assembly was pulled easily from the casing string, and the casing did not move.

The curved casing was cemented into place through the drill pipe by setting a cement plug, dropping a dart, then pumping cement until it came out the annulus. Once the cement had cured, a downhole motor-driven milling assembly was used to mill out the plug and retrieve it. A ring left in the hole was retrieved in one try with a specially-built fishing tool.

After a cleanup trip, the project team was ready to drill the horizontal section. The downhole system comprised of an 8-5/8" expandable bit, 4-3/4" drilling motor, TFI measuring device and 2-7/8" drill pipe was run into the hole along with the 6-5/8" HDPE slotted screen.

Once on bottom, the assembly began to drill immediately with no stalling or sticking. At the flow rate of 150 gpm , the system drilled at 2-3 ft/minute. It was found that pump rates have a significant affect on hole inclination. When flow rate was increased to 250 gpm to improve hole cleaning, inclination dropped by 8 degrees while drilling one 20 ft joint.

By orienting the toolface upwards and holding pump rate steady at 150-175 gpm, angle was built to horizontal and maintained until 400 ft of total departure was achieved. (See Figure 14). The project team believed they could drill further, but drilling was stopped because all test objectives had been met. Once total depth was reached, the drilling assembly was withdrawn from the hole.

Completion

One technical objective of the field test was to prove that a slotted casing could be drilled in place using the dual string drilling technique. This operation was successfully performed with slotted casing used from surface to total depth.

Several days after drilling was completed, a gravel packing procedure was attempted on the well. First a plug was set in the bottom of the well, and a wash sub, run on the drill pipe, was used to clean the well slots (which were 0.020" in width) only in the horizontal section. Pumps and seals were configured to reverse-circulate 1/8" HDPE pellets into the annulus between the well screen and the formation. When pumping commenced, it was found that the hole wall had bridged into the casing somewhere in the curve about the horizontal section, preventing gravel packing material from reaching the bottom of the hole. Work continues toward perfecting this gravel packing technique. Future gravel packing operations, for example, probably will circulate through the drill pipe and use slotted screen only in the zones of interest.

The project team also has investigated completion techniques that are less complicated than the gravel-packing method. Specifically, a new completion string, combining a fine mesh stainless screen with the HDPE slotted casing, has been designed since the initial field test. This system should provide adequate sand control in most situations.

Horizontal Wellbore #2

Based on the results of the intial test program some system components were modified and a second horizontal wellbore was planned. This test well would place approximately 130 ft of horizontal screen at a target depth of 30 ft. An additional objective would be to fully test all equipment to be included in the commercial drilling system, some of which were not available when the first horizontal test well was drilled.

Once the system was assembled, the rig mast was slanted to 60° from vertical and the 9 ft surface hole was augered with a special slant augering assembly. The surface casing was then cemented in place.

The hole beneath the surface pipe was drilled out approximately 3 ft using the augering assembly, then the curve drilling assembly, with casing, was run into the hole. After some initial difficulty in beginning the kickoff (which was corrected by adjusting drilling parameters), the curve was drilled according to plan, reaching horizontal at a depth of 30 ft below the surface. This operation took 4 -1/2 hours.

The casing was cemented by pumping cement through the drill pipe then waiting for the cement to harden before retrieving the casing plug from the hole. Once the cement was cured, an expanding bit with a tri-cone pilot bit was used to mill out cement remaining at the casing shoe.

Then the horizontal section was drilled, using the same assembly utilized on the previous horizontal well. A horizontal section of 129 ft was drilled in three hours, for an average penetration rate of 43 ft/hr. Slotted casing was installed as the hole was drilled.

This second horizontal well also demonstrated the effectiveness of the hydraulic pipe handling system, which manipulated the dual drill string safely and efficiently.

Figure 15 is a plot of this second horizontal well.

Conclusion

In conclusion, a new horizontal drilling and sampling system has been designed and built to meet the special requirements of the environmental industry. A prototype system has been successfully field tested, refined and introduced for commercial use. We believe there will be many applications for the new system as the environmental industry begins to remediate contaminated soil and groundwater.

In the future, other technologies are likely to be added to the horizontal wellbore system. These innovations could include methods for obtaining undisturbed formation samples and containerized gas samples beneath landfills and buildings; geophysical logging services adapted for horizontal data acquisition; and completion technology to isolate zones along the horizontal well for selective sampling and completion.

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TABLE 1: SYSTEM SPECIFICATIONS

Depth of Horizontal Section:	18 ft to 500$^+$ft below surface
Horizontal Length:	More than 500 ft
Screen Size in the Horizontal Section:	6-inch nominal (6-5/8" OD)
Casing Size in the Curve Section:	10-inch nominal (10-3/4" OD)
Casing and Screen Material:	High density polyethylene pipe
Horizontal Placement Accuracy:	True vertical depth: +/- 2 degrees
	Azimuth: +/- 2 degrees
Pumping Specifications:	Submersible pump ahead of screen
Seal Specifications:	Sand pack or other filter

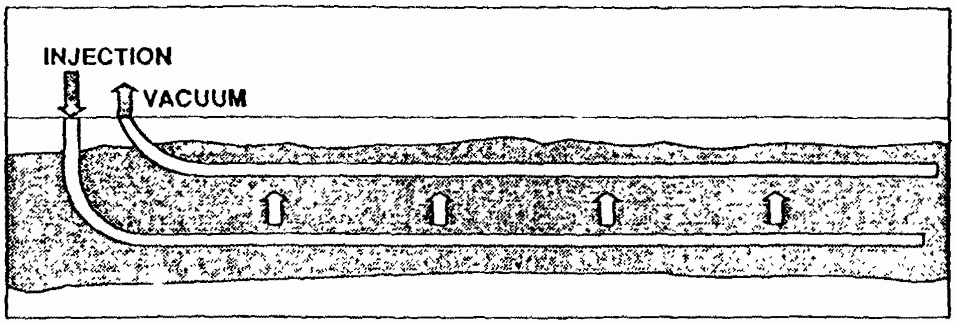


Figure 3: Soil Gas Extraction. VOC's are stripped from soil using parallel horizontal wells.

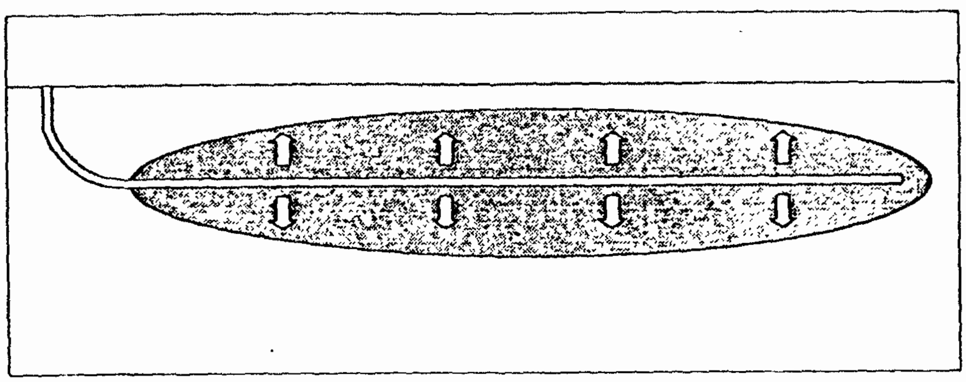


Figure 4: In-Situ Remediation. Horizontal well efficiently conveys bioremediation materials to plume.

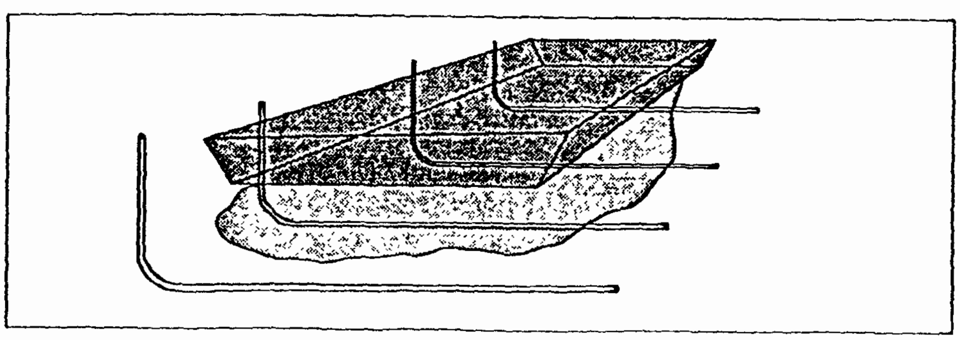


Figure 5: Barrier to Transport of Contaminants. Horizontal wells beneath a landfill protect groundwater.

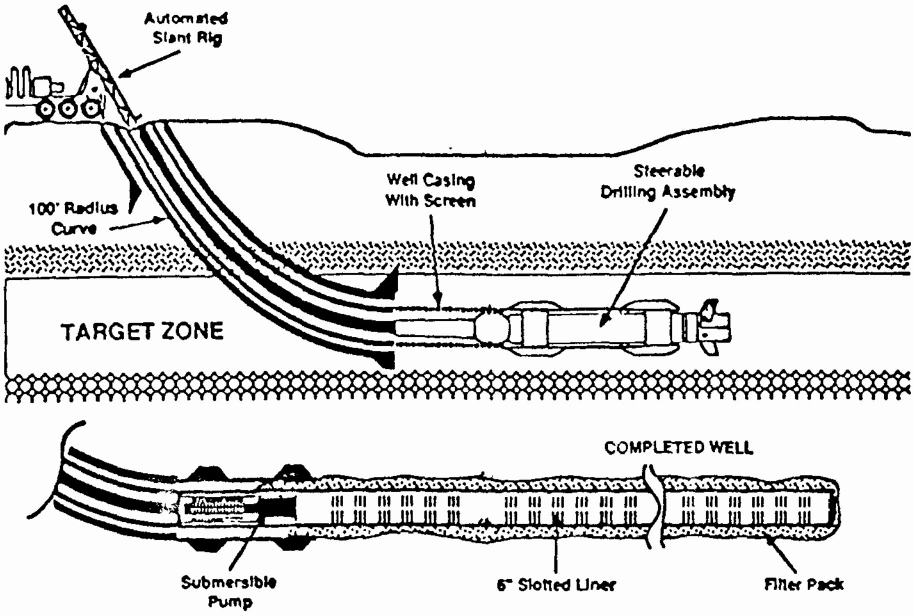


Figure 6: Horizontal Wellbore System

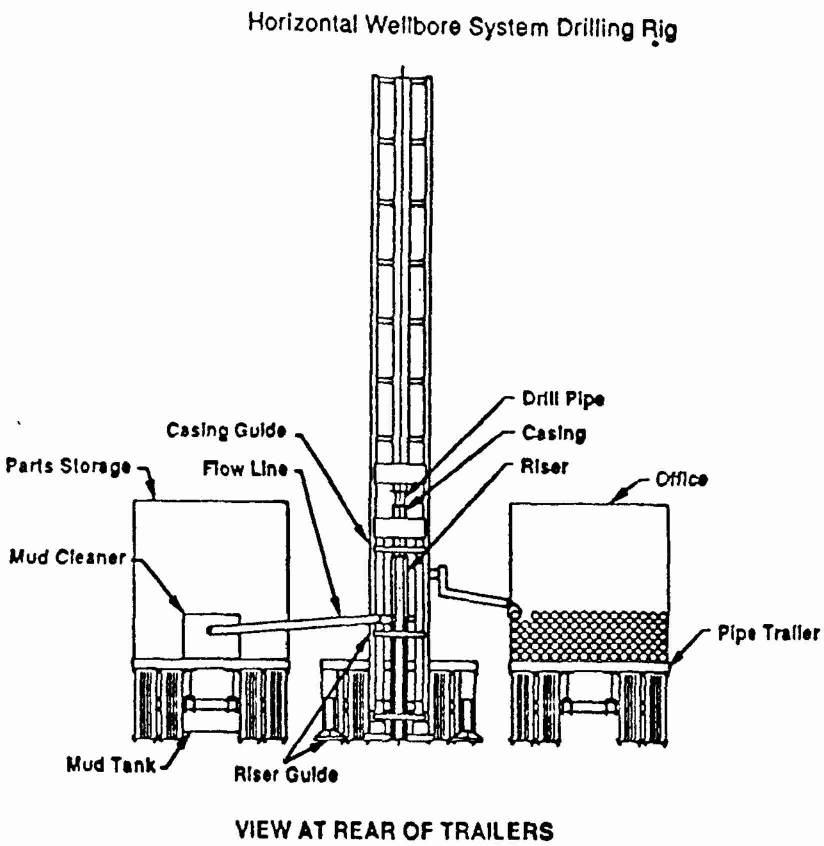


Figure 7: Surface Equipment Package

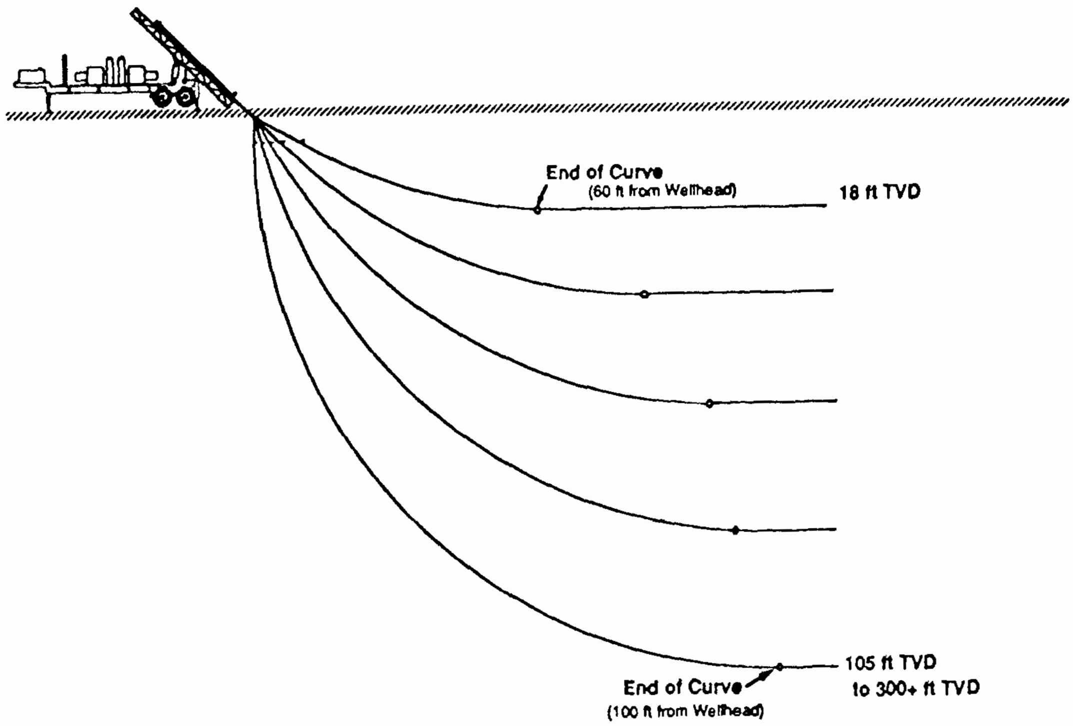


Figure 8: Depth Capability. Unit can place horizontal sections at any specified depth.

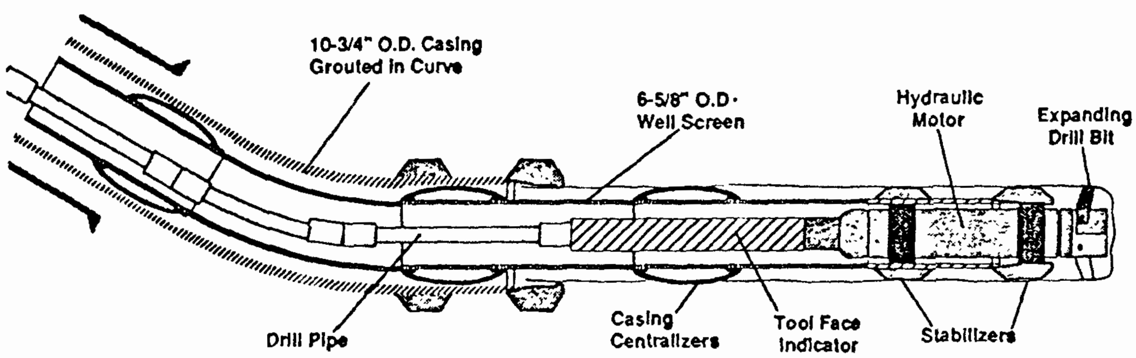


Figure 9: Downhole equipment permits simultaenous drilling and casing operations.

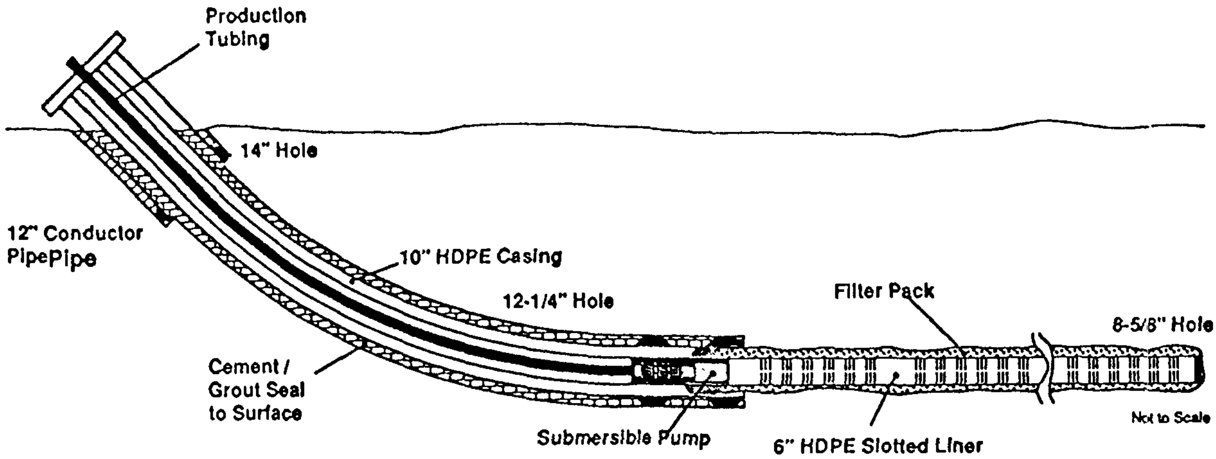


Figure 10: Typical horizontal well construction

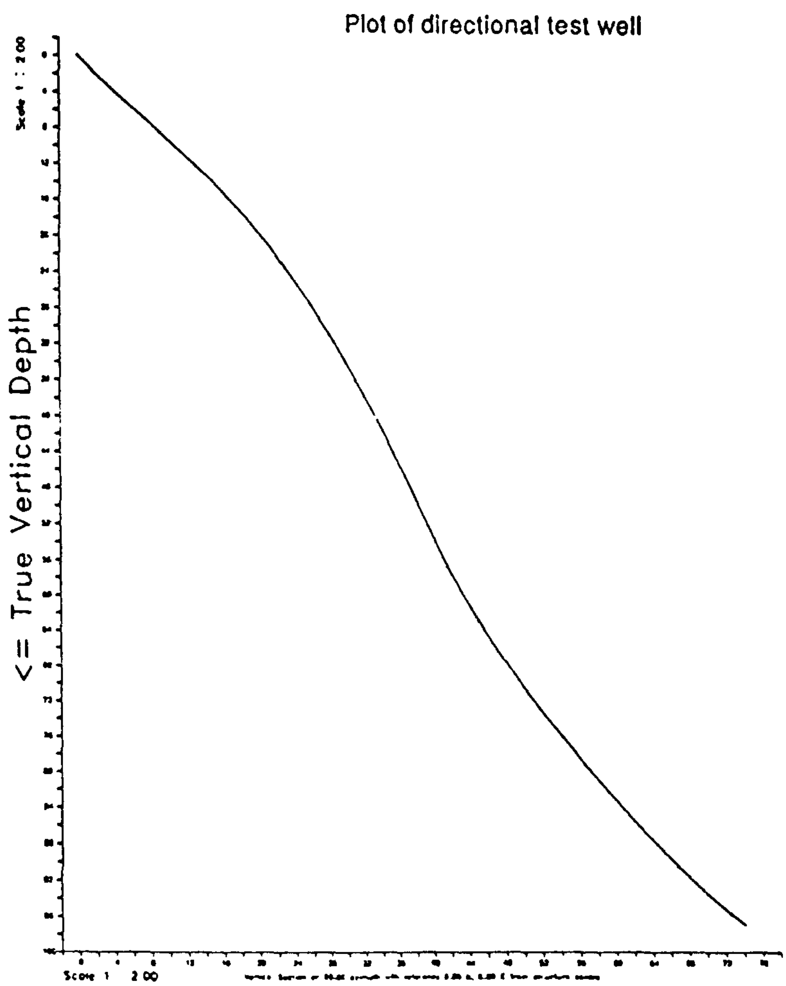


Figure 11: Directional test well.

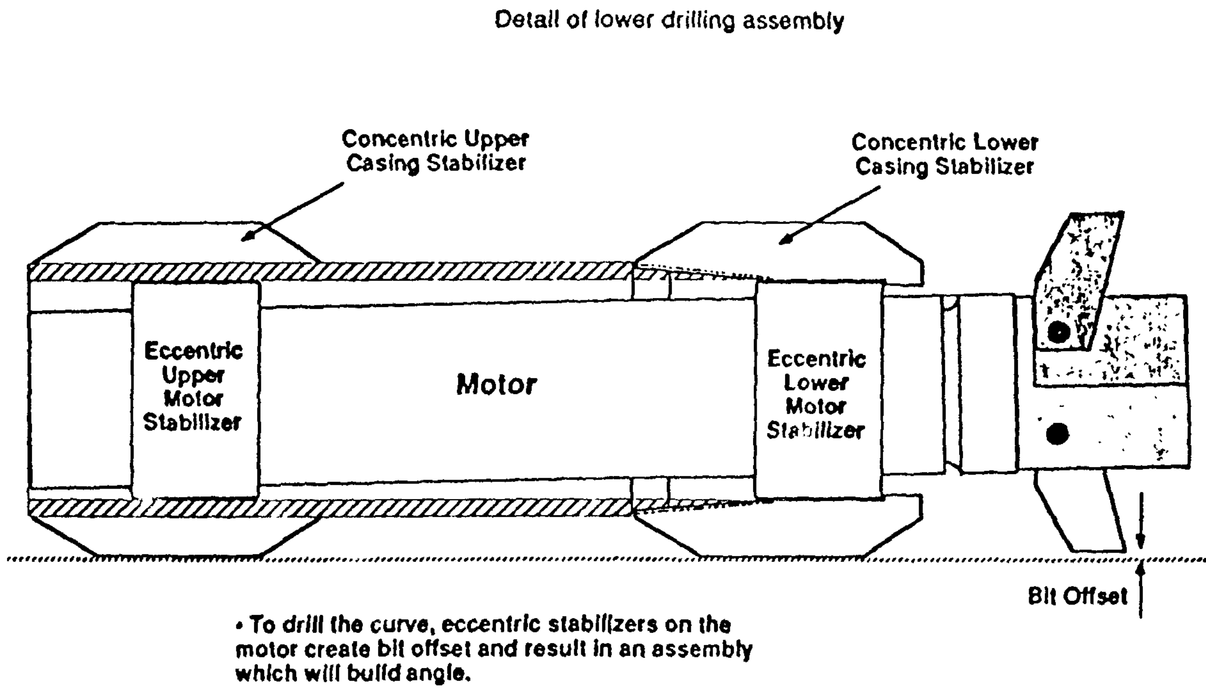
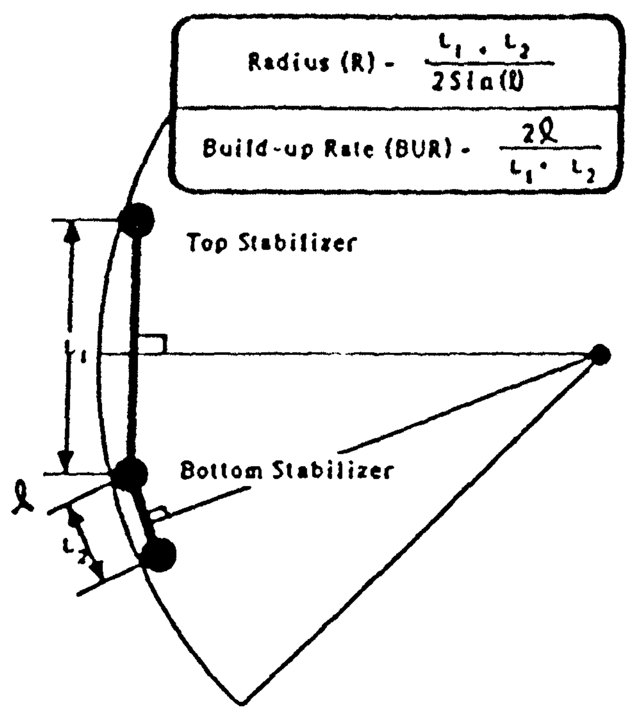


Figure 12: Curve Drilling Process



Calculation of Buildup Rates

Figure 13: Calculation of Build-up Rates

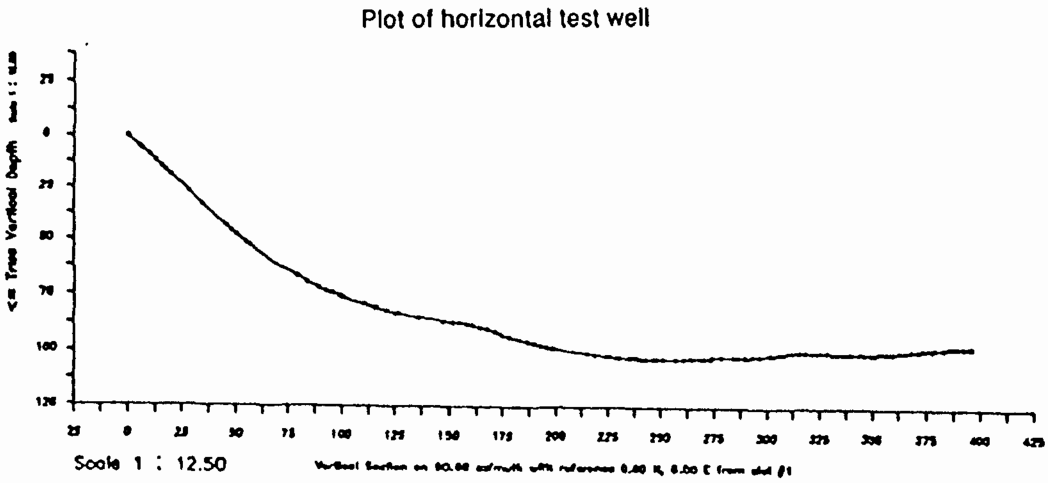


Figure 14: Vertical section of first horizontal test well,at 100 ft TVD.

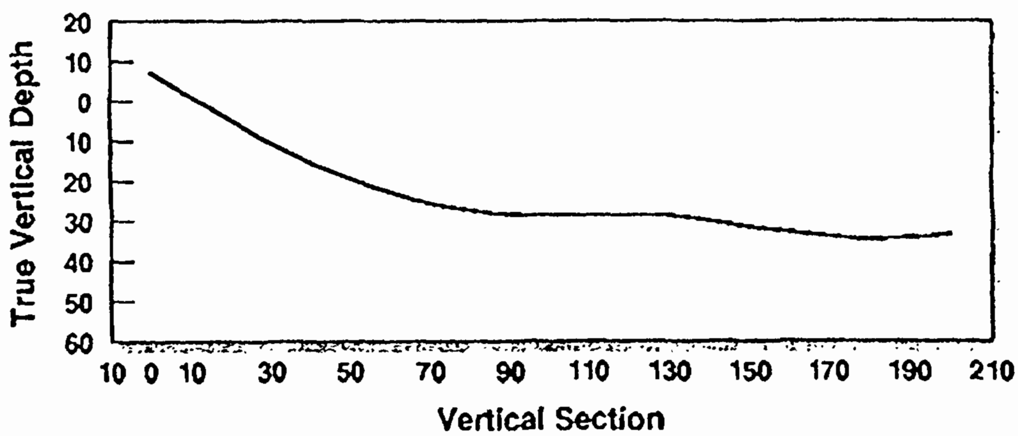


Figure 15: Vertical section of second horizontal test well, at 30 ft TVD.

Soil-Bentonite Backfill Mix Design/Compatibility Testing: A Case History

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INTRODUCTION

Soil-bentonite slurry trenches have been used in the U.S. as subsurface groundwater barriers since the 1940's (D'Appolonia, 1980). Construction consists of excavating the trench (typically 2-5 feet wide, keyed 3-5 feet into an impermeable formation such as rock or clay) while pumping in bentonite slurry to support the side walls. As slurry leaks into voids in the trench wall soils, clay particles build up in layers on the trench walls, forming a thin low permeability filter cake. The trench is then backfilled with a mixture of soil and bentonite, called the soil-bentonite backfill material. Backfilling with material of the proper consistency (unit weight about 15 pounds per cubic foot (pcf) greater than the slurry unit weight, with a concrete slump of 2 to 6 inches) does not substantially destroy the filter cake (D'Appolonia, 1980; Millet and Perez, 1981). Permeability of the completed trench is a function of both the filter cake and the soil-bentonite backfill material. The term "bentonite" is defined in the U.S. Environmental Protection Agency (USEPA) slurry trench design guidance document as a soil composed of at least 90 percent montmorillonite clay (JRB Associates, 1984). Many geotechnical textbooks, such as Lambe and Whitman (1969), define bentonite as montmorillonite clay containing primarily sodium as the exchangeable ions in its crystal structure. This paper utilizes the USEPA guidance document definition of bentonite.

The presence of chemical contaminants in soil and/or groundwater may significantly alter the rate of water movement through a soil-bentonite slurry trench (D'Appolonia, 1980; JRB Associates, 1984; Zappi et al., 1989b; Ayres et al., 1983). For example, calcium in soil or groundwater will displace some of the sodium ions in bentonite. This results in reduced swelling and increased permeability, not desirable for a groundwater barrier. While the effects of other individual chemicals have been studied and documented, the effect of multiple contaminants, which frequently exist at hazardous and toxic waste (HTW) sites, is largely unknown.

This paper presents a general overview of the Corps of Engineers Missouri River Division Laboratory (MRDL) mix design/compatibility testing methodology, while discussing in detail the testing program undertaken for the Lime Settling Basins (LSB) site at the Rocky Mountain Arsenal (RMA), Commerce City, Colorado. Objectives of the LSB testing program are to determine the optimum soil-bentonite backfill material mix design (soil and percent bentonite) necessary to achieve an in-place slurry trench permeability of 1 x 10-7 centimeters per second (cm/sec) or less, and to determine whether contaminants present in soil and groundwater at the LSB site will cause changes in soil-bentonite backfill permeability over time.

BACKGROUND

Site History. During the 1940's and 1950's, wastewater from production of Army agents was routinely treated prior to discharge to unlined evaporation ponds. This treatment involved the addition of lime to the wastewater to precipitate metals, principally mercury and arsenic. Wastewater produced in the South Plants was channeled into the LSB prior to gravity drainage to Basin A, an evaporation pond just to the north. The precipitation process produced a lime sludge that contained elevated levels of heavy metals, arsenic and mercury. Subsequent discharge of wastewater from production of pesticides resulted in the addition of pesticides to the LSB sludge. The LSB were removed from service in 1957. Studies have been conducted to characterize the nature and extent of contamination in the soil, sludge, and ground water in the vicinity of the LSB. The studies revealed the soil, sludge, and ground water contain elevated levels of organochlorine pesticides, organosulfer compounds, arsenic, mercury, and Inductively Coupled Plasma (ICP) metals (cadmium, chromium, copper, lead, and zinc).

Site Geology. Bedrock beneath the LSB area is the Cretaceous-Tertiary Denver Formation. The Denver Formation in the vicinity of the LSB consists of claystone and sandstone. The claystone is generally soft to moderately hard, brown to gray, and is occasionally silty. A thick, fine-grained sandstone lense is present in the northern section of the LSB area. The Denver Formation bedrock lies at depths of 13.0 to 33.0 feet below the surface in the LSB area. The local slope of the bedrock subcrop is about two degrees to the north-northeast. The dip of the Denver Formation has not been determined, but it is probably the same as the regional dip, about one degree or less to the southeast.

The overburden in the LSB area consists of Recent fill and Quaternary eluvial and alluvial deposits. The thickness ranges between 13.5 and 27.5 feet. Recent fill is present almost throughout the entire area and consists mostly of sludge removed from the LSB. The fill thickness ranges from 3 to 10 feet. The eluvial and alluvial materials consist mostly of poorly graded, silty, fine-grained sand with moderate amounts of sandy, silty clay and minor amounts of clayey sand, sandy clay, silty clay, and lean clay.

The contaminated aquifer is within the overburden and the material is essentially the same as that described above. The majority of groundwater movement occurs in unconsolidated, fine-grained sand and/or silty, fine-grained sand and clayey, fine-grained sand. The thickness of the aquifer ranges from 9.5 to 21.0 feet. The aquifer is unconfined and overlies the top of bedrock.

Contamination. Soil contamination in the LSB consists of raw materials, such as mustard agent production-related compounds; manufacturing by-products, such as volatile aromatic solvents; and degradation products from the synthesis of pesticides. Organochlorine pesticides that have been detected are dieldrin, aldrin, endrin and isodrin. Other contaminants detected were organosulphur compounds of chlorophenylmethyl sulfide, chlorophenylmethyl sulfoxide, and chlorophenylmethyl sulfone. DDT was also detected in an isolated area. Volatile organic compounds consist of chloroform, benzene, and chlorobenzene. The most prevalent metals are arsenic and mercury. Elevated concentrations of copper, lead, zinc, cadmium, and chromium were also detected.

Groundwater contaminants in the unconfined aquifer include volatile organic compounds, aromatics, metals, and organochlorine pesticides.

Arsenic, mercury, chromium, and copper are metals that have been detected in the ground water.

Decision Document Summary. The Interim Response Action for the LSB consists of moving the lime sludges currently located around the basins into the basins, a 360-degree subsurface groundwater barrier (slurry trench) around the basins to prevent migration of contaminated groundwater, a groundwater extraction system inside the isolation cell to maintain an inward hydraulic gradient, and a soil and vegetative cover over the cell to reduce infiltration of rainwater (Woodward-Clyde Consultants, 1990).

Pre-Design Field Investigations. Field investigations were conducted during June and July 1990. Investigations consisted of: electro-magnetic surveys for locating buried metallic objects (none were found); exploratory drilling and soil sampling in the LSB area; slug tests for hydraulic conductivity analysis; groundwater and tap water sampling; and bulk soil sampling of borrow areas. All investigations except the borrow investigations were conducted in level B personal protective equipment.

A total of 30 borings were drilled for this investigation. Nineteen borings were drilled along the alignment of the proposed slurry cutoff trench to identify the subsurface materials and to determine the consistency, density, and moisture content of the overburden; and also to determine the depth and characteristics of the claystone bedrock for design of the base of the proposed slurry trench. Eight borings were drilled outside the slurry trench area to further define the extent of the lime sludge material. Three wells were installed inside the slurry trench area for slug tests to determine the hydraulic conductivity of the overburden aquifer. Split-spoon samples were taken from all borings for geotechnical analyses, compatibility testing, and chemical analyses. All drill holes were backfilled with cement grout after completion.

Development of Laboratory Testing Methodology. In developing the MRDL's test equipment and procedures, various references were researched including work done by David J. D'Appolonia (1980), the U.S. Army Corps of Engineers Waterways Experiment Station (WES) (Zappi et al., 1989a, 1989b), the USEPA (JRB Associates, 1984), Dr. David Daniel (Daniel et al., 1984), and Goldberg-Zoino & Associates (GZA) (Ayres et al., 1983). The MRDL procedures were patterned after the work done in 1981 by GZA during design and construction of the Gilson Road Superfund Site cutoff wall. Procedural and equipment modifications were made at the MRDL based on early trial runs to address site specific conditions and speed up the overall test process. However, the basic concept of optimizing the mix design prior to long term compatibility testing was adhered to.

In reviewing the literature, there appeared to be no consensus on which type of permeameter, fixed wall or flexible wall, produced more realistic results. Each type of permeameter has its advantages and disadvantages and both can yield grossly misleading results under certain circumstances. Based on ease of operation and relatively expedient and reproducable results, fixed wall permeameters were selected for the mix design optimization phase. The flexible wall permeameter was selected for the long term compatibility phase because of its ability to accurately model various anticipated field stress conditions.

The equipment was designed and built at the MRDL with input from USACE engineers, technicians, and shop personnel. To prevent degradation of test equipment, anodized aluminum base and top caps, brass stones, stainless steel valves, teflon tubing, and glass burrettes were used. This allowed for multiple use of most of the equipment components after decontamination of the system prior to testing.

Backfill Soil Selection

To obtain a low permeability (typically 1 x 10-7 cm/sec or less is specified for completed soil-bentonite slurry trenches), soil with an appreciable amount of fines is necessary for the soil-bentonite backfill.

The USEPA recommends the following gradation criteria for backfill soils: maximum particle size of 5 inches, 65-100 percent passing 3/8 inch sieve, 35-85 percent passing the U.S. standard sieve #20, and 20-50 percent passing the U.S. standard #200 sieve. Plastic fines are preferred but not necessary (JRB Associates, 1984).

Soils excavated from the trench may be utilized for the backfill soil. This practice saves the time and money of locating, purchasing, developing, and hauling borrow soil to the site as well as disposal of the excavated soil. However, if the in situ soil is not suitable (for example coarse gravel) or is contaminated (as is often the case at HTW sites) imported borrow soil may be the only viable option.

Due to contamination of the in situ soil, the work plan called for testing of both in situ soil and a borrow source. Originally, a clay borrow area used in previous remediation projects at RMA was suggested. However, the clay borrow area is located in a bald eagle habitat which is closed to traffic from November 1 to April 1 and the amount of clay soil remaining is limited. Therefore stockpiles of soil excavated from the Lower Derby Dam spillway construction at the Arsenal were selected as the primary borrow soil. Soil from the clay borrow area would be used as a source of fines only, if necessary, to blend with either in situ or random fill borrow soil to achieve a low permeability.

Soil samples from several of the borings along the trench centerline were to be blended to form one composite in situ sample for mix design optimization and compatibility testing. During blending, however, the reddish brown soil developed a yellow staining over approximately 30 percent of the surface over one night. At that point Corps personnel decided not to consider the in situ soil for use in the trench or further testing because of potential field handling problems.

Figure 1 shows the grain size distribution and Atterberg limits for the random fill and clay borrow soils. The random fill soil contains more fines than EPA recommends. This is not considered to be a problem since a finer soil will make a low permeability easier to obtain.

Bentonite Selection

General. To obtain a general idea of the effect of site contaminants on bentonite, samples of the following four bentonites were obtained for this study:

S-5 Natural, Black Hills Bentonite, Rapid City, SD
BH-Natural, H&H Bentonite, Grand Junction, CO
Bara-kade 90 SP, NL Baroid, Houston, TX
Bara-kade 90, NL Baroid, Houston, TX (treated)

The Corps of Engineers' slurry trench guide specification requires use of premium-grade, ultrafine, natural sodium cation-based montmorillonite powders (Wyoming-type bentonite) that conforms to American Petroleum Institute (API) Specification 13A, Sections 5, 12 and 13 (API, 1990).

However, most commercially available bentonite is treated and conforms to Section 4, not 5 of API Specification 13A. Bara-kade 90 is the only bentonite studied which is treated and therefore conforms to Section 4 of API Specification 13A. Bara-kade 90 is the same bentonite as Bara-kade 90 SP, but one-quarter pound of a polymer is added per ton of bentonite to produce Bara-kade 90 (Anderson, 1991).

Free Swell Tests (McCandless and Bodocsi, 1987). "Free swell" is the increase in volume of a soil from a loose dry powder form when it is poured into water, expressed as a percentage of the original (dry) volume. Two grams (2.2 cubic centimeters) of bentonite is slowly poured into 100 milliliters (ml) of water, and the volume of settled solids is recorded after 2 and 24 hours. For this study, two tests were performed for each bentonite; one using tap water from the Arsenal and one using contaminated groundwater from the site. Table 1 shows results of the free swell tests. Percent

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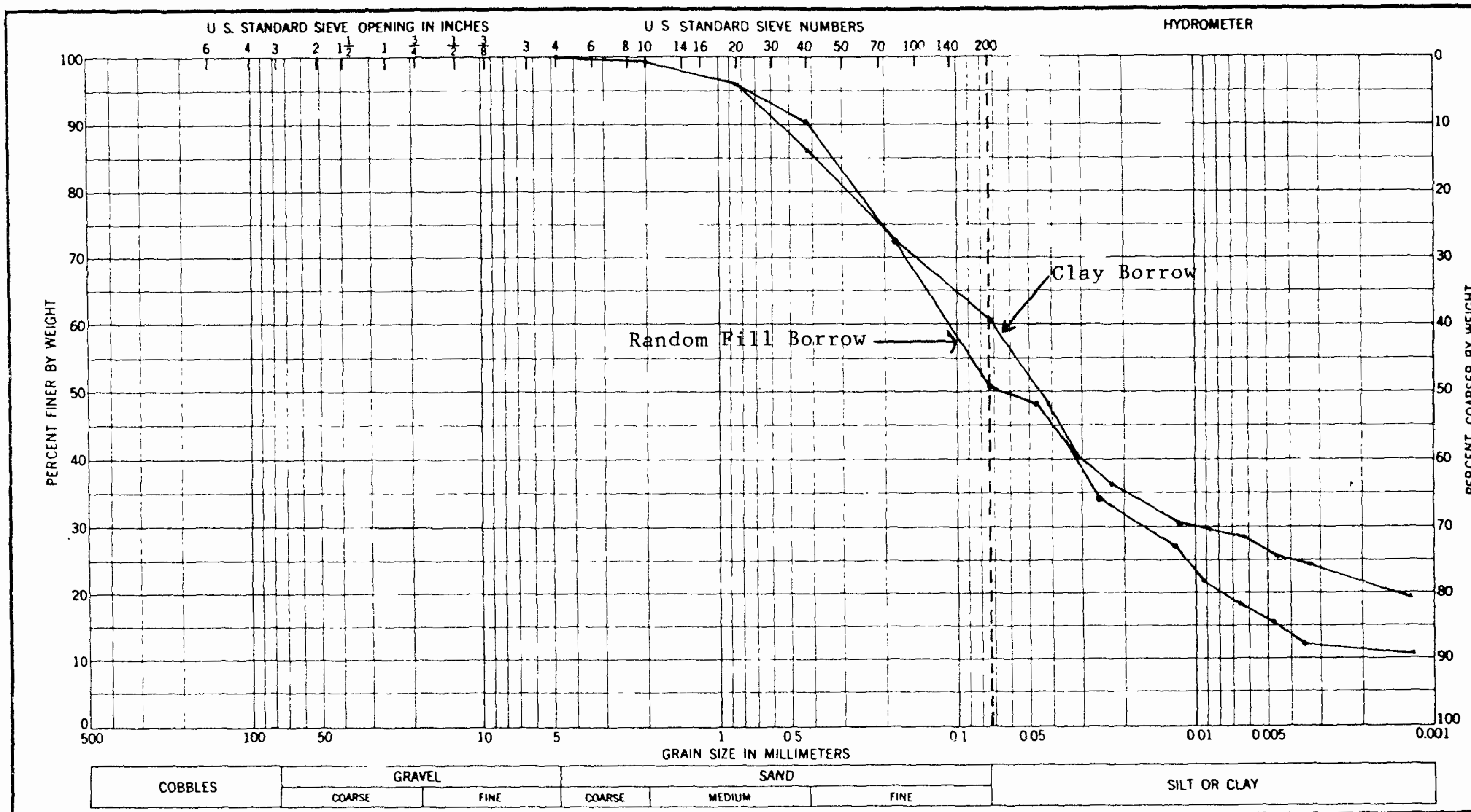

Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
Random Fill Borrow		CL Sandy clay	17.6	42	22	20
Clay Borrow		CL Sandy Clay	35.0	35	13	22

Project: Lime Settling Basins Slurry Wall
Area: Rocky Mountain Arsenal
Boring No: Borrow Areas
Date: 30 November 1990

Figure 1. GRADATION CURVES

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24-hour swell is the percentage of the "final" (24 hour) swell achieved after 2 hours (tap water samples). Percent tap water swell is the percentage, at the given time, of the tap water sample swell achieved by the groundwater sample. Contaminants decreased the percent swell of all the bentonites, with Bara-kade 90 exhibiting the greatest decrease (about 50 percent). S-5 takes longer than the others to achieve "final" swell with both tap water and groundwater. The free swell behavior of BH-Natural and Bara-kade 90 SP is very similar, with Bara-kade 90 SP showing a slightly higher percent 24-hour swell after 2 hours and percent tap water swell with groundwater.

Filter Cake Compatibility Tests (D'Appolonia, 1980). As stated previously, the filter cake is an important component of a completed slurry trench. Filter cake permeabilities may be as low as 10-9 cm/sec (Xanthakos, 1979). For this reason filter cake compatibility tests, in addition to free swell tests, were used to evaluate bentonite performance. Slurry from each bentonite (prepared using RMA tap water) was placed in fixed wall permeameters. Slurry was forced through filter paper overlying a porous stone at the bottom of the chamber by a chamber pressure of 10 pounds per square inch (psi) for 24 hours. During this time a filter cake of approximately one-half inch formed on the filter paper. The bentonite slurry was removed with a vacuum bulb and immediately replaced with either RMA tap water or contaminated groundwater (one of each for each bentonite, for a total of eight tests). Water was forced through the filter cakes by a chamber pressure of 2-3 psi. The volume of effluent was measured two or three times a day for two to five days and the permeability was calculated.

The USEPA recommends the following properties for bentonite slurries: viscosity (measured with a Marsh funnel) greater than 40 seconds, unit weight around 65 pcf, pH between 7 and 10, and a bentonite content of 4 to 8 percent (JRB Associates, 1984). Millet and Perez (1981) recommend; viscosity greater than 40 seconds, unit weight around 65 pcf, and pH between 6.5 and 10. D'Appolonia (1980) recommends; viscosity greater than 40 seconds, and bentonite content of 5 to 7 percent. In this filter cake study all bentonite slurries were prepared with 6 percent bentonite by weight.

Marsh funnel viscosity, unit weight, and pH were measured for each slurry and are listed in Table 2. Properties of all slurries lie within the recommended ranges.

Figures 2 and 3 show results of filter cake compatibility tests. Some filter cakes formed cracks upon initiation of the flow phase of testing. After test completion, cutting the filter cakes into quarters revealed the cracks extended most or all the way through the filter cakes. However, presence of cracks did not appear to affect the permeability of the filter cakes. All bentonites except Bara-kade 90 SP exhibit a slight downward trend in permeability over time. Bara-kade 90 shows the least variation in permeability between tap water and groundwater. The reason for the drop in permeability of Black Hills S-5 (tap water) between 1390 and 1770 minutes is not known.

Selection. The original work plan called for selecting the bentonite which showed the least variation in filter cake permeability and percent swell between tap water and groundwater for use during further testing.

However, the bentonite which exhibited the least variation in filter cake permeability (Bara-kade 90) exhibited the most variation in percent swell. The designers eliminated Black Hills S-5 due to the drop in filter cake permeability in tap water between 1390 and 1770 minutes and Bara-kade 90 due to the large difference in percent swell between tap water and groundwater. Bara-kade 90SP was chosen because it shows slightly less variation in both percent swell and filter cake permeability between tap water and groundwater than BH-Natural and it shows a slight increasing trend in filter cake permeability over time. A 6 percent Bara-kade 90SP bentonite (by weight) slurry was used in all subsequent testing.

Table 1.

Free Swell Test Results

Bentonite	Time	Tap Water % Swell	% 24-Hour Swell	Ground Water % Swell	% Tap Water Swell
Black Hills	2 hr.	530	73	445	83
S-5	24 hr.	720		490	68
H&H Bentonite	2 hr.	785	91	560	71
BH-Natural	24 hr.	855		560	65
NL Baroid	2 hr.	785	83	400	51
Bara-Kade 90	24 hr.	945		400	42
NL Baroid	2 hr.	765	94	560	73
Bara-Kade 90SP	24 hr.	810		560	69

Table 2.

Bentonite Slurry Properties
Filter Cake Compatibility Tests

Bentonite	Marsh Funnel Viscosity (seconds)	Density (pcf)	pH
Black Hills	1. 48	64.9	8.7
S-5	2. 48		
	3. 48		
H&H Bentonite	1. 52	65.0	8.8
BH-Natural	2. 51		
	3. 52		
NL Baroid	1. 61	65.1	9.5
Bara-Kade 90	2. 62		
	3. 64		
	4. 64		
NL Baroid	1. 44	65.1	9.1
Bara-Kade 90SP	2. 44		
	3. 44		

Figure 2
Filter Cake Compatibility Test Results

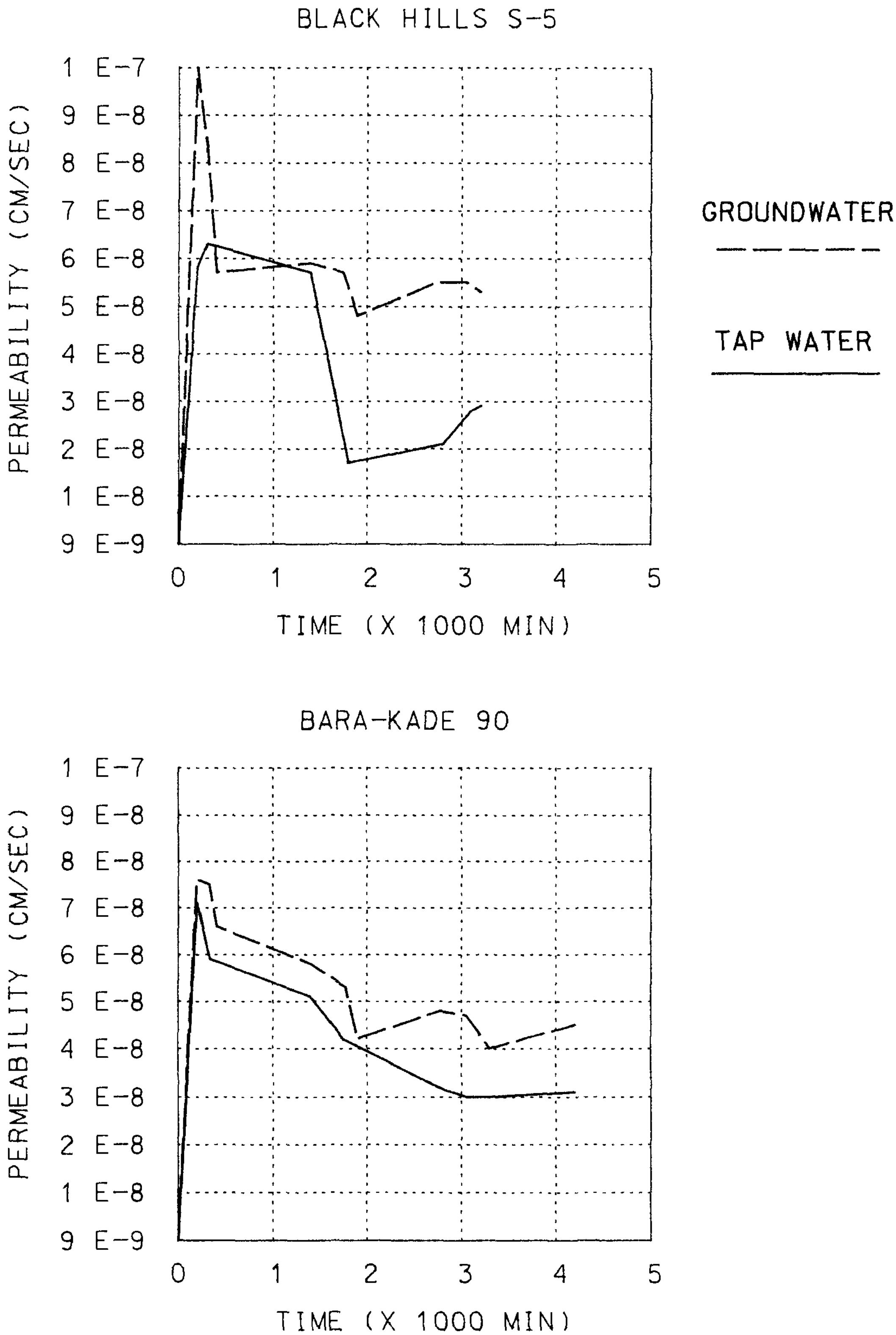
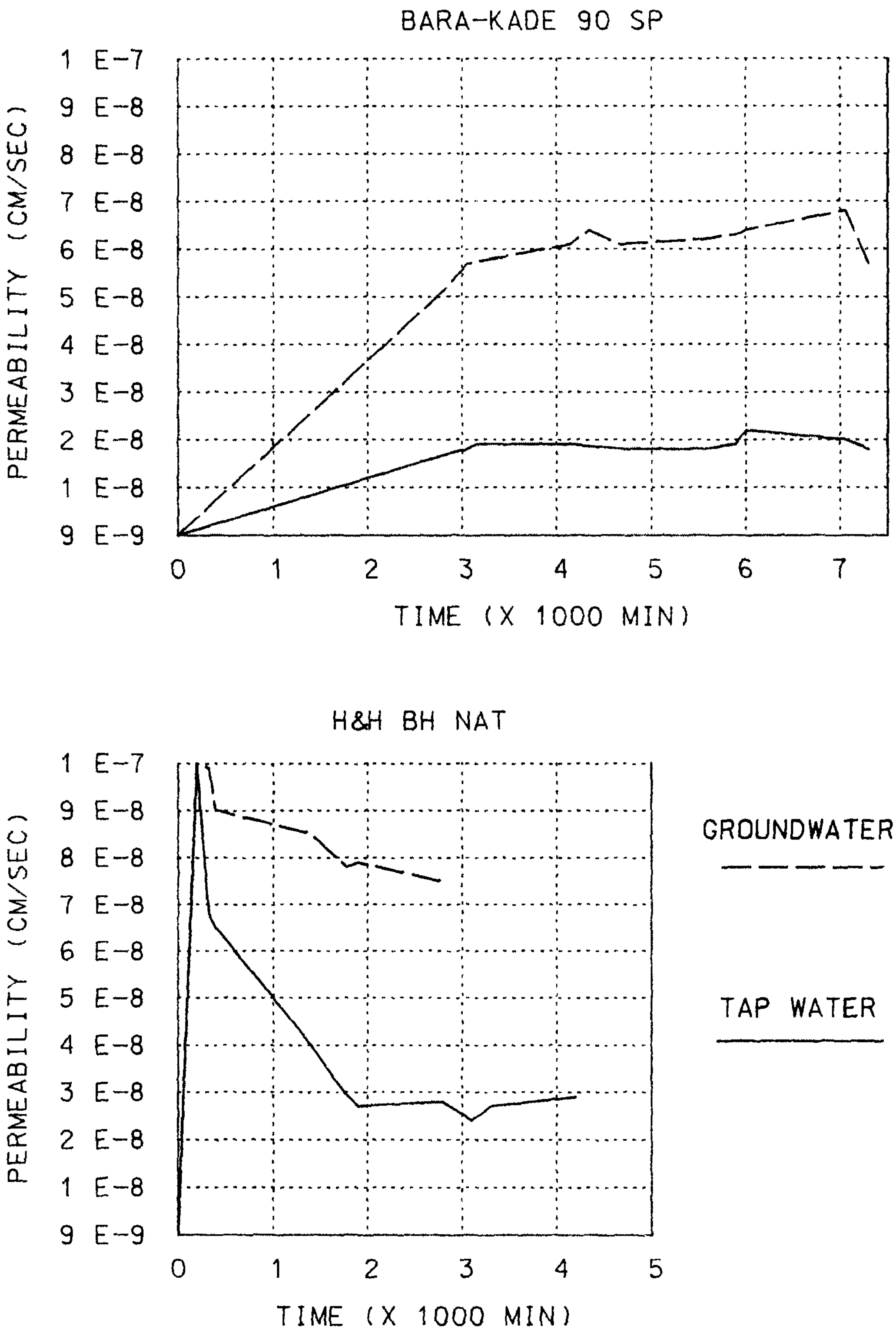


Figure 3

Filter Cake Compatibility Test Results



Mix Design Optimization

General. The purpose of this phase of testing is to determine the most economical mix of soil, dry bentonite, and bentonite slurry which will produce an in-place slurry trench permeability less than or equal to 1x 10-7 cm/sec. Because mixing and placing operations are less controlled in the field than in the laboratory, the designers specified a maximum laboratory permeability of 5 x 10-8 cm/sec for evaluation purposes.

Since borrow soil is available nearby at RMA, bentonite is the highest cost item. The HTW testing technical advisor assumed at some point it would be less expensive to decrease the permeability of soil-bentonite backfill material by adding additional fines (from a clay borrow area), rather than additional bentonite, to the random fill borrow soil. The "upper limit" bentonite content was set as 4 percent dry bentonite. Bentonite slurry is then added to the mixture to achieve a (concrete) slump between 4 and 6 inches.

Procedure. The work plan called for preparation of three samples of backfill soil with the addition of 0, 2, and 4 percent dry bentonite by weight. Bentonite slurry with a Marsh funnel viscosity of about 40 seconds is added to each sample to achieve a (concrete) slump of 4 to 6 inches. If fixed wall permeameter tests of 48 to 72 hours duration did not measure a permeability less than or equal to 5 x 10-8, clay borrow soil would be added to the random fill borrow soil to produce samples with approximately 10 percent greater fines content than the random fill borrow soil. The procedure (addition of dry bentonite and bentonite slurry, fixed wall permeameter tests) would be repeated. If measured permeabilities were still greater than 5 x 10-8 cm/sec, additional clay borrow soil would be added to produce samples with approximately 20 percent greater fines content than the random fill borrow soil. If measured permeabilities (after addition of dry bentonite and bentonite slurry) were still greater than 5 x 10-8 cm/sec, additional clay borrow soil would be added to produce samples with approximately 30 percent greater fines content than the random fill borrow soil.

Testing. The HTW testing technical advisor intended carrying out these tests in duplicate, using RMA tap water as the only permeant. The project designers misunderstood and requested one set of tests be performed using RMA tap water as permeant and one set be performed with contaminated groundwater as the permeant. In the first tests performed a few of the permeameters emptied of permeant over one night. The head pressures were 2 psi and the initial permeant volumes were approximately 200 ml. Examination revealed these specimens appeared to have contracted (specimens pulled approximately one-eighth of an inch away from the permeameter), pointing to a physical change as a result of some reaction with the permeant. To prevent preferrential flow of permeant between the permeameter wall and the sample, the permeameters had been coated with a bentonite paste (approximately 17 percent bentonite and 83 percent water by weight). The bentonite paste wall coatings were not evident at this point. These conditions occurred more frequently in the specimens permeated with contaminated groundwater, but also appeared in tap water permeated specimens as well. It was initially suggested that these failures may have been due to some lattice collapse in the bentonite resulting from ion exchange. The same or a similar process might possibly cause the cracks observed during filter cake compatibility tests.

The HTW testing technical advisor suggested attempting to discover the cause of the rapid permeant loss. In the interest of proceeding with testing, the advisor suggested, and the designers concurred, a triaxial permeability test be conducted using a 2 percent dry bentonite mix. Since the random fill borrow soil contains 51 percent fines and little difference exists in the grain size distributions of the two borrow soils (Figure 1), the addition of fines from the clay borrow soil would likely have a negligible effect on the permeability of the mix. Early results from a successful fixed wall permeability test indicated a permeability of approximately 5 x 10-8 cm/sec for a 2 percent dry bentonite mix.

While the triaxial test was being started, an investigation of the failed fixed wall tests was undertaken. Two paste coated jars, one filled with tap water and the other with contaminated groundwater were prepared. Several days of exposure to the liquids resulted in the tap water having a more detrimental effect on the paste than the groundwater. This was in contrast to the greater frequency of failed groundwater permeated fixed wall tests. Next, one still intact fixed wall test specimen was allowed to flow until the entire volume of permeant passed through it. Several hours later it appeared identical to the failed test specimens; the sample appeared to contract and the bentonite paste coating was missing.

This (very limited) investigation suggested that due to high permeability, cracking of the specimen, leakage along the permeameter walls, or a combination of the factors, permeant was forced through and/or around the specimen. Continued pressure application with no permeant caused drying of both the specimen and the bentonite paste. (The paste has a high water content (500 percent)). Drying could cause specimen shrinkage and give the appearance of a physical change due to some chemical reaction.

The HTW testing technical advisor thought not enough time was allowed between specimen set up and the start of flow. Persons at WES familiar with this type of testing concurred. All future fixed wall soil-bentonite backfill permeability testing will be run after incrementing the applied head pressures slowly over the course of several days.

Triaxial Permeameter Test Results. Figure 4 shows the results of the triaxial permeameter optimization test. The average permeability, approximately 4 x 10-8 cm/sec, is lower than the specified maximum of 5 x 10-8 cm/sec. Therefore the optimum mix design is 2 percent dry bentonite by weight and bentonite slurry added to the random fill borrow soil.

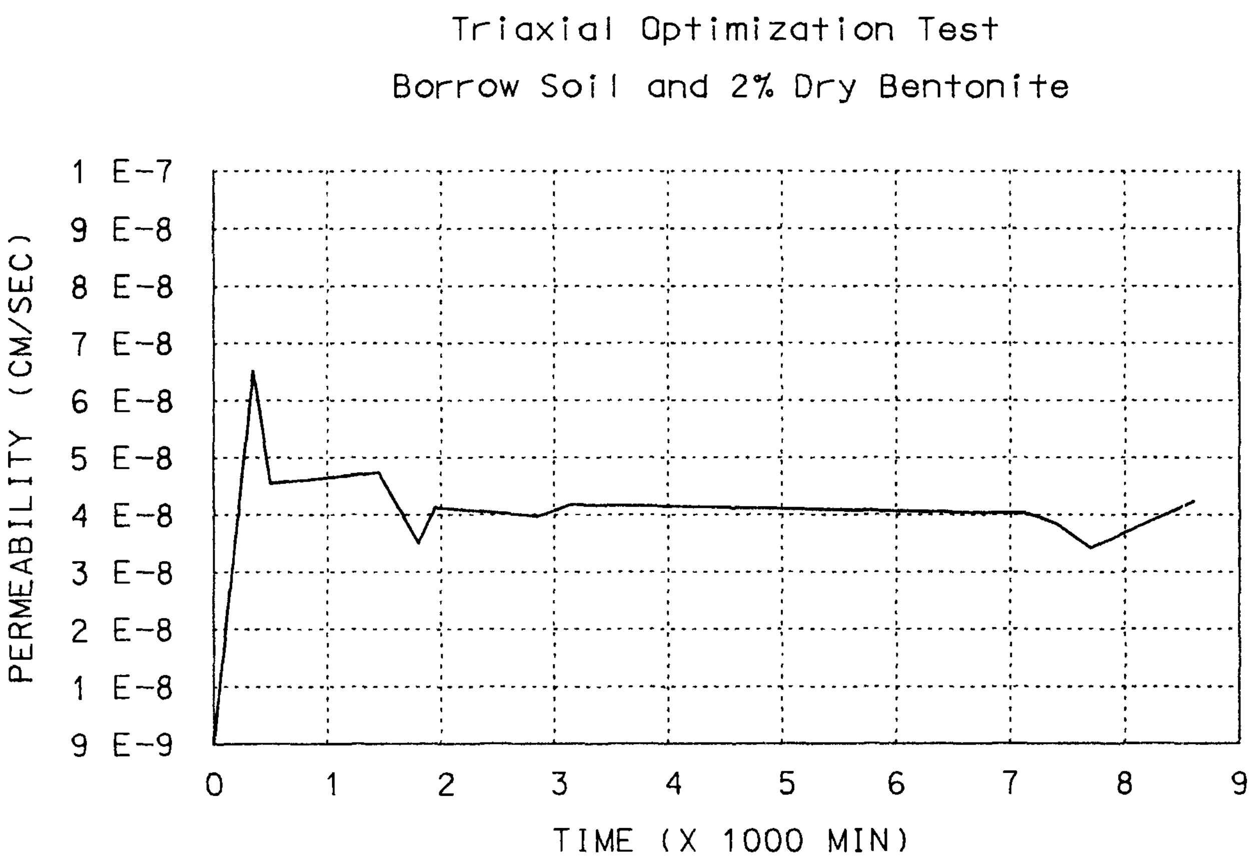
D'Appolonia (1980) recommends the following properties for soil-bentonite backfill material: slump between 2 and 6 inches, unit weight at least 15 pcf greater than the slurry unit weight, water content between 25 and 35 percent, minimum bentonite content of 1 percent, and a minimum fines content of 20 percent. Millet and Perez (1981) recommend a slump of 4 to 6 inches and a bentonite content of 2 to 4 percent. The USEPA recommends a bentonite content of 1 to 2 percent, water content of 25 to 35 percent, fines content of 20 to 60 percent, slump of 2 to 7 inches, and a unit weight at least 15 pcf greater than the slurry unit weight (JRB Associates, 1984). Table 3 lists physical properties of the triaxial permeameter specimen. All properties lie within the recommended ranges except water content. The reason for the high water content and it's effect on long-term permeability (if any) is not known.

Long Term Compatibility Tests

Flexible Wall Permeameter Equipment. The basic components of MRDL's flexible wall permeameter setup are: 1) Six modified triaxial permeameter cells, each consisting of anodized aluminum top and bottom cell bases, a clear lucite cylinder, anodized aluminum top and bottom specimen caps and brass porous stones; 2) Separate inflow and outlow glass burettes for flow quantity measurements; 3) Three pressure regulators with associated pressure gauges to control and monitor cell pressure, inflow, and outflow pore pressures; and 4) A stainless steel control panel with appropriate stainless steel valves, teflon tubing and spill containment tray. The LSB testing program utilizes air as a pressure source. For some permeant liquids, an inert gas (such as nitrogen) should be the pressure source to minimize biodegredation within the liquid.

Procedure. The test procedure can be broken down into six steps. The first step consists of forming a cylindrical specimen approximately 2.8 inches in diameter by 2.0 inches high out of the selected soil bentonite mix from the mix design optimization phase. This is done by using the bottom specimen

Figure 4



Triaxial Optimization Test
Borrow Soil and 2% Dry Bentonite
PERMEABILITY (CM/SEC)
1 E-7
9 E-8
8 E-8
7 E-8
6 E-8
5 E-8
4 E-8
3 E-8
2 E-8
1 E-8
9 E-9
0
1
2
3
4
5
6
7
8
9
TIME (X 1000 MIN)

Table 3.

Physical Properties - Triaxial Optimization Test

Total Percent Bentonite	4.2 percent
Slump	6.125 inches
Wet Density	112 pcf
Dry Density	71.5 pcf
Saturation	100 percent
Void Ratio	1.35
Water Content	56.6 percent

Table 4.

Physical Properties - Compatibility Tests

	2% Dry Bentonite		4% Dry Bentonite
Property	Specimen 1	Specimen 2	Specimen 3
Total Percent Bentonite	3.7	3.7	6.0
Slump (inches)	4.5	4.5	5.75
Wet Density (pcf)	109	108	104.5
Dry Density (pcf)	73	72	67
Saturation (%)	100	100	100
Void Ratio	1.31	1.35	1.52
Water Content (%)	49.3	50.0	55.9

cap and a latex membrane sleeve within a perforated plastic cylinder as a specimen mold. Soil-bentonite backfill material is carefully spooned into the mold in two lifts and rodded lightly to produce a homogeneous low density mass. After taking the necessary specimen measurements and weights, top cap is set and the cell is assembled. Step 2 consists of filling the inflow and outflow burettes and porewater lines with site tap water and the chamber with deaired water after making the appropriate connections to the control panel. Step 3 consists of backpressure saturating the specimen. Step 4 consists of consolidating the specimen to simulate field stress conditions. Step 5 consists of flow initiation from bottom to top within the specimen using a relatively low hydraulic gradient (e.g. 28). Inflow and outflow quantities are monitored until the rate of inflow equals the rate of outflow for at least 5 consecutive daily readings. In addition, at least one pore volume of water must flow through the specimen prior to introducing site (contaminated) groundwater. As with tap water, groundwater inflow and outflow are monitored and the test is run until at least two pore volumes of groundwater pass through the specimen. The final step consists of removing the specimen, obtaining final weights, measurements, moisture contents etc. Three test conditions are being evaluated: two specimens of the "optimum" mix design of 2 percent dry bentonite and bentonite slurry added to the random fill borrow soil and one specimen with 4 percent dry bentonite and bentonite slurry added to the borrow soil. After one pore volume of tap water passes through the samples, two of them (one optimum mix sample and the 4 percent dry bentonite sample) will be leached with contaminated groundwater. Results of the two tests using groundwater as the permeant can be compared to see whether a backfill with a higher bentonite content reduces changes in backfill permeability over time. Occasional sampling and chemical analysis of the effluent permeant is done to determine the effectiveness of the soil-bentonite backfill material in preventing migration of contaminants through the specimen. It is recommended that the flow phase of the tests be run at least two months to provide meaningful results concerning the effects of the groundwater on the soil-bentonite backfill material.

Testing. Long-term compatibility testing began in early March 1991. Presently the first pore volume of RMA tap water is flowing through the specimens. MRDL personnel anticipate beginning groundwater permeation (for two of the samples) sometime during the week of April 1, 1991. Therefore, the effect of site contaminants on the permeability of the soil-bentonite backfill material is not known at this time. Tap water permeabilities are averaging between 4 x 10-8 cm/sec and 5 x 10-8 cm/sec, similar to values obtained during the mix design optimization phase. Table 4 lists physical properties of the test specimens. Water contents are higher than recommended values for (as yet) unknown reasons.

The small volume of effluent to be produced precludes performing a wide range of chemical testing. Sodium, calcium, and total organic carbon tests will be performed after each pore volume has moved through the samples. An increase in the amount of sodium and a decrease in the amount of calcium in the permeameter effluent could indicate displacement of sodium ions in bentonite by calcium ions from the groundwater.

CONCLUSIONS

The following list of conclusions is to be considered incomplete due to the ongoing compatibility tests.

General Testing Methodology

(1) When designing soil-bentonite slurry trenches through highly contaminated areas, at least one uncontaminated imported borrow soil should be investigated and tested for use in the soil-bentonite backfill material. If the in situ soil contains too many contaminants for use, mix design and compatibility testing of the borrow soil can continue without delay.

(2) Due to the variability of commercially available bentonites, several should be evaluated for suitablility with site tap water and contaminated groundwater. The evaluation process should include both free swell and filter cake compatibility tests.

(3) When soils used in soil-bentonite backfill material contain a significant amount of fines, addition of fines during optimization testing as planned in this study may not be necessary.

(4) During rigid wall permeameter testing the applied head pressure should be incremented slowly over several days.

LSB Backfill Mix Design

(1) Addition of 2 percent dry bentonite and enough bentonite slurry to achieve a concrete slump between 4 and 6 inches to the borrow soil produces a soil-bentonite backfill material with a laboratory permeability less than 5 x 10-8 cm/sec.

DISCLAIMER

This paper is not intended to address every conceivable HTW site condition or all possible applications of soil-bentonite backfill mix design and/or compatibility testing. Mentioned commercial products are not the only products of their kind available. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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United Creosoting Company Superfund Site: A Case Study

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INTRODUCTION

In 1983 the United Creosoting Company (UCC) site was proposed for inclusion on the National Priorities List (NPL). With this action the Environmental Protection Agency (EPA) made it possible for Superfund money to be spent on the remediation of this complex wood preserving site. This paper will discuss the many challenges the site has posed as it has progressed through the Superfund "pipeline".

Complicating work on this project is the fact that this site entirely encompasses a residential subdivision and two industrial businesses. From the beginning residents have requested a complete buyout of the subdivision. The fact that EPA is unable to comply with their request makes community relations a challenge. Because of this, communication with the community has been a high priority. Intensive community relations efforts, both in the past and those planned for the future, will be discussed.

An innovative technology, available from only one vendor, was selected in 1989 as the method of remediation for the site. Because of this procurement will be different from what can be considered the norm. The combination sole source and competitive bid contracting strategy, proposed by the Texas Water Commission (TWC) to procure services to remediate the site, will also be examined.

BACKGROUND

SITE LOCATION AND HISTORY

The UCC site is located 40 miles north of Houston in the city of Conroe, Texas. Approximately 13,000 people currently live within a two-mile radius of the site. The site is occupied by two industrial properties and a residential subdivision (Figure 1).

UCC operated as a wood preserving facility from 1946 through the summer of 1972, when it was abandoned. Formed lumber, such as telephone poles and railroad ties, were treated in a two-step process by the pressurized addition of pentachlorophenol (PCP) and creosote. The pressure cylinders were rinsed and wastewater routed to one of the two process waste ponds located onsite.

In the late 1970's the property was divided and sold to several entities. At some time the pit used for tank bottoms and other residues was covered with soil. Shortly thereafter a portion of the site was developed into a residential community and the rest became a light industrial area.

During the summer of 1980 surface soils and pond backfill from one of the industrial properties were donated to the County by the property owner for use on improvements to several Conroe roads. The soil had been moved and stockpiled by the owner to allow for the installation of paving on his

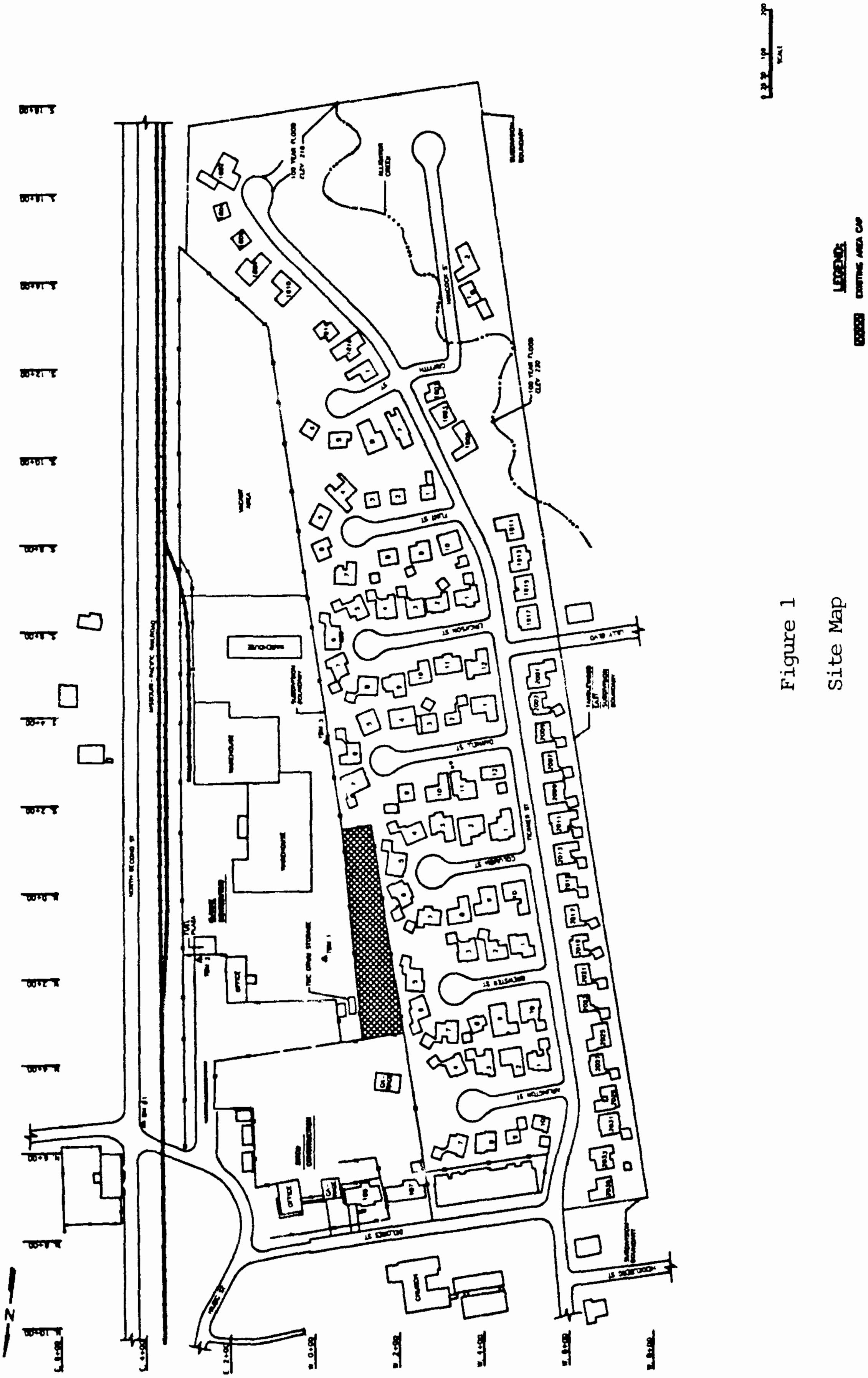


Figure 1
Site Map

property. After citizens living along one of the roads complained of headaches, burns, respiratory problems, and damage to vegetation, the contaminated soils were excavated from the roads and disposed of, and investigations were initiated. The site was proposed for the NPL in September 1983.

Fieldwork for the Remedial Investigation was conducted in December 1984 and August 1985. The Feasibility Study was completed in May 1986, and a Record of Decision (ROD) signed September 1986. During the Remedial Investigation and Feasibility Study phase it was concluded that seven properties, six with houses on them, were directly in the way of any future excavation of the old waste pond. The only method known at the time which could address the contamination at the site was incineration. As there were no offsite incinerators which would accept the dioxin contaminated waste, the incineration would have to be conducted onsite. This information was presented to the community along with the idea of a temporary solution, with final solutions to be evaluated as technologies developed. The community strongly opposed the incineration proposal. EPA selected the temporary remedy, which included the following:

- Purchase seven properties located above and adjacent to a former pond area;
- Permanently relocate the persons living in the six houses located on those properties;
- Demolish the six houses;
- Consolidate soils contaminated above health-based levels and visibly contaminated soils in the pond area;
- Construct a temporary cap over the pond area;
- Evaluate innovative technologies as possible permanent remedies, and;
- Natural attenuation of the ground water contamination.

EPA promised in the ROD to re-evaluate this remedy in five years if no innovative technologies became available. The health based action levels selected in this ROD are listed in Table 1.

TABLE 1

SOIL ACTION LEVELS FROM THE 1986 ROD

COMPOUND	CONCENTRATION
Total Polyaromatic Hydrocarbons (PAHs)	100 mg/kg
Pentachlorophenol	150 mg/kg
Tetra-Dioxin	1 ug/kg
Penta-Dioxin	5 ug/kg
Hexa-Dioxin	25 ug/kg
Hepta-Dioxin	1000 ug/kg

Through the support of EPA initiatives, potential technologies for treatment of creosote by-products did become available shortly after the ROD was signed. This led to a biological treatment bench scale study in 1988 and a critical fluid extraction study in 1989. Biological treatment was satisfactory at degrading the PAHs, but was not sufficiently successful at destroying the dioxins to the necessary extent. The critical fluid extraction process, on the other hand, showed satisfactory results for both

PAHs and dioxins. Based on an evaluation which considered the results from these studies, and other proposed remedies, critical fluid extraction was selected as the remediation method for the site in September 1989.

The second ROD stipulates the following:

- Sample the residential area to better delineate all soils falling above the target action levels.
- Excavate soils from residential and commercial portions of the site that are above the action level and treat via critical fluid extraction.
- Dispose of the organic concentrate from the extraction process by off-site incineration.
- As the action levels and treatment standards for K001 contaminated soils are met, rebury treated soils on the appropriate portion of the site.

The selection of this remedy initiated a second operable unit and precluded the necessity of consolidating and temporarily capping the soils from the pond areas. New action levels were set in the ROD by using the most current risk assessment guidance. These new levels are listed in Table 2. The new guidance allows for use of benzo(a)pyrene (BAP) equivalents and 2,3,7,8-tetrachlorodibenzodioxin (TCDD) equivalents for estimating the carcinogenicity of other PAHs and isomers of dioxin and furans, respectively. The changing of the action levels caused considerable confusion among the residents and special efforts were made to communicate the meaning of the changes and the reasons for them to the community.

The purchase of the 7 properties as specified in the first ROD, by the Federal Emergency Management Agency (FEMA), was completed by the transfer of titles to EPA in August 1990. Several factors contributed to the long duration in getting the houses purchased. Initially the State and EPA could not agree on who would hold the titles to the properties once they were purchased. Eventually it was decided that the Federal government would take the titles until the remedial action was completed, after which time they would be transferred to the state of Texas. Another problem arose when several of the houses were appraised at a lower value than the mortgage on them. This necessitated special procedures by FEMA to allow the purchase of these houses at more than their appraised value. Finally, an Internal Revenue Service (IRS) tax lean on one house led to delays until negotiations between FEMA and the IRS settled the matter.

Once purchase of the properties was accomplished the house demolition could commence and a Notice to Proceed for this work was issued by TWC in October 1990. This interim remedial action work included demolition of six houses, and erection of a fence around the now vacant lots. The demolition activities were originally designed and bid to be entirely non-hazardous work. Demolition of the houses was completed in December 1990.

In January 1990 the additional sampling stipulated in the 1989 ROD was performed as a focused site investigation. The impact of excavation on local air quality was also evaluated during this effort, and from this study, is expected to be insignificant.

TWC initiated the design phase for the final remedy in January 1991. A Design Concept Memorandum is in the process of being finalized at this time. This memorandum will outline basic design decisions and options in an effort to minimize redesign time due to changes in direction in future design deliverables. The design of the final remedy is scheduled to be completed January 1992.

TABLE 2

SOIL ACTION LEVELS FROM THE 1989 ROD

COMPOUND	RESIDENTIAL SOIL ACTION LEVEL (PPM)	INDUSTRIAL SOIL ACTION LEVEL (PPM)	APPLICABILITY
carcinogenic PAHs (in BAP equivalents)	.33	40	surface soils
non-carcinogenic PAHs	2000	2000	surface and subsurface soils
carcinogenic dioxins and furans (in 2,3,7,8-TCDD equivalents)	.001	.02	surface soils
PCP	150	150	surface and subsurface soils

COMMUNITY RELATIONS BACKGROUND

This site represents an extraordinary challenge because of the active residential community located within the site and on top of some of the waste. Community relations has been a major consideration from very early in the project. The community has been vocal in asserting its concerns and has been able to generate significant media and Congressional involvement. The resident's primary aspiration is to have the entire subdivision of nearly 100 residences and 28 vacant lots bought by the government. However, under Superfund, there are only two circumstances when EPA may purchase property: (1) when the purchase of the property is necessary to physically implement the remedial action, or (2) when the final remediation for the site cannot otherwise eliminate long term health dangers.

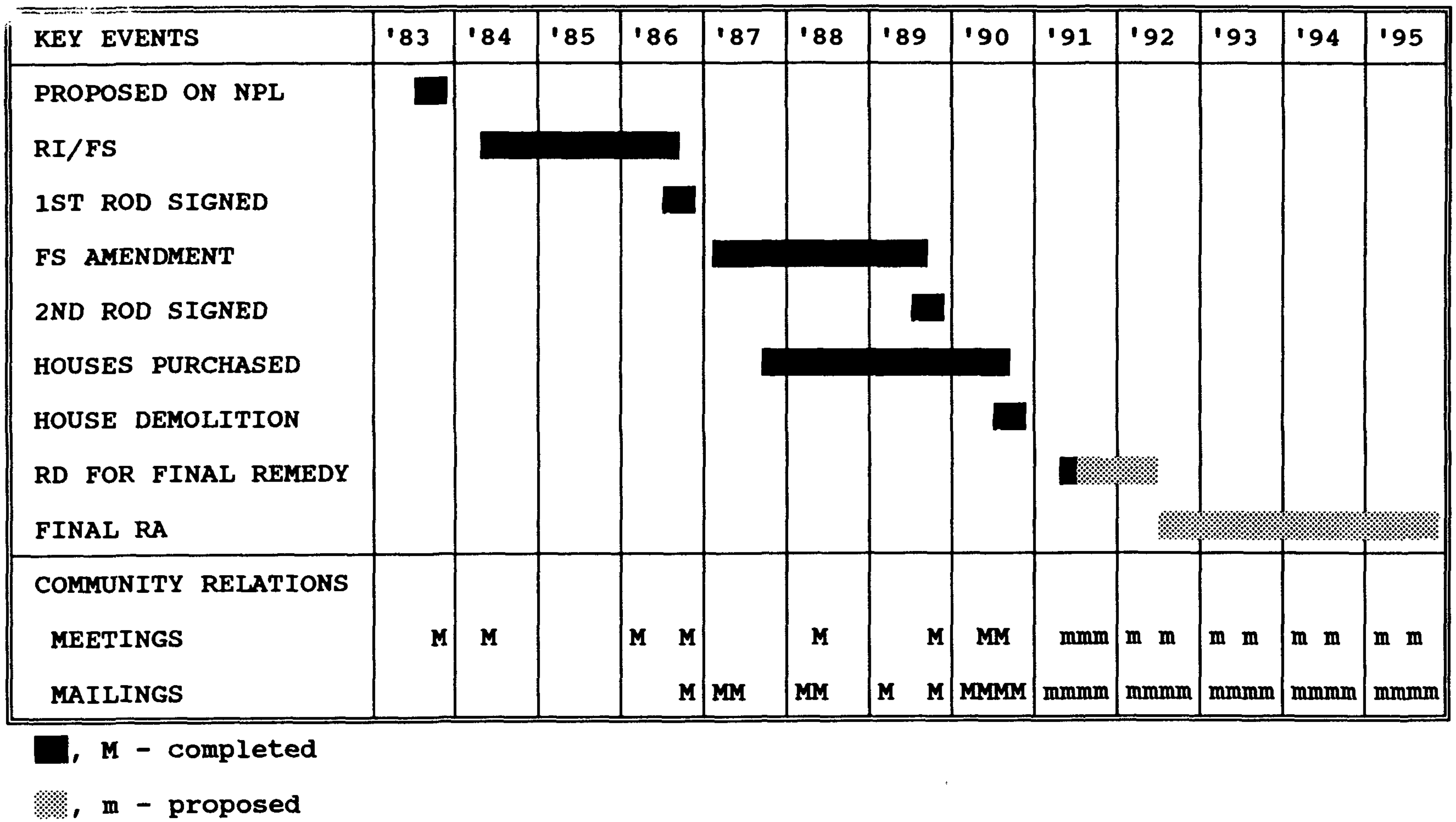
Complicating the buyout issue recently has been the fact that EPA has recently been ordered by Congress to "buyout" a similar site in Texas. Neither site meets the two circumstances listed above which would warrant a buyout. Nevertheless, EPA must purchase the other subdivision but cannot, according to policy, purchase the one in Conroe. A site related lawsuit between some of the residents and TWC serves to further complicate community relations.

In the past, area citizens have been kept informed of activities at the site through the extensive use of community relations meetings. From 1983, when the site was proposed for the NPL, to the signing of the second ROD in 1989, nine meetings were held with the residents. These have included informal meetings with the homeowners association, work shops, open houses, and when necessary, formal public meetings. In addition, press releases and direct mailings to the community have been employed to update concerned citizens about site activities. A chronology of past and future major milestones and community relations activities is shown in Figure 2.

It was decided at the beginning of the focused site investigation that even these extensive measures could be improved on in order to increase public understanding and cooperation. Prior to starting fieldwork for the focused site investigation, an open house was held to inform the residents of the

FIGURE 2

UNITED CREOSOTING SUPERFUND SITE CHRONOLOGY



upcoming sampling event and to give them an opportunity to have input on the locations of the samples. Samples were to be taken primarily in residential yards, necessitating the obtaining of approximately 50 access agreements over a short period of time. The Remedial Project Manager obtained access agreements by going door-to-door in the community. Contact was attempted at each residence in the community, regardless of whether access was needed, in order to give residents a personal update on what was occurring in the neighborhood. In cases where the resident was not the property owner access was obtained from both, and both were given a personal update on the project.

Beginning concurrently with the January 1990 fieldwork EPA began mailing monthly site updates to the community. These monthly mailings generally included the following type of information regarding the site.

- o Status updates on the various phases of work on the site.
- o Common questions and EPA answers.
- o Requests for input from the community on specific topics.
- o Explanations of how to interpret data presented to the community.
- o Schedule of upcoming activities.
- o Contacts for additional information and repositories locations.

Another effort to become more accessible to the public was the implementation of a 1-800 phone line with an answering machine for 24-hour service. In each mailing the community was reminded of this toll free number. This number has since been made available for use on all Region 6 Superfund sites.

After results from the sampling became available EPA prepared a set of data packages geared specifically to the residents. These packages presented the results of the sampling on each resident's, and their immediate neighbor's, yards in an easy to follow format, both in a table and graphically. Accompanying these packages was a letter telling the resident whether the data indicated their yard was eligible for replacement during implementation of the permanent remedy. Shortly after these packages were mailed a work shop was held to inform residents on the impact of the information on the community and to allow residents the opportunity to discuss their data package results with representatives from EPA and TWC.

Once the data had been thoroughly interpreted and the air modelling completed an open house was held to present the final report for the focused site investigation. At this meeting large maps showing proposed excavation were available for review. Before this meeting was held the final reports had been sent to the repositories for access by the community.

Prior to community meetings to discuss the focused site investigation all TWC and EPA attendees were thoroughly briefed on the status of the project and recent developments. This preparation went as far as the development of a list of questions expected from the people attending, and responses to them. These questions were generated from various sources, such as issues raised in the media, and calls and letters from the residents. Responses to the questions were developed cooperatively by EPA and TWC. Some examples of the most major concerns, and the EPA responses, are on Table 3.

Following the open house to present the final report for the focused site investigation the questions and responses were refined and sent to the community in the monthly site update. These questions and responses were culled from monthly mailings, the questions and answers developed in preparation for community meetings, and questions asked during the community meetings themselves.

TABLE 3
CITIZEN CONCERNS AND EPA RESPONSES

Concern	Response
Wouldn't it be cheaper for EPA to buyout the residents than remediate the neighborhood? The value of houses in the area have been ruined.	Response: Adding the cost of residential buyout to the cost of remediation does not make the overall cost less expensive since, under the Superfund law, EPA must still remediate the site. Additionally, the quantity of soils to be remediated in the current residential area represents less than a sixth of the total soils to be handled at the site, so that a significant cost would still be required to remedy the remainder of the site even if EPA could forego cleaning up the residential area. EPA recognizes that property values may have been depressed but the Superfund law does not provide for EPA to pay for economic loss of homeowners. Economic damages are normally the concern of civil courts. The remedial actions planned for this site should, however, remove the stigma associated with being a Superfund site from the community.
Why can EPA buyuot another very similar site, but they do not have the authority to do so at United Creosoting.	Under Superfund, there are two circumstances when EPA may purchase property: (1) when the purchase of the property is necessary to physically implement the remedial action, or (2) when the final remediation for the site cannot otherwise eliminate long term health dangers. EPA does not believe that either of the two circumstances cited above exist at either United Creosoting or the other similar site, thus EPA did not propose a buyout at either subdivision. The buyuot at the other site results from a line item, which was not added at EPA's request, included in the Agency's appropriations bill.
My health may be endangered by living in the subdivision.	Health professionals at the EPA, ATSDR, and the Texas Department of Health have reviewed data collected from the site and agree that an immediate health risk from contaminants is not present in the community. Because areas of neighborhood properties have levels of creosote contamination above concentrations that would be potentially acceptable for a lifetime of exposure, the remedy EPA selected for the site includes replacement of these soils.

How can the remediation be effective when EPA is not removing contaminants under walks, driveways, and streets? What about contamination in soil under large trees, or immediately adjacent to house foundations?

EPA does not expect this to be a problem for a number of reasons. First, when the contaminants are covered by concrete, there is no exposure of the material to people since a pathway for direct contact does not exist. There is no evidence to indicate there are contaminants under houses, driveways, or streets at concentrations that would cause health effects if they migrated, except in the area atop an old waste pit where the houses have already been purchased by EPA. Also, migration of contaminants from beneath a foundation, road, or concrete is unlikely because the area is covered and it is not exposed to water or forces which would cause the contaminants to move. EPA will address the problem of excavation around (and protection of) house foundations and large trees during the remedial design. Those large trees that people wish removed will be replaced with smaller trees. We believe that surface soils can still be excavated to some degree under large trees which will remain. There should not be sufficient contamination left next to foundations or under the large trees to pose a risk to residents. The risk assessment scenario for this site assumed residents would be exposed to contaminants throughout their yards. Because the yards are being replaced with clean soil, the only material left where potential exposure could take place is below the surface next to the foundations or within the root system of large trees.

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INNOVATIVE TECHNOLOGY BACKGROUND

The technology selected for this site is available only from C.F. Systems (CFS), the patent holder. CFS is not planning on making the technology available to other manufacturers. Because of this TWC will be unable to procure the remediation of the site through a single competitive bid, as is the norm. Instead, at least a part of the design and remediation will have to be secured using noncompetitive procurement methods. Federal cooperative agreement procurement regulations allow noncompetitive procurement under four circumstances:

1) the technology is available from only one vendor,

2) an emergency exists which will not permit a delay resulting from procurement,

3) the award official authorizes it, or

4) after solicitation competition is determined to be inadequate.Condition one is met for the treatment technology. A cost analysis must always be performed when noncompetitive procurement methods are used.

DISCUSSION

COMMUNITY RELATIONS TECHNIQUES

Although public meetings are necessary during the ROD public comment period, informal meetings, such as work shops and open houses can be a more effective tool for informing the community. Work shops are run very similarly to public meetings, except they are much more informal. Although a formal transcript is not generated, an informal summary is usually developed either from personal notes or a tape recording. Generally, the work shop focuses on a specific topic, such as a recent report made available in the repositories. Presentations are kept short in duration, minimizing background information which has been presented in the past, and focusing instead on specific issues or future activities. A significant portion of the work shop is dedicated to responding to questions, which are taken informally from the attendees without the use of a microphone (which many people find threatening). Open discussion is encouraged, leading to a more conversational approach to addressing questions.

Open houses are just what the name implies. Posters and informative handouts are made available for attendees to peruse at their own pace. No formal presentations are made, however, representatives from all involved government agencies are available to respond to questions.

PROPOSED COMMUNITY RELATIONS EFFORTS

From past experience Region 6 has discovered that the more opportunity the community is given for input the less likely they are to try and block efforts by EPA to move forward with the remedy. This is because their concerns are addressed early, before it becomes difficult to change direction due to their input. TWC has proposed several ways to continue with the expanded community relations efforts.

At this time TWC intends to make the design deliverables available to the community. This means the design concept memorandum, 30%, 60%, and 95% complete designs will be sent to the repositories rather than the final design only, as is typically done. Meetings will be held with the community to discuss these documents following their delivery to the repositories. The community will be allowed to voice any concerns they may have on the content or direction of the design. The intent of doing this is to reduce the likelihood of major community disagreements with the final design. If the community is not given the opportunity to have input early in the design their comments could lead to revisions in the final design. Or, if their concerns are not addressed, it could lead the community to look for to sources, such as their congressmen, in order to have their desired changes made. Many people who may not have had major concerns with the design may decide to disagree with it simply because they were not allowed input by not being contacted until the design was final. TWC intends to continue the use of work shops and open houses during the remedial design and remedial action to keep the public informed.

TWC will continue the frequent, regular mailings initiated by EPA during the focused site investigation. This effort will continue through the remedial design and remedial action process. By mailing updates regularly to the community they are informed that progress is being made. It also serves to remind them of their responsibility to stay informed on the direction of the project.

A visitor's center is proposed for the site during the remedial action. This center would provide the community a place to pick up the most recent information available on the site, leave comments, and possibly even see a video of the remediation process. This center is expected to reduce the feeling of being denied access to the project which may result from the increased security for certain areas during remediation. It will also encourage community involvement and self-education.

PROPOSED CONTRACTING METHOD

The treatment technology for this site is available from only one source, leading to the need to use a different approach for contracting and procurement at this site than is normally used. Typically Superfund remedial actions are procured using a detailed set of plans and specifications developed by the design engineer. These plans and specifications are used to invite bids for the project and award of the contract is to the lowest bidder, leading to a competitive procurement. For this project, however, TWC's design engineer will prepare a set of plans and specifications for all of the work except the treatment of contaminated soils. These plans and specifications will be used to competitively procure a contractor (henceforth called the major contractor) to conduct the site preparation, excavation, materials handling, site restoration, etc. By splitting out the treatment portion of the contract TWC intends to maximize the amount of the contract being competitively procured.

To secure the treatment of the contaminated soils, TWC proposes to contract separately with CFS. The first contract with CFS will be to design the system needed for the site. This work will be performed concurrently with the design of the competitively procured work. During the design phase CFS will provide the specific parameters needed for the soils to be processed through the treatment system. These parameters will be placed into the competitive contract specifications as the conditions of the soil necessary for CFS to accept them for treatment. The major contractor will be required to verify that these conditions are being met. This dual contracting for remedial design will mean coordinating between the design engineer and CFS to produce a biddable design.

During remedial action CFS will be contracted with to provide and operate the treatment system to within an agreed to set of criteria. The major contractor will excavate, stage, and pretreat soil as specified in the contract prior to turning it over to CFS. CFS will then treat the soil to the treatment standards and turn it back over to the major contractor. The major contractor will then place onsite the treated soil onsite as specified and restore the excavated areas. The current design engineer will be contracted with to provide oversight of both the major contractor and CFS.

An alternative to having CFS contract directly with the TWC would have been to make them a mandatory subcontractor to the prime contractor. This would have been accomplished by negotiating a fixed price with CFS to be inserted in all of the submitted bids. One reason the contracts are not being set up this way is the potential legal issues over forcing a contractor to take a mandatory subcontractor. Another reason is that this would delay TWC from having any contractual commitment with CFS until after the remedial action is procured. This issue is crucial as some of CFS's equipment could take a year to receive from the time it is ordered from the manufacturer. By contracting with CFS separately, to produce the design and perform the treatment, CFS should be able to begin procuring the equipment necessary for the system significantly ahead of the time the competitively bid contract is signed. Setting the contracts up this way will increase the amount of oversight necessary during remedial action, but will also give TWC more direct control over CFS.

CONCLUSIONS

EPA and TWC have found at this site that more extensive community relations activities have improved the progress of the project. It is possible to work with the community and gain their trust and consent, even if they continue to maintain different goals from the Agency. As the project managers and the residents get to know one another on a personal basis all parties become more comfortable in communicating with each other. The project managers are less defensive when discussing work at the site and the residents learn to trust the managers on a one-to-one basis. Frequent personal interaction between the project managers and the community, such as door-to-door contact, accelerates the gaining of this trust.

Work shops and open houses have been found to be effective tools when communicating with the community. Both of these type of community meetings offer advantages over public meetings. There is lower pressure on the government representatives and less posturing by all participants. Thorough preparation for the meetings increases the meetings' effectiveness and the consistency of responses from different representatives at the meeting. Frequent mailings which contain requests for input keep the community informed and at the same time make them a part of the process.

Community relations can be especially effective if the government representatives involved have good people skills, which is the case for the United Creosoting site. The progress with the community at this site is going to be continued through extensive interaction, such as the use of regular mailings, frequent work shops on the intermediate design documents, and proactive efforts during the remedial action.

It is recommended that during the community relations process in remedial design the effected community is encouraged to take responsibility for their involvement. Let the community know early on that after the remedial action starts it is too late to make changes which could have been handled during the remedial design. On the other hand, remember that having the flexibility to change plans can improve relations and build trust in the community by showing them their best interests are being considered, if possible.

Procuring innovative technologies can be uncomplicated for State-lead projects, due to the straightforward requirements of the procurement regulations for cooperative agreements. By splitting the contracts in the way described the amount of the sole source contract is minimized. This should reduce the costs of the project by maximizing the amount of work to be competitively procured. Also, as discussed, by keeping the contracts separate TWC will be allowed more direct control of the soils treatment contract and CFS can initiate purchase of equipment earlier. A potential disadvantage is that by procuring the work in this way the contracts will have to be written such that the necessary interaction between the major contractor and CFS is clearly defined. Otherwise, conflicts could arise between the two contractors.

DISCLAIMER

This paper was prepared for presentation at the May 1991, Conference on Design and Construction Issues at Hazardous Waste Sites sponsored by the United States Environmental Protection Agency's (U.S.EPA) Office of Emergency and Remedial Response. This paper reflects the opinions of the authors only. This paper does not contain either regional or national policy and should not be construed as such.

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Considerations For Procurement of Innovative Technologies at Superfund Sites

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1. INTRODUCTION

A discussion of issues related to potential institutional barriers associated with the procurement of innovative or patented technologies at Superfund sites would be useful to government and private sector employees. This paper explores applicable requirements of Superfund-specific regulations, Federal procurement regulations, including the Federal Acquisition Regulations (FAR) and the U.S. Environmental Protection Agency (EPA) Acquisition Regulation (EPAAR,) and certain State-specific procurement regulations. Requirements for competition and sole-source procurement are summarized.

Pre- and post-Record of Decision (ROD) solutions to innovative technology procurement barriers, including use of non-inhibiting Record of Decision wording and consideration of early design 'prequalification' of potential vendors, are included. Pros and cons of contract method and type, including whether sealed bid or negotiated procurement is preferred, are discussed. A brief discussion of PRP-lead issues is provided. Where possible, site-specific examples are provided.

2. BACKGROUND

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA,) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that EPA give strong preference towards achieving protective remedies through the use of treatment technologies that significantly reduce the toxicity, mobility, and/or volume of hazardous waste.[1] SARA specifically supported the selection of innovative technologies by allowing the selection of an alternative remedial action in a Superfund ROD regardless of whether or not such an action has shown to be successful at any other facility or site.[2] SARA also directed EPA to use up to $10 million per year through 1991 to establish an "Alternative or Innovative Treatment Technology Research and Demonstration Program."[3]

The recently updated National Contingency Plan (NCP) identifies EPA's expectation that innovative technology remedies be considered when they offer "the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies"[4]. The NCP encourages the development of technologies that have not yet been proven in practice in order to promote the development of new treatment methods for hazardous substances.[5] The EPA Administrator, as well as Congress's Office of Technology Assessment, also stressed that EPA improve the promotion and use of innovative technologies in the Superfund Program, and reduce the institutional barriers which make implementation of these technologies difficult[6,7].

EPA's Office of Research and Development (ORD) conducts the Superfund Innovative Technology Evaluation (SITE) program was organized to maximize the use of alternatives to land disposal in Superfund through field-scale demonstration and evaluation of innovative technologies which offer some advantage over existing technologies. ORD defined alternative technologies as those alternatives to current procedures and practices categorized as follows: a) "available alternative technology" - fully proven and in routine commercial or private use; b) "innovative alternative technology" - fully developed technology for which performance or cost information is incomplete, thus hindering routine use at Superfund sites; and c) "emerging alternative technology" - an alternative technology at a stage where lab testing has been completed and pilot-scale work is now necessary.[8]

The SITE program fosters commercialization of innovative technologies through two sub-categories of testing: a) "Demonstration" — at full or pilot scale; or b) "Emerging" — at lab scale. In both cases, technology developers provide and operate the technology and EPA conducts sampling and analyses[9]. Currently 31 technologies are participating in SITE's Emerging Technologies program, and range from electoacoustical decontamination to bench and pilot studies of a laser-stimulated photochemical oxidation process.[8] ORD, in conjunction with EPA's Office of Solid Waste and Emergency Response's Technology Innovation Office (TIO), also conducts conferences to help introduce promising international technologies through technical paper and poster displays, and showcase SITE and other domestic innovative technologies.[10] Three conferences of this sort have been conducted to date. TIO also has historical information regarding where and when innovative treatment technologies have been conducted. Requests for information from the SITE program may be made by calling (703) 308-8800.

Through 1989, EPA has selected innovative technologies in 37% of Superfund source control Records of Decision (RODs) which selected treatment technologies. Of these, vacuum extraction (12%,) bioremediation (8%,) thermal desorption (5%,) in-situ soil flushing (4%,) soil washing (3%,) chemical extraction (2%,) chemical treatment (2%,) and in-situ vitrification (1%) were selected. Incineration and solidification/stabilization, which are considered non-innovative, account for another 35% and 25% of the RODs selecting treatment technologies, respectively. Innovative technologies have been selected more frequently in recent years (52% of the FY-89 RODs involving source control treatment were innovative technologies)[11].

3. DISCUSSION

Due to the general unknowns associated with Superfund sites (e.g., difficulties associated with properly characterizing the nature and extent of contamination and health risks,) and the general need to move quickly with implementing remedial actions to protect human health and the environment, Superfund construction and operation and maintenance (O&M) projects may generally be considered more likely to experience problems and changes than non-Superfund construction projects. Design and construction of innovative technology Superfund remedies (RD/RAs) may be more likely to fail (in terms of non-success in meeting performance/remediation goals and remedial objectives) as non-innovative Superfund RD/RAs. This is because these technologies, by definition, have not been fully demonstrated on a number of sites and thus have incomplete performance or cost information, and few, if any, vendors have sufficiently proven their expertise through implementation.

EPA and the States often work together to manage the remediation of wastes at Superfund sites. Procedures for the management of projects of both the State and Federal project managers are well described in EPA's "Superfund Federal-Lead Remedial Management Handbook" and "Superfund State-Lead Remedial Management Handbook;"[12,13] these handbooks should be used as a guide by project managers when developing strategies to address the issues outlined below.

3.1. Competition

3.1.1. General

The term "noncompetitive" is often used to mean other than full and open competition. This means not only sole source acquisitions, but also those situations where an agency is permitted to limit the number of sources solicited. Executive Order 12352, signed by the President on March 17, 1982, requires agencies of the Federal government to "establish criteria for enhancing effective competition and limiting non-competitive actions"[14]. The EPA Administrator has also emphasized the need to broaden competition where possible in contracting the Agency has involvement in.[15] This direction from the EPA Administrator resulted in an EPA Order entitled Contracting at EPA, in which it is made clear that procurement strategies which broaden contractor resources available for a particular function should be favored.[16]

The Competition in Contracting Act of 1984[17] (CICA) further specifies requirements for enhancing competition. CICA also provides for the use of "other than full and open competition" for some acquisitions. Although not statutorily defined, CICA lists seven different procurement options that would allow for "other than full and open competition," as follows: 1) only one source available; 2) unusual or compelling urgency; 3) necessary to maintain a particular service for national security; 4) international agreement; 5) a statute authorizes a brand name or specific source; 6) national security would be breached if not done so; or 7) head of agency determines the need, and notifies Congress 30 days prior to the procurement.[19]

FAR Parts 6.303 and 6.304 require "Justification and Approval" by an appropriate agency employee (normally a contracting officer) to use one of these options. This justification, as required by statute, must include: a) a description of the agency's needs; b) identification and discussion of the need for the option used; c) a determination that the anticipated cost will be fair and reasonable; d) a description of a market survey conducted or the reasons why one was not conducted; e) a listing of the sources, if any, which expressed in writing an interest in the procurement; and f) a statement of the actions, if any, the agency may take to remove or overcome any barrier to competition before a subsequent procurement for such needs.[14] For innovative technology justifications, a brief description of the technology, how the equipment would be used, why there is a need for sole source procurement, and a reference back to the ROD, might all be warranted in addition to the above.

3.1.2. FAR Requirements

FAR Part 36.209 notes that "no contract for construction of a project shall be awarded to the firm which designed it" or provided a 'significant contribution' to the design without approval of the appropriate agency officials. FAR Part 9.5 discusses general prohibitions against allowing contractors to perform work for which it received an unfair advantage during procurement.

The "Buy American" Act (41 USC 10) was issued in response to concerns that a significant amount of Federal funding was being used to purchase foreign materials, and hence help other countries become competitive in the United States. As a result of this Act, FAR Part 52.225-5 requires that contractors will use only "domestic construction materials" when constructing a project under Federal procurement. A "domestic construction material" must pass a two-part test: a) manufactured in the U.S.; and b) cost of domestic components must exceed the cost of all components. As defined, construction material is made up of components (e.g., a transformer is a construction material; the piping, container, electrical circuits, etc. are components;) a component does not include labor or manufacturing costs. If the use of domestic construction material would unreasonably increase the price, or would be impracticable, 'Buy American' restrictions would not apply.[19] If a promising international innovative technology were the technology of choice at a site, the project personnel should solicit government contracting officer assistance to determine whether the FAR's 'Buy American' requirements apply, and how to address these requirements.

3.1.3. Environmental Protection Agency Acquisition Regulation (EPAAR) Requirements

EPA's Procurement and Contracts Management Division (PCMD) has made several efforts to help eliminate constraints to the procurement of treatment technologies. 48 CFR Part 1536 of the EPAAR was recently added by PCMD to clarify the applicability of FAR Part 36.209. Under this rule, subcontractors performing treatability studies are not prohibited from being awarded the construction contract for a project. Other subcontractors are also not prohibited from being awarded the construction contract for a project unless their work substantially affected the course of the design. Prime contractors of the design and subcontractors whose work substantially affects the course of the design must receive prior approval by the responsible Associate Director of PCMD under EPA's Office of Administration and Resources Management before they can be awarded the contract.

3.1.4. State-Lead Requirements

The June 1990 40 CFR Part 35, Subpart O regulations (EPA Grants Regulations)[20] establish administrative requirements for CERCLA-funded Cooperative Agreements and Superfund State Contracts for States, political subdivisions thereof, and Federally recognized Indian Tribes. It discusses EPA's allowable procurement procedures for state-lead remedial actions. Part 35.6555 notes that the state "must conduct all procurement actions in a manner providing maximum full and open competition," and, under (a)(6,) that specifying only a brand name product without allowing "an equal" product to be offered is considered an inappropriate restriction on competition. However, (c)(1)(iii) notes that specifications may be written where competition may be justifiably restricted if the material, product or service is necessary to promote the use of innovative technologies in a procurement. If noncompetitive procurement is conducted using such justification, and assuming a "small purchase exemption" can not be conducted for an innovative technology item [under $25,000, see Part 35.6565(a)], Part 35.6565(d) requirements apply, and a cost/price/profit analysis in accordance with Part 35.6585 is required.

40 CFR Part 31.6 (EPA Grants Regulations) note that the Director of EPA's Grants Administration Division is authorized to approve exceptions from non-statutory provisions of the Subpart O regulations on a case by case basis. Such "deviations," as allowed in Part 35.6025, might include a cost/price/profit analysis.

3.2. Sole Source Procurement

3.2.1. General

Sole source procurement is the broadest and potentially the most utilized exception used to justify "other than full and open competition" under CICA. As noted previously, any agency using this justification must reasonably show that only one source, and no others, will satisfy the agency's need. Adequate efforts must be made to ensure that sole source is required. It is improper for an agency to rely on the sole source contractor for technical advice and expertise; agencies should independently evaluate technical criteria and make their own decisions. Sole source determinations by agencies have been overturned when the facts have indicated that other sources could have satisfactorily met the Government's stated needs[14].

Government contracting officers (CO's) frequently require protracted negotiations with the technical staff on a project to make clear that conducting a sole source procurement is warranted. In one case negotiations took over a year to reach agreement to use sole source procurement. These up-front delays do not appear to be offset by time savings in the proposal evaluation process.[21] The reluctance of the CO's to sole source is primarily based on and justifiable due to the overarching statutory and regulatory emphasis for competition.

Activities such as market surveys and cost and profit analyses should be conducted in a proper and complete manner by agencies before making the decision to use sole source procurement. Comparability is a common element to be considered, among others; the reader should solicit the available reference documents available on how to do these surveys and analyses during project planning.[22] Literature reviews, value engineering, and pre-design brainstorming sessions should also be conducted. If this effort shows that other contractors may reasonably be able to meet the government's needs, possibly through minor adjustments to the plans/specifications and/or remedial action objectives and remediation goals, the government should not use sole source procurement.

With regard to commercial availability of an item (which could be considered a "standard product") required under the terms of the contract, there is ordinarily an implied government warranty that such items will be commercially available. Thus, if a sole source supplier is out of business at the time of award, the government would, thus, likely be liable for ramifications resulting from having required a non-procurable specification.[14]

The lead agency for RD could consider publishing a notice in the Commerce Business Daily (CBD) near the end of design to advertise that the government is considering sole source procurement for an item, and possibly publishing the justification the agency prepared to use for the sole source procurement. If vendors other than the sole source express an interest and can provide an 'equal' performance for the government's needs, the lead agency could then reconsider the sole source contracting mechanism and/or strategy being taken.

Competitive procurement can also be made for the entire project, with only the technology's 'black box' (e.g., patented item) being a sole-source procurement. Any responsive and responsible contractor would be considered competitive, as long as one of the subcontractors is the sole source vendor. If, for example, five proposals from different prime contractors are received that all identify a certain subcontractor for implementing the innovative technology portion of the contract, a sole source procurement occurs. In a related manner, this occurred in EPA Region 3 for an RA at the Alladin Plating site, where all potential bidders identified the same Treatment, Storage and Disposal (TSD) subcontractor for offsite disposal of excavated hazardous wastes. The EPA Region 3 contracting officer determined that even though the RD did not require a specific offsite TSD, the low bidder was required to submit cost and pricing information in order to make a determination that the costs were fair and reasonable.[23]

3.2.2. Patent issues

3.2.2.1 General

Patents for innovative technologies will periodically play a role in selecting and implementing remedies in Superfund. For example, remedies involving soil vapor extraction, in-situ vitrification, thermal desorption, bioremediation, chemical extraction, and chemical treatment have been patented wholly or in part by the process, technology and/or specific component. Although a relatively new factor in the Superfund Program, patent rights have been a long-standing concern of the Federal Government. FAR Part 27 , "Patents, Data, and Copyrights," is written in a manner that protects the mutual interest of the contractor and the government, and encourages the contractor to develop and patent innovative technologies. When new technologies are conceived, a contractor may elect to retain the title to an invention. If the new technology is conceived in performance of a government contract, the government retains a royalty free, non-exclusive, irrevocable license for use of the invention.

Ownership of, or rights in, a patent does not by itself qualify a prospective contractor for sole source treatment. In fact, the U.S. Comptroller General adopted a position in 1958 disfavoring preferential treatment of patentees or licensees. The contracting party (government) may, however, acquire a patent license prior to entering into a contract; this might put an unfair advantage or disadvantage to unlicensed sources during procurement. Notice of such a license should be placed by the government in the solicitation to advise offerors (potential contractors for the construction who have placed a proposal to the government's Request for Proposal (RFP,) or a bid to the government's Invitation for Bids (IFB)) that if the offeror has not received a license, their bid will be increased by the royalty the government is obligated to pay[24].

EPA's Superfund Program prefers options for obtaining license rights to use patents. Instructing contractors to risk patent infringement or initiating a patent challenge are the least desirable options, since this would be contrary to EPA's and the Federal government's policy of creating an environment favorable to the development of new and innovative technologies. However, in limited cases, decisions to not obtaining license rights to use patents might be necessary, even though such decisions might risk patent infringement or initiate a patent challenge. Prior to selection of a patented technology for use, EPA should consider the necessity and reasonableness of the royalty, the cost for use of the patent, and the options to provide for competitive procurement, if any[25].

A strategy involving formation of a team comprised of government contracting officers, technical representatives knowledgeable of the technology and legal personnel knowledgeable in patent law would be an effective approach for properly dealing with patents in Superfund. Once the patent holder and patent validity are determined by a patent lawyer, it would be up to the team to determine what would cause or not cause a project to infringe on the patent, and consider whether and how to obtain a license for its use.

3.2.2.2. Infringement, Royalties and Licenses

Infringement of a patent consists of an unlicensed making, using or selling a patented invention. If a patent is infringed by or on behalf of the government, a patent owner's sole remedy is under 28 USC 1498 against the government in the U.S. Claims Court for "reasonable and entire" compensation. The government does not take the property, strictly speaking, and the government's contractors cannot be enjoined from using a patented invention. The government generally uses previous case law to determine "reasonableness;" the royalty generally should not exceed the lowest rate at which the licensor has offered or licensed a public or private entity. To ensure that the work of a contractor is not enjoined by reason of patent infringement, a FAR "authorization and consent" clause should be invoked by the government. The government may also shift the financial burden for patent infringement to the contractor by including a FAR patent indemnity clause in the contract. Use of this clause is limited to construction or service contracts and to contracts for supplies[24].

Prior to selecting a patented product, apparatus, or process for the remedial response, on which a royalty must be paid, the contracting party should consider: a) the necessity and reasonableness of the royalty; b) the royalty in any cost-effective analysis and as an evaluation factor in any analysis of the bid or proposal; c) the use of performance type specifications for competitive procurement of a royalty-free product, apparatus or process; and d) the use of bid or proposal alternatives to each proposed patented product, apparatus, of process on which a royalty must be paid[26].

The following determinations regarding infringement should be made as soon as possible prior to 'start up' of the patented technology, process, or item (i.e., the technology, process or item mechanically begins the treatment process for which it was designed and constructed,) or if treatability studies on the patented technology are planned: a) clear infringement of a patent (negotiate a license agreement generally at the patentee's royalty fee, if determined to be reasonable); b) clearly no infringement (conduct procurement without further ado); or c) a gray area regarding infringement (negotiate a license agreement, possibly for less than the patentee's specified royalty fee.)

EPA has planned for obtaining license rights to patented treatment technologies. Basic ordering agreements (BOA) for treatment technologies are recommended, and EPA has developed a standardized or model BOA for this purpose.[27] The model BOA provides the terms and clauses for agreements to obtain license rights for treatment technologies in Superfund.

After taking into account the foregoing suggestions, it may be desirable to negotiate with the patent owner to receive a license for patent use. Royalties for existing patents are generally considered allowable costs as long as the costs are reasonable. In order to help ensure national consistency, any government agency carrying out a Fund-lead Superfund remediation that is planning to negotiate for and receive a license for patent use of an innovative technology at a Superfund site should contact EPA's Design and Construction Management Branch prior to initiating the negotiations.

3.2.2.3. Federal Acquisition Regulation

CO's have the responsibility to apply FAR Part 27 to any Superfund project. For Federal-lead construction project RFP's and/or IFB's involving procurement of patented technologies, certain FAR clauses should generally be invoked in the RFP/IFB clauses and/or specifications. This is recommended in order to provide the maximum allowable assurances the government can give to potential offerors or bidders that the government would, under certain circumstances, assume the liability associated with potential patent infringement and/or authorizes the use of a patent.

These clauses are: 1) FAR 52.227-1, "Authorization and Consent," paragraphs (a) and (b) only (no Alternates); 2) FAR 52.227-2, "Notice and Assistance Regarding Patent and Copyright Infringement," paragraphs (a,) (b,) and (c); and 3) FAR 52-227-4, entitled "Patent Indemnity-Construction Contracts." FAR 52-227-4 Regarding FAR 52.227-4, the present single paragraph of this section should be designated (a,) and 'Alternate I' of this section should be designated (b) in the clause use in the RFP/IFB.

FAR 52.227.3, "Patent Indemnity," should not be invoked in construction contracts, since FAR 52-227-4, "Patent Indemnity-Construction Contracts," applies and should be used. EPA Regions, with the Director of EPA's Procurement and Contracts Management Division approval, may invoke FAR 52.227-5, "Waiver of Indemnity," into an RFP/IFB, providing that the patents are identified by number. If -5 is used, it may not be necessary to also invoke -4, since -4 uses a description of the patented technology, and -5 identifies the patent by number. Government CO's should provide direction on this matter.

FAR 52.227-4 and/or 5 are inserted into construction contracts in order to provide protection to contractors if they will infringe a patent when carrying out the construction according to specification. It should be noted that a waiver of indemnity may not necessarily cover the contractor from all lawsuit costs if a patent is infringed, since the government can only provide contractor protection to the extent that is authorized by statute and regulation. If only the authorization/consent and indemnity clauses were invoked (without the waiver of indemnity clause,) costs for infringement would likely be borne by the government due to FAR 52.227-1.

3.2.2.4. State-Lead Projects

Part 35.6565(d) of the Subpart O EPA Grants Regulation notes that noncompetitive proposals may be procured if the item desired by the government is known to be only available from a single source, or after solicitation of a number of known sources is shown to be noncompetitive. In this situation, this section notes that the state must request use of sole source for this item from the EPA Regional award official (usually either the Superfund Division Director or the Regional Administrator) and provide a justification for its use, as well as conduct a cost or price analysis, and a profit analysis giving consideration to the establishment of a fair and reasonable profit, in accordance with the requirements set forth in part 35.6585.[20]

State procurement laws and regulations may also have additional requirements in order to sole source. An investigation into this, including discussions with Superfund Program managers, Counsel and the Federal and state agency's Grants Administration Divisions and contract specialists, should be conducted.

3.3. Acquisition Planning

3.3.1. General

As noted previously, Superfund remediation projects might be considered more prone to problems and changes than non-Superfund construction projects, since they have incomplete performance or cost information, and few, if any, vendors have sufficiently proven their expertise in implementing these technologies. When dealing with high risk procurement, it generally is worthwhile to spend additional effort in the planning stages prior to procurement to ensure that the best possible strategies are considered and utilized.

3.3.2. Pre-Record of Decision (ROD) and ROD

3.3.2.1. RI/FS Treatability Studies

The NCP identifies EPA's emphasis on the need to perform treatability studies early in the remedial process. It notes that since innovative technologies may not have been as thoroughly demonstrated as other technologies, treatability studies during the Remedial Investigation and Feasibility Study (RI/FS) may be necessary to provide an appropriate evaluation of these technologies. The goal is to, "through good science and engineering, establish the probable effectiveness of innovative technologies." If treatability studies are conducted, EPA can eliminate those innovative technologies which have little potential for performing well at specific sites[28]. It is especially important to conduct treatability studies, and where appropriate, pilot-scale testing of innovative technologies during the RI/FS, in order to better understand a technology's advantages and disadvantages. These studies and tests will also provide important information with which a proper detailed analysis of a remedial alternative against the 'nine criteria' may be conducted during the FS.[5] The nine criteria encompass statutory requirements and include other gauges of the overall feasibility of remedial alternatives. Analyses performed pursuant to the nine criteria (e.g., reduction of toxicity, mobility, or volume through treatment; cost; implementability;...) concludes with selection of a remedy that meets the statutory mandates.[29]

An inventory of treatability study vendors has been prepared and continually updated through EPA's Office of Research and Development (ORD.) This can be used to gather information regarding the availability of vendors to conduct a particular treatability study for a specified technology. In addition, treatability studies conducted to date on particular technologies have been gathered by ORD for use by the Superfund program and general public. Benjamen Blaney, Kenneth Dostal or Joan

Colson of EPA's Risk Reduction Engineering Laboratory in Cincinnati Ohio may be contacted for more information regarding these documents, at (513) 569-7406. These reports have been computerized through EPA's ATTIC program. Although some difficulty regarding data retrieval has been reported, information on ATTIC can be gathered by calling (202) 382-5747.

EPA's Off-Site policy and RCRA (40 CFR 261.4) regulation allows up to 1000kg of waste to be brought off-site to a non-permitted facility for treatability testing without obtaining permits; separate facilities for separate tests can each receive up to 1000kg of waste. After testing is done, the EPA project manager may authorize the residuals to be returned to the site and stored until the RA begins. Some concerns have been raised that 1000kg of wastes (approximately three drums) may not be sufficient to conduct an adequate treatability study. 40 CFR 261.4 allows the EPA Regional Administrator to authorize an additional 500kg of wastes to be transported offsite for these purposes. It may even be possible to bring more than 1000kg at one time to a non-permitted offsite treatability facility by: a) immediately beginning 'treatability testing' on up to 1000 kg of the wastes; and b) storing up to 1000kg of the wastes on the property of the treatability facility according to RCRA storage requirements. Storing wastes on a transportable tanker, truck, etc. at a separate facility in a manner complying with the RCRA waste transportation requirements might also be an option to bring more wastes offsite for these purposes. Concurrence on these and potentially other options should be received from the appropriate EPA Regional RCRA and/or RCRA Authorized State regulatory contact.

If the waste is considered acutely toxic, a treatability exclusion may not be allowable. Also, a 45 day waiting period may be required to allow for a treatability exclusion, unless the State in which the treatability tests will be conducted is delegated RCRA and has waived this requirement.

3.3.2.2. Forward Planning

Complete forward planning activities must be conducted prior to the initial RI sampling; these should include historical gathering of data regarding what contamination was dumped at the site or caused the site to be listed on the NPL. Properly conducted early rounds of sampling could then reveal, through experienced and best engineering judgement, what two or three remedies would likely be most successful at the site, including whether conditions would favor use of an innovative technology. As early as possible during the RI, forward-thinking government and private engineers and scientists, with strong, field-tested experience in hazardous waste design and construction and well versed with lessons learned in both procurement/contracting and technical issues, should be solicited for their judgement on all of these decisions.

These efforts would result in more pilot studies of innovative technologies being conducted during RIs, and might prevent losses in time and money due to non-implementable RODs. More accurate cost and implementability estimates can be made during the FS, and a stronger technical database can be developed to help scope any additional design investigations that might be required to properly procure an RA contractor and construct the technology.

3.3.2.3. Community and Public Input

Community input as it relates to innovative technologies should not be put off until the formal public comment period, since more time may be needed to understand the advantages of the technology. Any uncertainties and short-term impacts, including mitigating measures, should be presented to the community. On-site, pilot scale treatability studies should be coordinated with the community prior to starting work.[5] In addition, it is recommended that the formal public comment period be used to provide commercial interests with an opportunity to comment on the government's plan for sole source procurement, if applicable. This strategy of providing a period of time for comment before remedy selection, and of properly responding to comments received in the responsiveness summary, provides for enhanced 'due process,' and stronger justification for sole source procurement might be realized. Also, the potential for future claims might also be lessened.

3.3.2.4. Cost Estimating

It is recommended that Feasibility Studies should develop order of magnitude cost estimates for RA alternatives which have a desired accuracy of +50 percent to -30 percent.[30] Properly conducted pilot studies can generate the data needed to estimate the RA and O&M costs of the technology within this desired accuracy. In addition, the potential license cost to construct and operate a patented technology should be considered during FS alternative analyses.

3.3.2.5. Interim Action RODs

The NCP identifies that interim actions may be undertaken at a site to address a pressing problem which will worsen if not addressed quickly. Examples of interim remedies include construction of temporary caps to control or reduce exposures, or on-site containment structures into which highly mobile and toxic contaminants may be placed. An interim remedy must be followed by a final remedy which provides long-term protection of human health and the environment and fully addresses the principal threats and the statutory preference for treatment remedies.[18,31]

The concept of addressing contamination on an interim basis is not a new idea. In European countries, highly mobile and toxic soils and media found at abandoned waste sites are commonly excavated and placed into conveniently located containment structures. These materials, once contained, are then studied in a methodical manner to determine which technology would best treat the waste. Should an innovative technology be considered but fail or not perform satisfactorily, another technology or approach is considered. Since the wastes are contained, considering innovative means to deal with the waste need not necessarily result in a worsening of the problem if failure during testing occurs[32]. Interim remedies, particularly temporary caps over highly mobile surface soil contamination, should be considered and used more often in the Superfund Program; such actions might further the use of innovative technologies at sites.

3.3.2.6. Contingency RODs

When selecting innovative technology remedies with uncertainties for success during remediation, and a pilot scale treatability studies are proposed during design, proven, non-innovative technologies could be included in the Proposed Remedial Action Plan (PRAP) and ROD as contingent remedies. If two different innovative technologies appear to be equivalent during FS evaluations, one may be identified as the selected remedy and the other as a contingent remedy. Information contemplated by the ROD but developed after its issuance may encourage the lead Agency to select the contingent remedy.[1]9 The PRAP should and the ROD must identify the preferred alternative or selected remedy and the contingency remedy. In the FS, both remedies should be featured in the Alternatives Evaluation section as able to fulfill the statutory requirements of Section 121 of CERCLA. An "Explanation of Significant Differences" (ESD) should be issued and made available to the public if the contingent remedy will be implemented during RD, RA, or O&M.[33]

The 'two-headed' ROD option helps move innovative technology projects through the pipeline quicker since, if the innovative technology pilot study or the construction/O&M fails to meet the performance goals identified in the ROD, design of the contingent remedy can immediately begin without the need to reopen the ROD and solicit additional public comment. Further, parallel designs of both the selected and contingent remedy might also be considered beneficial, in order to ward off the potential loss of time should the selected remedy fail.

Caution is recommended when selecting and implementing contingent remedies. A remedy should only be selected if there is strong reason and justification that it will be successful. The EPA Region should also not automatically begin implementing a contingent remedy if the selected remedy is not initially meeting the ROD's performance goals during it's RD treatability study or RA; adjustments to the selected remedy's RD treatability study or RA should be attempted before abandoning the remedy as non-implementable.

3.3.2.7. Non-Inhibitory ROD Language

The selected remedy in a ROD can appropriately or inappropriately narrow the scope of technologies available and able to treat wastes at a site. The generic type of technology or treatment family can be described when choosing a remedy. Specific process options within those categories should be described if there is confidence that those options will be used. For example, an alternative can be described as employing thermal destruction rather than rotary kiln incineration if other than rotary kiln thermal processes are potentially usable.[34] With this expansion of potential remedies which could be used, a performance-based design could then be prepared. This might be preferable since any advancements or expansions of the number of specific technologies in the generic treatment family since the ROD was signed can be considered.[35]

However, certain drawbacks may exist with choosing generic RODs. An ESD might potentially be required when the decision for a specific technology to implement a generic ROD is made. Also, Applicable or Relevant and Appropriate Requirements (ARARs) for the RA are generally considered 'frozen' at the time of ROD signing; ARARs promulgated after that time should not be required provided such ARARs could have been identified before the ROD was signed. If a component of a remedy is not identified at the time of ROD signing (e.g., a particular form of thermal treatment such as rotary kiln incineration,) requirements in effect when the component is later identified during RD or at time of RA contract award will be used to determine ARARs.[36] Thus, for example, if new RCRA treatment standard requirements were placed on rotary kiln incinerators in 1989, but a 1987 ROD identified that rotary kiln would be used, only the RCRA requirements for rotary kiln treatment in 1987 would need to be met. However, if a thermal treatment ROD were identified in 1987, and the decision to used rotary kiln were made in 1990, the 1989 requirements must be met.

In addition, the NCP identified the need for better accuracy in and stronger reliability of RI/FS cost analyses.[37] Generic alternatives generally cannot have a detailed cost analysis, since the specific remedy is not identified; less certainty in the overall cost of the remedy would result, and inaccurate RA cost planning might occur.

Generic remedies or technologies can maximize competition and potentially prevent bid protests or claims during RD/RA. These benefits are especially important when choosing innovative technologies as the sole remedy, since, in general, few vendors or companies will have experience in implementing them, and competition is limited. With the above concerns in mind, it is encouraged that EPA Regions consider generic remedies during remedy selection.

3.3.2.8. Sole Source

In certain cases, only one technology, process or potentially only one vendor can and will be considered/determined able to address the risks at a site before finalization of the ROD (e.g., in-situ vitrification.) In this situation, the PRAP and ROD should clearly specify that that technology, process or particular vendor's material, product, or service is the only available item that can properly address the risks at the site. The rationale for such focus must be clearly provided in the PRAP and ROD; a complete cost and market analyses and other activities identified under Section 3.2.1. of this paper should be conducted during the FS to justify such a decision.

The FS should consider the availability of and ability to procure necessary equipment and specialists, specifically during the implementability and cost analyses of alternatives. As noted previously, the public could provide an early review and comment on the sole source option in the PRAP, and the ROD would address the public's concerns in a responsiveness summary. A strong rationale for conducting a sole source procurement would then be available, and a detailed design specification using sole source to procure the particular item might then be possible without further need to brainstorm and consider other procurement options during design. This rationale would serve as the basis of the "Justification and Approval" effort required by Federal and state government contracting officers who will utilize "other than full and open competition" during RA procurement.

3.3.3. Pre-Design Planning

3.3.3.1. Pre-Design Technical Summary (PDTS) and Remedial Management Strategy (RMS)

"The Preliminary or Design Report Phase" is customary between the planning and design phases of engineering projects.[38] During this phase in Superfund the ROD and supporting documents are converted to a statement of work (SOW) for RD/RA by expressing EPA's technical and managerial requirements. The Pre-Design Technical Summary (PDTS) and Remedial Management Strategy (RMS,) completed during the pre-design planning phase, link the scientific site assessment and the engineered solution. The PDTS is a comprehensive compilation of technical information to ensure that the designer fully understands the technical objectives of the RA. The RMS identifies the number and type of procurement methods, and types of contracts and specifications applicable to the remedy[39]. The actual decisions regarding which procurement strategy and type of contract and specification to be prepared will be proposed by the design contractor, and reviewed by, discussed with and approved by the lead and support agencies.

The current EPA policy for pre-design planning is that the lead agency is responsible for brainstorming and developing a 'project delivery strategy' which will be folded into the SOW for RD/RA. RMS and PDTS concepts are part of that strategy - they need not be formally prepared, but the thought process identified in both documents must be completed prior to the SOW. Preferably, this thinking occurs during the FS, specifically during the implementability and detailed cost analysis of alternatives evaluation. If an innovative technology alternative's design, construction or O&M will have significant technical difficulties or unknowns, will pose substantial risk for success, or will create a procurement nightmare, ramifications therein should be considered and balanced against its benefits and those of other alternatives prior to its selection as the remedy.

3.3.3.2. Design vs. Performance Specifications.

All specifications must be as clear, complete and definite as possible, as well as not be unduly restrictive. They must contain the essential physical characteristics and functions required to meet the minimum needs of EPA, not the maximum desired.[40] The party contracting for RA warrants that the RA contractor will be able to fulfill its responsibilities if it makes a good faith effort to follow "design" specifications which precisely state how the contract is to be performed. If the RA contractor fails to comply because the contract documents are inadequate, the contracting party bears the risk of loss. In contrast, if the party contracting for RA allows the contractor discretion in how to meet the contract obligations by providing "performance" specifications and no explicit statement of how to design or build the item is provided by the contracting party, the inability to complete the contract is borne by the RA contractor. If the RA contractor has undertaken an impossible task, meets technological problems, or cannot complete performance because of its lack of experience, the contractor and not the contracting party, bears the risk of loss.[41]

Performance specifications generally encourage innovation and competition and allow contractors flexibility in approaching a design and construction item which has intentionally not been precisely designed. Unless: a) a technology can be efficiently and properly designed to ensure little risk of failure; b) competition is reasonably expected; and/or c) a sole source procurement is planned, performance specifications for the procurement of innovative technologies is recommended.

3.3.3.3. Contract Type and Method To Be Used

3.3.3.3.1. General

There are several key references to help determine the proper contract method and type to be used during procurement of hazardous waste projects. The nature of the project, the degree of risk willing to be accepted, and level of 'known unknowns and unknown unknowns' are discussed, and excellent comparative analyses regarding the pros and cons of each, are provided.[14,19,39,40,41,42,43]

Two primary contract methods may be used for the procurement of supplies, services, and RA. These are the solicitation of sealed bids (formal advertising method) and the request for competitive proposals (competitive negotiation method.) The term "contract type" has several different connotations. Often it is used to indicate the various methods of pricing arrangements, of which there are two basic types: fixed-price contracts and cost-reimbursement contracts. In considering the appropriate competitive procedures to be used, a public agency should determine: a) the time available for the solicitation, submission, and evaluation of offers; b) if the award will be made on the basis of price, other factors or a combination; c) if it is necessary to conduct discussions with the responding source about their offers; and d) if there is a reasonable expectation of receiving more than one offer.[41]

The FAR permits the government a variety of choices in selection of contract type. The Government decides where it wishes to place its resources and risk in the completion of a project. Fixed price contracts force the Government to do a thorough investigation and design prior to solicitation; these contracts minimize risk allocation to the Government and have the lowest price at the time of solicitation. The other types of contracting allow an expedited solicitation while placing greater demands on the Government in contract administration, risk allocation and potential cost.[43]

The following is a brief and generalized overview of the applicability of specific contract types and methods for innovative technology procurement, and is based on certain references.[14,19]

3.3.3.3.2. Contract Type To Be Used (FAR Part 16)

3.3.3.3.2.1. Fixed Price

Due to the lack of proven cost data, firm fixed-price (lump-sum) specifications for innovative technologies may generally not be in the government's best interests. This type should only be used when the specifications and costs can be tightly defined.

3.3.3.3.2.2. Unit Price

Under unit price contracts, the government estimates quantities and pays on the actual costs. Due to the unknowns associated with these technologies, this type is generally recommended since some cost risk is shifted away from the contractor.

3.3.3.3.2.3. Cost Reimbursement

Under cost reimbursement contracts, the government also shares in the risk, and provides a means for the government to enhance its knowledge base. Costs involved are actual, not those determined by a contractor trying to consider all possible contingencies during the solicitation. Modification to the technology during the contract is easier to accomplish. These contracts require substantial government construction contract management[43] in the form of heavy oversight, in order to assure that the costs are 'actual.'

3.3.3.3.2.4. Indefinite Delivery

For this type of contract the maximums and minimums for each order are set. Although it may be preferable for service procurement, this contract type might not be preferable for innovative technology procurement.

3.3.3.3.3. Contract Method To Be Used (FAR Part 13)

3.3.3.3.3.1. Small Purchase

If the cost for procuring a technology or an item is under $25,000, less formal justification for sole source is required.

3.3.3.3.3.2. Sealed Bidding

The sealed bidding method is time consuming and the contract is awarded based on price; no discussion with the offerors is necessary. Quality, price, and business reputation usually cannot be bargained for. As such, it is generally not recommended for innovative technologies.

3.3.3.3.3.3. Negotiation (RFP)

Negotiation is involved in most procurement methods other than sealed bidding, and is generally recommended for innovative technology procurement. Bids must be responsive, but can be negotiated. Performance specifications for this method are preferred. The government identifies which offeror is in the 'competitive range,' and negotiations commence to award to the firm with the best combination of factors identified in the RFP and their proposal. For innovative projects, key factors include experience, personnel qualifications, past performance, cost, and technical excellence. Selection should be based on competence, cost, and ability/experience with other similar projects.

A key advantage with negotiated procurement is that it allows the Government discretion in selecting a successful offeror. The Government, through a source selection plan, determines evaluation factors, relative importance of the factors and importance of the cost differentials of the offers. Government evaluators use weighted evaluation factors as a guide in selecting the best offer. Inclusion of these factors in relative order in the RFP informs potential offerors of the areas considered critical by the Government. The offeror can limit its risk by further defining its proposed actions within the specifications, and seeking clarification on technical issues which could reduce their risk and subsequent offer.[43]

3.3.3.3.4. Modified Two-Step Sealed-Bid through Prequalification of Vendors and/or RA Constructors

3.3.3.3.4.1. General

Consideration should be given towards 'prequalification' of potential vendors and/or constructors for RA of an innovative technology; certain technologies with multiple possible vendors (e.g., chemical extraction and soil washing) might best be procured this way. For instance, at the beginning of design, an announcement can be made in the Commerce Business Daily (CBD) calling for the prequalification of vendors by conducting pilot-scale studies on wastes at the site over a given period of time during design. Information regarding the remedy, cleanup goals, type and concentrations of contaminated media, and other pertinent information should be provided. In order to encourage competition, the government might pay some of the costs for the pilot studies (e.g., lab testing.) A reasonable amount of time should be provided to those who might conduct such studies. All vendors who performed satisfactorily (e.g., met the cleanup goal) would then be considered 'prequalified'.

The government would conduct discussions after prequalification to solicit criteria the vendors feel should be put in the plans and specifications on which they would bid for the project. At this time the government should consider asking for plans and specifications of the treatability systems used by the vendors. After a solicitation for this information, the government would carefully assess the information from the pilot studies and discussions with vendors, and prepare a set of plans and specifications on which competitive sealed bids would be made. The treatment process would be a performance specification, for which the low bid would be awarded the project. The Chemical Control site in New Jersey used this approach for procurement of a vendor to perform solidification/stabilization; although this is a non-innovative remedy, the procedure is applicable to innovative projects.[44]

An alternative to the above is to conduct the CBD solicitation at the completion of design. In some respects, competition would be enhanced since additional time for new vendors to come into the marketplace is provided. However, conducting the call for vendors after the design is completed might unduly restrict competition. As such, the government should consider conducting two CBD solicitations: one at the beginning of design as discussed above, and one at the end of design. The second solicitation would be for sealed bids, and allow companies who did not attempt to prequalify to bid. These companies would be provided samples of the waste to be treated, and required to submit information in the form of pilot or bench study data, and/or plans and specifications for their process in sufficient detail to allow the government to make a judgement that that process would have reasonable chance for success in meeting the performance goals. If one of these companies were the low bidder, they would be awarded the contract, possibly on a contingent basis. If no pilot study data were submitted with the bid, the contractor would construct their process at no charge to the government to full scale at the site. If the process could not meet performance goals, the contractor would demobilize at no charge to the government; the next lowest bidder with pilot study data would be awarded the contract.

3.3.3.3.4.2. Treatability Studies

EPA is limited in the number of treatability studies it can perform at a site. Competition would likely be increased by using a prequalifying method which provides samples of site wastes to prequalified vendors who can prove they can treat the waste at their facility. It is likely that vendors will invest in a test during design rather than RI/FS, since the RFP for a specific technology is forthcoming. Depending on the need for design data, the results of vendor treatability study data may or may not be incorporated into the RD specifications. If the data is not needed, independent vendor tests could occur at the same time as design activities, so as not to delay the project. Prequalification requirements could include permitting at the vendors facility, ownership of pilot or full-scale equipment, a proper QA/QC plan, and provisions for residual disposal. Providing vendors with the opportunity to conduct these tests might make it less likely that a bid protest will occur if a treatability vendor wins the RA contract;[21] the number of responsive and responsible bidders capable of meeting the treatment goals would have been narrowed in a justifiable manner, and protests from those not capable of meeting such goals can be determined to be non-responsive.

3.3.3.3.5. Service Contract using Competitive Proposals

A fixed price combination of lump sum and unit price may be an option for innovative technologies. A service contract may be procured using competitive proposals, and bonds would not be required. Evaluation criteria might weigh technical concerns at 60%, with price weighing at 40%. Construction specifications for soil excavation would be written; since 'construction' is occurring, wage rates subject to the Davis Bacon Act would apply. Service specifications, with the principal purpose being to treat contaminated soils using a mobile treatment unit, would be used; unit price per cubic yard treated would be the measurement and payment basis. The government would pay if the treatment goal were achieved.[45]

3.3.4. Remedial Design (RD)

3.3.4.1. General

As noted previously, the actual decisions regarding which procurement strategy and type of contract and specification to be prepared will be proposed by the design contractor in their RD Work Plan. The firm would use all information gathered to date to assist in developing this strategy. The RD workplan is the first major design deliverable, provided soon after the design contract is awarded to the firm, and is reviewed by, discussed with and approved by the lead and support agencies.

This effort, the design field investigation, or value engineering efforts might result in a decision to expand the procurement to a more generic category if it was convincingly determined that other technologies might also achieve the ROD's remediation goals. If an inappropriately narrow ROD has been issued, the EPA Region should consider preparing a documentation of non-significant differences, an ESD or a "ROD Amendment" as early as possible during the design phase to prevent major disruptions to the project schedule or cost.

3.3.4.2. Data Gathering

Accurate data on heat transfer, mixing, separation, etc. gathered during design, or even the RI/FS, might provide for better design reliability and greater confidence, thus likely lessening an offeror's potential bid contingencies to cover unknowns and reducing the overall cost of the RA. Interviews with a number of potential vendors and/or construction firms who might be candidates for the construction of the innovative technology soon after the ROD might help guide the direction of the RI/FS and/or design data gathering effort. Among other things, information regarding what engineering or investigatory data would be needed to bid the project should be discussed.

Information regarding the availability of data, including what physical/chemical data collected to date, and how it can be retrieved, should be identified. Materials information, particularly volume estimation with a basis of calculations, should be provided.[46] In general, four major categories of site characterization data are needed to effectively remediate subsurface contamination, including source remediation. These data categories include site data, geochemical data, geotechnical data, and hydrogeological data.[47]

3.3.4.3. Treatability Studies

As noted previously, it is recommended to conduct pilot-scale treatability studies of innovative technologies prior to finalization of the ROD. During the design phase, in order to make more realistic judgments regarding construction costs, and to help in deciding what risk exists regarding whether the technology will meet the performance goals set in the ROD, it might be useful to scale-up the pilot scale treatability study.

For example, at the Wide Beach site in New York State, a ROD for "chemical treatment" was signed, and a treatability study during the RD using potassium polyethylene glycolate (KPEG) dechlorination was conducted. An RFP for PCB dechlorination was advertised, but required a demonstrated technology which has proven it could treat wastes similar to those at the site. The prime contractor awarded the RA had KPEG as the PCB dechlorination process and used the same vendor who did the treatability studies as a subcontractor. The selected vendor went directly from pilot scale to full scale on-site remediation (from a 40 gallon pilot reactor to eight 3000 gal reactors.) Although the project is considered successful, a potentially significant cost savings might have been realized if the designer had scaled up and fully tested one of the 3000 gal reactors. As noted previously, this data could have provided more accurate data on heat transfer, mixing, separation, etc. to the offerors and/or bidders for the RA. This data would have provided better design reliability and greater confidence, thus likely lessening an offeror's potential bid contingencies to cover unknowns and reducing the overall cost of the RA.[48]

It is possible that further treatability studies beyond those conducted during the RI/FS may not be required in design; verification testing at the start of actual site cleanup may suffice.[35] However, it should be carefully investigated whether RI/FS treatability studies are sufficient to properly design the remedy, provide sufficient information to potential offerors and/or bidders, and provide for competitive procurement, as discussed previously.

3.3.4.4. RFP and/or IFB Instructions to Offerors and Clauses

Throughout the remedial pipeline but particularly near the end of design, design contractors and government contracting officials should critically evaluate the risk of innovative technology procurement success and failure to the government, design firm, and construction contractor. This assessment of risk should play an important role in determining what instructions to offerors and clauses will be inserted into the RFP and/or IFB. The government has an obligation to inform the potential RA construction firm of known 'unknowns' of the project in the specifications. Special consideration should be given to inserting and/or reinforcing the following clauses and/or instructions if innovative technologies are being procured: a) Patents, Data, and Copyrights; b) claims and change order procedures; c) termination for convenience; d) variation in quantity; e) change in site conditions; f) certification of performance; g) suspension of work; h) measurement and payment; and i) default.

3.3.4.5. RD Claims Review

A "claims prevention" review should be conducted as part of the prefinal design review to eliminate conflicts, inconsistencies, ambiguities, errors, omissions or other identifiable problems in the plans, specifications and contract documents that may become the source of change orders and claims. This review should attempt to eliminate unduly restrictive specifications and review "brand name or equal specifications" to assure that salient characteristics to be met are specified.[49] Several key papers were presented on claims and change orders between May 1-3, 1991 in Dallas TX at EPA's 'Design and Construction Issues at Hazardous Waste Sites' national conference; these papers should be referenced for more information regarding how to prevent these issues.

3.3.5. Remedial Action (RA) Documentation

Heidi Facklam of the U.S. Army Corps of Engineers (USACE) has reported that RD/RA's need to be properly documented and evaluated; in particular, construction records, conditions and activities should be recorded and preserved in a readily accessible form. Data regarding construction modifications and changed conditions, long term performance monitoring and site maintenance, and baseline information for design of repair/modifications in case of failure should be systematically gathered and prepared jointly by the design and construction staff. The knowledge gained and lessons learned during the construction process would provide valuable insight for future construction projects. Documentation reports for this type of information have been required for nearly one hundred years for USACE engineering structures.[50]

Due to the inherent unknowns associated with innovative technology implementation at Superfund sites, a standardized and routine documentation effort similar to that required for USACE projects would provide a vital service by eventually lessening the procurement risks associated with such technologies. With the availability of such standardized and readily accessible reports, actual cost data could be analyzed, designs could be improved and RA change orders minimized. In the absence of a specific national guidance and/or policy for such documentation, it is recommended that USACE's documentation requirements as outlined in Ms. Facklam's report be followed immediately.

3.4. Enforcement Considerations

The following four considerations are provided regarding Potentially Responsible Parties (PRPs) and innovative technology RODs: (1) PRP concerns generally focus on cost and continued liability in the event of remedy failure or implementability problems. If a treatment remedy fails or costs are relatively high compared to other arguably effective remedies, PRPs will attempt to argue that EPA is not entitled to full cost recovery. It is therefore important to conduct treatability studies during the RI/FS stage. (2) Contingent RODs can improve or detract from the lead agencies negotiating position, depending on the contingencies involved. It is therefore important to clearly identify the expected performance levels for the innovative technology in the ROD, or negotiation delays will result. (3) When practicable, contingent RODs for two innovative technologies could provide an opportunity to generate design-specific data related to the performance of the technology prior to the final specification of the technology to be implemented. This might allow PRPs to achieve performance requirements without necessarily being required to implement the most expensive remedy. However, costs associated with the RD treatability testing of a non-selected innovative technology contingent remedy may be challenged in cost recovery.[5] (4) As noted previously, generic alternatives generally cannot have a detailed cost analysis; less certainty in the overall cost of the remedy would result, and potential difficulties in settlement negotiations with PRPs interested primarily in the 'bottom line' (costs) might occur.

4. CONCLUSION

4.1 Summary

EPA's Superfund 90-Day Study[6] makes clear that better ways to enhance the development of innovative technologies are needed. EPA's PCMD has made several efforts to help eliminate constraints to the procurement of treatment technologies, and has pledged to continue to work with the Superfund Program to explore ways to expand the use of innovative technology.[51] EPA's Office of Solid Waste and Emergency Response, and in particular the SITE Program and the Remedial Operations and Guidance Branch of the Hazardous Site Control Division, have also made progress towards this goal. These efforts should and will continue.

The following constitutes a summarization of considerations which might help reduce constraints to the procurement of innovative treatment technologies:

A) Spend additional efforts in the planning stages prior to innovative technology procurement to ensure that the best possible strategies are considered and utilized. A team of those associated with the site should meet soon after the ROD to brainstorm; the team should include: a) government contracting officers, project managers, legal counsel and technical representatives; b) government contractors (including RI/FS and design) and construction representatives; and c) potential offerors, bidders and/or vendors.

B) Continue to sponsor national conferences on a yearly basis which help introduce promising international technologies through technical paper and poster displays, and showcase SITE and other domestic innovative technologies. On an annual or biennial basis, continue to conduct a national conference geared towards design and construction issues at hazardous waste sites, in order to have an open exchange of ideas and promote formal and informal discussion of design and construction issues. PRPs, private organizations such as the Hazardous Waste Action Coalition and the American Council of Engineering Consultants, States, Federal agencies, and private construction firms, vendors, consultants, corporations, and individuals should all be actively solicited for their participation and insight. These conferences will encourage national consistency, help develop more efficient and practical means to move innovative technology projects through the pipeline, and augment EPA's current efforts to revise its Superfund remediation guidance and policies.

C) Increase involvement of top engineering colleges and graduate schools in the research and development of new and improved innovative technologies, particularly in the civil, environmental, chemical and mechanical disciplines. Many of the graduates of these schools join those organizations leading the effort in hazardous site remediation; their efforts can strongly influence the regulated community. In addition, as students, they comprise an excellent form of relatively 'cheap labor.'

D) Utilize performance specifications vs. design specifications when feasible since they encourage innovation and competition and allow contractors flexibility when approaching a design and construction item.

E) Interview a number of potential vendors and/or construction firms who might be candidates for the construction of the innovative technology soon after the ROD. Develop a checklist of items to be asked, including what specifications should be performance vs. design, what contracting type and method are recommended, what engineering or investigatory data would be needed to bid the project, etc. Use the interviews to help guide the direction of the design and/or construction.

F) Increase the emphasis on the use and development of national innovative technology databases of treatability studies, treatability study vendors, and post construction reports. These databases should be user-friendly and accessible to anyone.

G) Increase the consideration and use of interim remedy temporary containment options and/or Regional facilities which address certain forms of contamination or provide certain types of treatment.

4.2 Concluding Comments

It has been eminently stated that "innovation is a mandate in the Superfund program. Innovation and project complexity involve cost, time, and performance risks because of the lack of precedent...there shall be compromises...The terms of the compromises - including inexperience, overly restrictive technical or managerial requirements, pressures of deadlines and economy in cost - vary the shape of the project to be designed...wise and carefully selected technical and managerial requirements (must be set..).Unfortunately, compromise implies a degree of failure. It is then the responsibility of the designer to obviate failure within the context of the technical and managerial requirements articulated (by the government...) It is, however, impossible for any design to be 'the logical outcome of the requirements' simply because, the requirements being in conflict, their logical outcome is an impossibility."[41]

A Physics Professor commenced his first thermodynamics lecture by rewording the three thermo laws: 1) You can't win; 2) You can't break even; 3) You can't get out of the game.[52] At one time or another, those with experience in Superfund might feel this Professor has unwittingly and neatly described the Program. Since 'we can't get out of the game,' early and well reasoned procurement planning can speed the development and success ratio of innovative technologies at Superfund sites. We might 'win' or at least 'break even' more frequently, and continue to improve the methods used in Superfund to provide protection of human health and the environment.

5. DISCLAIMER

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Your comments on the utility of this paper and how it might be improved to better serve the Superfund program's needs are encouraged. Comments may be forwarded to the attention of Kenneth Ayers, Design and Construction Management Branch, USEPA, Mailcode OS-220W, Washington DC 20460.

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Trial Burn at MOTCO Superfund Site
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Dallas, Texas May 1-3

INTRODUCTION

At the MOTCO Superfund Site, the MOTCO Trust Group and the U.S. Environmental Protection Agency (EPA), have begun incinerating 11 to 15 million gallons of waste, consisting of waste oils, and industrial process wastes including styrene tars, vinyl chloride, and small concentrations of PCBs, mercury and lead. The purpose of this paper is to discuss the initial trial burn and the results. The discussion will also include operational difficulties and potential concerns of an incinerator.

BACKGROUND

In May 1990, the EPA approved a plan for conducting trial burns of hazardous waste in two incinerators called Hybrid Thermal Treatment System (HTTS) units, constructed onsite. One unit, HTTS-2, will be used to process solid material, sludges, aqueous waste, and organic liquids. The second unit, HTTS-3, is processing aqueous waste and organic liquids.

In early operations, the incinerators were tested using uncontaminated dirt, water, and oil. On May 23, 1990 waste was introduced into HTTS-3 unit to begin to bring the incinerator up to full operation. IT Corporation conducted three pretests on July 4-5, July 25-26, and September 6. The trial burn for the HTTS-3 unit started October 9 and was completed on October 12. The HTTS-3 unit is continuing to burn waste at conditions based on the operating parameters demonstrated as safe during the pretests.

The results of the initial pretest conducted by the MOTCO Trust Group on July 4 and 5 met the performance standards for the Destruction Removal Efficiencies (DREs) of 99.9999% for carbon tetrachloride and 1,1,2 trichloroethane, and 99.99% for napthalene. The emissions of particulates or solid particles did, however, exceed the performance standard of an allowable concentration of 0.08

grains/dry standard cubic foot during the first two pretests. Therefore, in August, IT installed a Hydro-Sonic Super-Sub steam assembly to increase the particulate removal. Results from the pretest conducted on September 6 show the particulate level met the performance standard.

Trial burn results were received by the EPA on February 27, 1991. Incineration of all onsite waste material is expected to take at least 14 months after the trial burn of HTTS-2. Delisted ash from the incineration process will be disposed of onsite, and, after the project is completed, the process equipment will be dismantled and removed from the site. An impervious clay cap will be constructed onsite over the delisted ash and covered with a layer of topsoil. The area will then be graded and seeded, and a security fence will be installed. The MOTCO Trust Group, with EPA oversight, will monitor the property for at least 30 years to ensure site safety and protection of human health and the environment.

DISCUSSION

DESIGN AND OPERATION (OF THE HTTS-3)

OVERALL CONFIGURATION

The HTTS-3, a liquids incineration, consists fundamentally of the following functional components:

(1) the waste and fuel preparation and feed system;

(2) the combustion chamber;

(3) the quench chamber;

(4) the gas conditioning system;

(5) the dual Hydrosonic scrubber units;

(6) the induced draft fan;

(7) the stack.

In addition, auxiliary equipment required for supplying, recycling, conditioning and purging the quench/scrubber liquids contributes to the overall functioning of the gas cleaning system.

The inter-relationships of the various components of HTTS-3 are shown schematically in Figure 1. Also shown in their approximate locations are the various points of sampling of the flow streams of the incineration process.

A portion of the fuel and liquid waste feeds are pumped to burners/injectors in the upper section of the HTTS-3 burner chamber. Both primary and secondary combustion air are introduced into this section of the HTTS-3 combustion chamber. Near the top of the bottom combustion chamber, additional waste oil and aqueous waste can be introduced. The minimum 2-second retention time would be computed on the basis of the remaining chamber volume, starting somewhat below the last (vertical) point of introduction of waste, and the actual volumetric flow rate of the combustion gases.

The combustion gases then flow in sequence through the gas cleaning system, consisting of the quench chamber, the gas conditioning system, and the Hydrosonic scrubber, and through the induced-draft fan and up the stack. Caustic is added at certain points in the gas cleaning system so that the acid

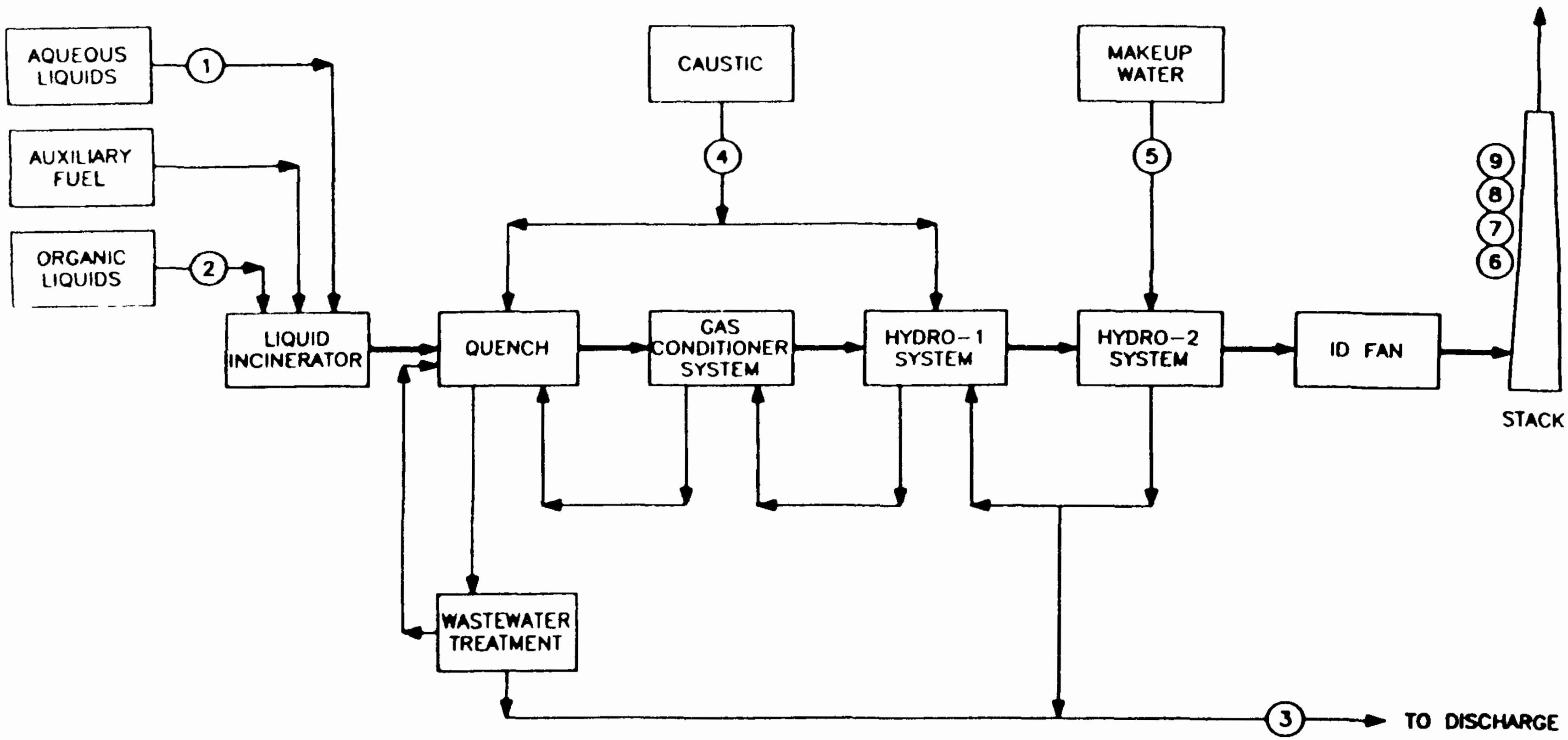

FIGURE 1. SCHEMATIC FLOW DIAGRAM OF MOTCO SITE HTTS-3 AND SAMPLING POINT LOCATIONS

gases, HCl and SO_2, as well as particulates are removed from the combustion gas stream before it is discharged to the atmosphere.

Many additional supporting items of equipment needed for introducing fuel, waste, and combustion air, and for removing various wastes generated are an inherent part of the overall system. The digital electronic control system, supplied with instantaneous information by various sensors, measuring intensive and extensive parameters, are used for observing and controlling the system operation.

OPERATIONAL DIFFICULTIES

Observed difficulties in operation can be considered to stem primarily from two sources. First, the waste oil feed was not sufficiently characterized from a process standpoint. This was in spite of the multitude of samples taken and analyzed during the Site Investigation (SI) and Remedial Investigation (RI) phases of this project. Characteristics such as viscosity, viscosity index, surface tension, and polymerization potential, important to operation of the incineration system, are generally not measured or considered significant when the evaluation of risk is of primary concern. And, follow-up testing to define these additional characteristics was not performed prior to system design.

Second, the combustion characteristics of the wastes were not measured or evaluated. This aspect proved to be important because of the distribution of particulate sizes passing through or generated during the combustion process.

An early difficulty in the operation of the incineration system was an observed inability to feed sufficient quantities of waste oil through the waste oil burners. This was due to the undersizing of the motor and pump used for this purpose. Lack of understanding of the viscosity characteristics of the waste oil led to this event. Even though the waste oil feed was heated to lower its viscosity, a several factor increase in pump size and drive horse power was needed to achieve satisfactory operation.

The heating of the waste oil feed to achieve lowered viscosities resulted in another problem, again, at least partially due to inadequate characterization of the waste oil. The problem manifested itself as plugging of lines, valves, burner nozzles, etc. This plugging was attributed to polymerizing of components of the waste oil into highly viscous, adhering materials which would coat surfaces and plug flow-line components. The lack of recognition of this potential difficulty probably goes back to inadequate SI and RI sampling techniques for obtaining representative samples of highly volatile materials such as styrene.

Waste characterization did not identify the process problems that would be caused by the presence in the waste oil of millions of tiny, floating plastic beads. These beads rapidly clogged filters, valves, etc., and just as rapidly shut down the waste oil injection system. The procedure for rectifying these plugging problems was very time-consuming and required disassembling, cleaning out the various components, and then reassembling the waste oil feed system.

During the pretest leading up to the trial burn for the HTTS-3, it was observed that particulate loadings in the stack were somewhat above the 0.08 grains/standard cubic foot regulatory standard. After consideration of the possible causes for this and discussions with the Hydrosonics unit manufacturer, the site remediation contractor concluded that the size distribution of particulates generated was the cause of poor performance of the gas cleaning system. There was a much higher concentration of less than -0.5-micron-sized particles than might be expected. Thus, a so-called Supersub component, for which space had been provided in the original design, was installed and implemented. The particulate loadings then decreased into the acceptable range.

POTENTIAL CONCERNS

Concerns at the MOTCO site relate to the potential for human health and environmental risks for off-site areas and for safety and human health risks for personnel working onsite. Releases of potentially toxic and hazardous materials can originate from exposed onsite materials or from the dispersion of emissions and residues resulting from materials processing and incinerator operation. The potential concerns and the mechanisms for assuring control are summarized in Table 1.

The adherence to documented and approved protocols for site operations will satisfy both off-site and onsite protection and control purposes. So, the concern then is to assure that the incineration process itself will provide the destruction of the waste hazardous materials to a high degree of effectiveness and that any potentially hazardous materials in the emissions are effectively controlled. Such assurance is the objective of the trial burn.

Table 1. Potential Concerns of Site Emissions

Source	Medium	Assurance of Control
Incinerator Stack	Gas/Vapor	Incinerator operating conditions and gas composition
	Particulates	Incinerator operating conditions and plume opacity
Incinerator Residues	Incinerator Ash	EP Tox or TCLP
Site Fugitive Emissions	Gas/Vapor	Perimeter Monitoring
	Particulates	Perimeter Monitoring

Emissions from the stack are the primary concern. These emissions could have small concentrations of hazardous materials vapors or have small amounts of particulates. These uncollected particles could have adsorbed hazardous vapors and contain toxic metals. Thus, the stack sampling, to be discussed later, has the objective of measuring the quantities of potentially harmful materials emitted to assure that the emission levels are satisfactory from two standpoints: First, the DREs must be at least as high as those specified by the regulations for the toxic and hazardous organic materials being treated. And, second, the particulate emissions must be lower than the limits imposed by air pollution control regulations.

As a potential portion of the stack emissions, acid gases formed in the combustion process also must be controlled, as specified by regulations. The acid gases generated in the incineration include HCl, SO_2 and NO_x.

Ultimately, the dispersion in the air of all potentially harmful emissions must be sufficient, before reaching any receptor location, to achieve extremely low concentration levels. These extremely low concentration levels are those needed to assure negligible risk to humans and the environment. Thus, the emission values measured and achieved during the trial burn testing and controlled thereafter by specifying the operating conditions to be those under which they were achieved are those which provide the assurance of negligible risk.

All other residues from the site operations and incinerator operation ultimately end up in the incinerator ash, since all other residues will be processed by the incinerator. The incinerator ash is analyzed by TCLP (Toxicity Characteristic Leaching Procedure) or by methods shown to be equivalent or representative to show its suitability for disposal back to the site.

Thus, all potential concerns are resolved by: 1) performing the trial burn to establish suitable operating conditions, 2) assuring negligible risk through dispersion calculations and risk assessment, and 3) analyzing the ash to show its acceptable nature.

OPERATING CONDITIONS

As indicated previously, the objective of the trial burn tests is to verify the performance of the incinerator system. That is, the operating parameters demonstrated in the trial burn must be shown to provide the DREs required and, also, to provide sufficient control of other potentially harmful materials generated in the combustion (incineration) process. These other potentially harmful materials are the acid gases and particulate matter.

Time, temperature, and oxygen concentration are the regulatory conditions which are specified and which must be met to assure adequate DREs. Nominally, these values must be at a minimum: 2 seconds, 2012°F and 3 percent, respectively. In addition, there must be sufficient turbulence in the combustion chamber to provide the intimate mixing of the combustion gases, thus assuring intimate molecular level contact of oxidizer and organic species. Continuous verification of the efficacy of the organic destruction process is provided by the measurement of CO levels in the stack. Low levels, 0 to 10 ppm, indicate a highly efficient combustion process. A limit of 100 ppm (as a 1-hr rolling average) is used as a cut-off value.

Temperature, oxygen, and CO levels are intensive variables and thus can be directly measured. Residence time, on the other hand, must be computed from two extensive values, combustion gas flow rate and combustion volume. Combustion volume is generally taken as that volume where the gas temperature and oxygen are at the required levels to achieve rapid organics destruction.

The performance achieved in the trial burn of the HTTS-3 unit is summarized in Table 2. These conditions form the basis for the permissible operating conditions for site materials remediation.

Table 2

Comparison of Regulatory Requirements with Operating Conditions

Performance Characteristic	Regulatory Requirement	Trial Burn Operating Conditions
Combustion Chamber Temperature	>2012°F	2080, 2079, 2080°F
Total Heat Release		64.6, 68.5, 55.0 x 10^6 Btu/hr
Pressure Drop Across Gas Cleaning System		42.5, 41.3, 42.2 in. H_2O
Stack gas Flow Rates		43,772, 44,638, 44,451 acfm
Retention Time (Based on 2880 cu ft combustion volume)	>2 sec	3.95, 3.87, 3.87 sec
CO (maximum) (Based on 99.9% combustion efficiency)	<120 ppm @12.0% CO_2	3, 0, 0 ppm
Oxygen Concentration	>3.0%	4.1, 3.9, 3.9%

ACHIEVEMENT OF PERFORMANCE STANDARDS

During the conduct of the trial burn for IT Corporation's HTTS-3 at the MOTCO Site, sampling of the waste feed streams, sampling of the scrubber influent and effluent, sampling of the incinerator ash and sampling of the stack gases were performed. Three (3) replicate sampling runs were required to be conducted for each different process operating condition. An operating condition is defined as the same waste stream, feed rate, temperature and excess oxygen condition. If any of these are changed, a new operating condition is defined.

For some incinerators, the owner/operator may want to change one or more of the following: 1) increase the feed rate, 2) change a waste stream, 3) lower the combustion chamber temperature or 4) increase the oxygen or combustion air flow to the incinerator. Any one or more of these changes will constitute a new operating condition, thus requiring a separate set of three (3) replicate sampling runs. IT Corporation decided to conduct the trial burn under one operating condition. All three (3) replicate runs were required to meet the performance standards of the RCRA Regulations. These performance standards are shown in Figures 2, 3 and 4.

Figure 2. Destruction & Removal Efficiency for each POHC

$$DRE = \frac{W_{in} - W_{out}}{W_{in}} \times 100$$

where:

W_{in} = mass feed rate of one POHC in the waste stream feeding the incinerator, and

W_{out} = mass emission rate of the same POHC present in exhaust stack prior to release to the atmosphere.

The DRE for each POHC must be ≥ 99.99% for RCRA and 99.9999% for TSCA

Figure 3. Particulate Emission Rate

$$P_c = P_m \times \frac{14}{21 - Y}$$

where,

P_c = corrected particulate concentration in the stack, gr/dscf,

P_m = measured particulate concentration in the stack, gr/dscf and

Y = measured concentration of oxygen in stack gas, % using the Orsat method.

The Particulate Concentration, P_c must be ≤ 0.08 gr/dscf

Figure 4. Hydrogen Chloride (HCl) Emissions

An incinerator burning chlorinated waste and producing stack emissions of more than 4 lb/hour of HCl must control the HCl emissions such that the rate of emission is no greater than the larger of either 4 lb/hour or 1% of the HCl in the stack gas measured prior to its entering any air pollution control equipment.

The HCl removal efficiency of the APC device must be ≥ 99%

Sufficient waste was available in order to be able to complete all three (3) sampling runs for the specific operating condition approved in the Trial Burn Plan. Since each sampling run took six (6) hours to complete, only one (1) run was completed each day.

The results of the trial burn which were reported by IT Corporation are presented in Table 3 and Table 4. It should be noted that the data presented in this paper in Table 3 and Table 4 have not been validated by EPA, Region 6.

It was agreed upon in the Trial Burn Plan that carbon tetrachloride and trichloroethane would be used as surrogates for demonstrating the destruction and removal efficiency for PCBs. The DRE required was 99.9999%. Since naphthalene was a constituent in the waste and it is a solid at room temperature, it was also selected as a compound to demonstrate the DRE of 99.99%

If ultimately verified, the data shown in Table 3 indicate that the HTTS-3 incinerator met the DRE requirements for the three organic compounds and met the particulate emission concentration of 0.08 gr/dscf. The gaseous pollutants, CO, O_2, NO_x and SO_2 all met the stated objectives. In addition the opacity of the plume and the combustion efficiency of the incinerator met the stated objectives.

Table 4 shows the metal removal efficiencies for the spiked metals. The emission rates of dioxins, furans and PCBs are also shown in Table 4. The removal efficiency of HCl is shown in Table 5. The removal efficiency exceeded 99.0% for the HCl generated in the combustion gases.

CONCLUSIONS

Despite the operational and weather-related difficulties encountered, the trial burn runs necessary for proving the performance of the HTTS-3 were completed successfully. Currently, the results presented by the Trial Burn Report are being validated by EPA.

Operational problems encountered might have been mitigated somewhat by better physical and chemical characterization of the feed materials prior to system design; the characteristics would include items such as: viscosity, viscosity index, surface tension, and polymerization potential.

Better design of the gas cleaning system might have been achieved if the particle size distribution and amounts generated during combustion were evaluated earlier.

Perimeter monitoring assures that site emissions are being sufficiently controlled.

REFERENCES

- IT Corporation, May 30, 1990, Trial Burn Plan

- IT Corporation, February 1991, Trial Burn Report for HTTS-3, Report Volumes 1-3

- 40 CFR paragraph 264.343 Performance Standards

TABLE 3 PERFORMANCE SUMMARY FOR TRIAL BURN

PARAMETER	UNITS	OBJECTIVE	RUN 1	RUN 2	RUN 3
DRE - CARBON TETRACHLORIDE	%	> 99.9999	> 99.99993	> 99.99994	> 99.99996
DRE - 1,1,2 TRI-CHLOROETHANE	%	> 99.9999	> 99.999996	> 99.999997	> 99.999994
DRE - NAPHTHALENE	%	> 99.99	> 99.998	> 99.998	> 99.998
HCl REMOVAL EFFICIENCY	%	> 99	> 99.90	> 99.92	> 99.94
HCl EMISSIONS	lbs/hr	< 4	< 0.90	< 0.79	< 0.71
PARTICULATE MATTER (a)	gr/dscf	< 0.08	0.073	0.049	0.059
CARBON MONOXIDE (a,b,c)	ppm	< 100	3	0	0
OXIDES OF NITROGEN	lbs/hr	< 10.3	5.9	5.2	5.1
SULFUR DIOXIDE	lbs/hr	< 31.17	0.7	3.8	1.3
VISIBLE EMISSIONS	% opacity	< 20	1	10	10
COMBUSTION EFFICIENCY	%	> 99.9	99.99	99.99	99.99

TABLE 4 PERFORMANCE SUMMARY FOR TRIAL BURN

PARAMETER	UNITS	OBJECTIVE	RUN 1	RUN 2	RUN 3
METAL REMOVAL EFFICIENCIES:					
As	%	-	> 98.4	> 97.7	> 96.7
Be	%	-	> 94.8	> 94.9	> 93.9
Cd	%	-	> 90.3	> 90.0	> 86.7
Cr	%	-	96.7	96.6	95.3
Pb	%	-	88.4	91.8	84.7
DIOXIN/FURANS					
2,3,7,8 TCDD	ng/m3	< 10	< 0.2	< 0.2	< 0.2
TOTAL TCDD	ng/m3	< 10	< 0.3	< 0.3	< 0.4
TOTAL PCDD	ng/m3	< 10	< 1.3	< 1.3	< 1.4
2,3,7,8 TCDF	ng/m3	< 10	< 0.2	< 0.2	< 0.2
TOTAL TCDF	ng/m3	< 10	< 2.6	< 2.6	< 2.7
TOTAL PCDF	ng/m3	< 10	< 5.0	< 5.0	< 5.2
TOTAL PCB EMISSIONS	lb/hr	-	< 1.4E-04	< 1.4E-04	< 1.5E-04

(a) Corrected to seven percent oxygen, dry basis.
(b) One hour rolling average.
(c) Dry basis

TABLE 5 HCl REMOVAL EFFICIENCIES

	Units	RUN 1	RUN 2	RUN 3
HCl Generated	g/hr	4.28E+05	4.66E+05	5.01E+05
	lb/hr	943	1027	1105
HCl Emission Rate	g/hr	< 409	< 359	< 322
	lb/hr	< 0.90	< 0.79	< 0.71
HCl Removal Efficiency	percent	> 99.90	> 99.92	> 99.94

Construction of Groundwater Extraction Trenches

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INTRODUCTION

At the Millcreek Superfund Site, located in Erie County Pennsylvania, the remedial activity was divided into three (3) phases: I) ground water extraction trenches and collection sumps, II) treatment plant and pumps and piping necessary to transfer ground water from sumps to plant, and III) closure cap and flood retention basin. Each phase was to be performed via separate contract. The contract mechanism for Phase I of the remedial activity, the ground water extraction trenches and collection sumps, was a negotiated delivery order under a pre-placed remedial action contract. During pre-award negotiations with the contractor, a continuous trenching machine was chosen as the means for installing the extraction trenches in view of the potential cost savings and the attractive safety aspects from limited confined space entry. The trenching machine selected by the contractor was capable of excavating the trench, installing piping to a depth of approximately twenty (20) feet, and backfilling with select granular material all in one operation. This paper addresses the operation of the trenching machine and the problems/experiences associated with this relatively innovative trenching technique.

BACKGROUND

The Millcreek site is an 84.5-acre tract of land located in Millcreek Township, Erie County, Pennsylvania, which is situated in the northwest corner of the state along the southern shore of Lake Erie. The site is adjacent to a highly developed residential and commercial area within the Township of Millcreek. The topography is relatively flat, with sparse vegetative growth in the central portion of the site. A wetland of approximately four acres lies southeast of the site, and the eastern edge of the site lies within the 100-year floodplain of Marshall's Run, an intermittent stream bordering the east side of the site. The average fill depth on-site is approximately seven feet, and the depth to ground water on the site varies from zero to several feet.

The site was once a 75-acre freshwater wetland. Between 1941 and 1981, all but 4 acres were filled with foundry sand and industrial and municipal waste, including drums of solvents, waste oils, polyester resins, ink wastes, caustics, paint wastes, slag, construction and demolition debris, including creosote-treated railroad ties, and municipal refuse.

The Pennsylvania Department of Environmental Resources (PADER) first advised the landfill operator to cease operations in August 1980. In July 1982, at the request of PADER, five monitoring wells were installed by the Millcreek Township on the Township's 4-acre parcel of land. A hazard ranking score was determined after a United States Environmental Protection Agency (USEPA) Technical Assistance Team performed a site assessment in August 1982. USEPA Region III's Remedial Investigation, completed in 1985, discovered extensive soil, sediment, and surface water contamination. The major classes of compounds detected included:

- Volatile organic compounds (VOC's) such as vinyl chloride; trichloroethylene; 1,2 - dichloroethylene (acetylene dichloride); 1,1,1 - trichloroethane (methyl chloroform); 1,2 - dichloroethane (ethylene dichloride); and 1,1 - dicholorethylene (vinylidene chloride) in the ground water.

- semi-volatile organic chemicals such as bis-(2-ethylhexyl) phthalate, naphthalene and benzo (a) pyrene in on-site fill materials;

- Polychlorinated biphenyls (PCB's) in the fill and in some sediment samples, and;

- lead in the fill.

In addition to the contaminants listed, numerous other metals, polynuclear aromatic hydrocarbons (PNAs) and phthalates were detected in the fill materials.

On May 1, 1986 the USEPA issued a Record of Decision (ROD) which proposed remedial actions for the site based on the Remedial Investigation/Feasibility Study (RI/FS). In 1989, a pre-design study was completed in which remedial actions were recommended to:

- prevent the air dispersion and off-site transport of contaminants;

- prevent direct contact with contaminants by humans and wildlife; and

- reduce soil, sediment, surface water and ground water contaminant concentrations to levels acceptable to the USEPA and the PADER.

The selected remedial actions for the site included:

- consolidation of contaminated soils and sediments under a soil cap;

- site grading/placing a vegetated soil cover over low-level contaminated soils;

- construction of surface water management basins and ditches;

- installation of additional monitoring wells; and

- extraction and treatment of contaminated groun water.

As stated previously in the Introduction, this paper deals exclusively with the installation of the system that was designed to extract the contaminated ground water. The groundwater extraction system was designed to remove contaminated ground water down gradient of the site contamination. The extraction of contaminated ground water would prevent continued off-site migration of the contaminants and would possibly capture some contaminants already down gradient of the site.

Extensive ground water modeling was performed during the Remedial Clean-up Treatability Study to simulate steady state flow through the shallow water-bearing zone beneath the Millcreek Site and to model movement of contaminants in this ground water. The Prickett-Lonnquist Aquifer Simulation Model (PLASM), (Prickett and Lonnquist, 1971) was used to simulate two-dimensional flow of ground water collection alternatives. A second model, the RANDOM WALK Mass Transport Model (Prickett, et al., 1981), was used to simulate horizontal movement of the contaminant plume on the site.

The groundwater modeling provided data on the required location of the collection trenches and the volume of water to be removed from each of the trenches. From the modeling results, it was determined five (5) trenches would be required and the optimum location would be the northeast corner of the site. The results also indicated extracted flows of 8016, 2759, 14067, 16936 and 38621 gpd for Trenches 1 through 5 respectively, for a total volume of 80,339 gpd. With the exception of Trench 3, water levels in the trenches were lowered to an elevation of 700.00 feet, which was approximately fourteen (14) feet below existing grade. The water level in Trench 3 was lowered to 699.00 feet. The trench system was designed to extract flows at rates above these levels, and the hydraulics of the systems are more than adequate to accommodate this intent.

Prior to selection of the collection trenches, several alternatives were considered during the initial design stage. A site-wide network of extraction/recharge wells was eliminated from consideration as a remedial alternative due to the low potential yield of the contaminated aquifer. Modeling indicated that the pumping of individual wells at a rate of 24 gpm as listed in the ROD would result in required differential heads in excess of 80 feet. Field investigations substantiated this with data indicating that only low sustained yields (less than 5 gpm per well in recent field tests) could be produced from individual on-site wells.

A series of well-point systems was also considered, but this alternative was abandoned in light of the superior long term reliability of the collection trenches. Major factors that contributed to the selection of the trenches over the well-point system were: 1) the trench system provides a continuous capture over the length of each trench, 2) extraction velocities from the trenches are significantly lower, thereby reducing the potential for siltation, and 3) less mechanical equipment is required for the trench system, thereby reducing maintenance costs and downtime resulting from mechanical failures.

DISCUSSION

DESIGN CONSIDERATIONS

The collection trenches were designed so that contaminated ground water could be extracted and treated rather than migrate from the site. Trenches 1, 3 and 5 located along the northern edge of the site were to be installed to the top of the underlying glacial till layers at depths of approximately 24, 26 and 24 feet respectively. Trenches 2 and 4 along the eastern edge of the site were to be installed to the interface between the coarse and fine sediments at depths of approximately 22 and 20 feet respectively.

Each collection trench, as originally designed, consisted of the following items: a 200-foot section of 6-inch diameter slotted polyvinyl chloride (PVC) Schedule 80 pipe; a solid PVC Schedule 80 clean-out section, which added approximately 30 feet of additional piping, including a flushing riser; a 4-foot diameter precast concrete collection sump for future installation of duplex submersible pumps (under Phase II of the project); a shut-off plug valve with valve box; a piezometer located approximately midway between the flushing riser and the collection sump; and a two-stage granular filter pack in the trench.
The pipe diameter of 6 inches was specified to facilitate periodic cleaning of the system. Although a 4-inch diameter line could have been specified since it could be cleaned by standard sewer flushing jets, the 6-inch line provided extra assurance against any flushing problems.

Schedule 80 slotted PVC pipe was specified because it has excellent chemical resistance, it is capable of withstanding the loading at the depth of trench required, and because of the variation of slot sizes available, it could be used in conjunction with the two-stage granular filter pack to provide excellent drainage capacity. The width of the slots was specified to be 0.020 inches.

The two-stage granular filter pack was designed to work in conjunction with the slotted pipe with no requirement for a filter fabric to control silting. This would eliminate the chance of clogging of the filter fabric. The gradation of the primary sand pack around the pipe was specified to provide a granular material that would not contaminate the pipe, i.e., it would have particles large enough to be contained outside the pipe and not slip through the 0.020-inch slots in the pipe.

The specified gradation for the primary sand pack was as follows:

Sieve Designation	Percentage by Weight Passing Square-Mesh Sieves
No. 10	100
No. 40	0-5

The specified gradation of the secondary sand pack was based on the existing soil conditions at the site. The specified gradation for the secondary sand pack was as follows:

Sieve Description	Percentage by Weight Passing Square-Mesh Sieves
No. 4	98-100
No. 10	75-90
No. 20	40-60
No. 40	12-40
No. 60	0-20

Top-of-cover elevations for monitoring wells and flushing risers, and top-of-slab elevations for collections sumps were based on existing grade.

CONVENTIONAL METHOD VS. TRENCHING MACHINE

Prior to award of the contract, the selected contractor was requested to provide bid proposals on two types of methods of installation, the conventional method and a method utilizing a trenching machine. The conventional method employs tight sheeting and dewatering, with confined space entry required to work in the trench. The trenching machine incorporates trench excavation, pipe insertion and placing of select granular fill material in the same operation. The apparent advantages and disadvantages of each method are described below:

Conventional Method - provides for clear controlled inspection of backfill procedures during construction and thus provides a more consistent final product. This controlled inspection also provides the necessary data for a conventional quality assurance/quality control program. The method does, however, require major excavation, tight sheeting and dewatering and the employment of confined space entry techniques whenever workers are inside the excavation. The proposed cost for this method was $3.62 million.

Trenching Machine Method - does not require a sheeted trench. With the exception of the sump installation, all work can be performed on the surface, thereby minimizing the safety hazards associated with confined space entry. It also eliminates the need for large excavations, which, in turn, should result in a time savings. However, this method does not provide the opportunity for visual inspection of the backfill and therefore, there is the potential of undetected bridging of the backfill material leading to a gap in the filter pack and, ultimately, a silting problem. The proposed cost for this method was $2.46 million.

In light of the potential cost savings, the minimization of safety hazards and the push for innovative technologies, the trenching method was selected. Inherent with this method were several design changes, as listed below:

1. Change in material composition of the pipe from slotted Schedule 80 PVC to slotted corrugated high-density polyethylene drainage tubing conforming to AASHTO M252 with a geotextile filter sock. The diameter of the tubing remained as originally designed, i.e., 6 inches.

2. Change in granular filter pack from two-stage to single stage. Single stage sand pack was of the same gradation of that specified for the secondary sand pack of the two-stage sand pack.

3. Change in trench width from 30 inches to 14 inches.

CONSTRUCTION SEQUENCE

The initial phase in constructing the trenches, as is the case in almost any construction operation, was clearing and grubbing. All refuse, except salvageable timber, was chipped and stockpiled at a designated area on site. This stockpile area was secured by a permanent chain-link fence installed by the contractor. Salvageable timber was stored separately on site for inspection by the property owner at a later date. The areas cleared for installation of each trench were approximately 75 feet wide and 350 feet long.

Control points for each trench were installed at the outermost edges of the cleared areas. The cleared trench areas were secured by erecting a snow fence around the perimeters of each area. Silt fence was installed along the northern and eastern boundaries of the site to control sediment runoff from the cleared areas.

The contractor elected to construct one complete trench at a time, although the specifications allowed concurrent construction. The sequence described in the following paragraphs applies to the construction of one complete trench.

The next step was the installation of the concrete collection sump, which required dewatering and shoring to depths of approximately 25 feet. Localized dewatering at the first sump area was attempted by installing a shallow trench upgradient using the trenching machine. This dewatering approach proved ineffective, and after several modifications, the upgradient trench was abandoned in favor of a well-point system. The ground water removed through the well-point system was pumped to a holding tank and then transferred via another pumping system to a ground water disposal area designated by the Government and permanently secured via a chain-link fence.

The top elevation of each sump was established at 714.5 feet mean sea level (MSL) to permit consistent grading throughout the entire site. The existing ground surrounding the collection sumps and trenches was eventually graded to an elevation of 714 feet MSL.

The excavation for the collection sump was accomplished using a track-mounted excavator. The excavated soil, since it was considered contaminated, was placed in dump trucks or front-end loaders and was transported to the designated excess soil storage area. This area was within the chain-link fence enclosure for the chipped debris stockpile previously discussed.

A standard Occupational Health and Safety Administration (OSHA) approved trench shield was used to shore the collection sump excavation. The steel trench shield was similar to that used for utility trenches. The dimensions of the trench shield were 24 feet long by 6.5 feet wide by 10 feet high. Once the trench shield was in place inside the excavation, 1-inch thick by 24-feet high by 10-feet wide steel plates were driven down the outside of the trench shield to below grade, using a vibratory hammer. These steel plates were braced to secure the excavation.

Prior to placement of the precast concrete sections of the collection sump, a layer of crushed stone bedding, 12 inches thick, was placed in the excavation to support the basin. Each section of the sump was placed in the excavation using a track-mounted excavator. The top section of the sump contained pipe sleeves for electrical service and piping to be installed under Phase II of the project. Material was then partially backfilled around the lowest section of the sump in preparation for placement of the plug valve and piping accessories.

Upon completion of the collection sump and prior to placement of any additional backfill, a preassembled unit consisting of a five-foot section of solid Schedule 80 PVC pipe, a six-inch plug valve, and a one-foot section of solid Schedule 80 PVC pipe was lowered into the excavation. The free end of the longer section of pipe was attached to the collection sump using a gasketed flexible coupling similar to that used in sanitary sewer construction. The shorter section of pipe was for connecting the slotted polyethylene drainage tubing to the valve assembly. The valve itself rested on a three-foot square concrete pad. A valve stem was attached to the valve and extended to the ground surface to allow for operation of the valve. Eventually, when the granular material was placed around the valve assembly, a valve box was installed to protect the valve. The backfilling around the sump and valve assembly was not performed until the drainage tubing had been connected to the valve assembly and the trenching machine had placed enough tubing to eliminate the possibility of conflicts between the backfilling operation and the trenching operation.

After installation of the valve assembly, a shallow bench was excavated along the entire length of the trench to accommodate the maximum digging depth of the trenching machine. Since the trenching machine could dig to a depth of approximately 20 feet, and the trenches were as deep as 26 feet, the benches were necessary to compensate for the difference in depth. The benches were approximately 16 feet wide to accommodate the width of the trenching machine.

The trenching machine used at the Millcreek site was a 1984 Steenbergen/Hollanddrain Trencher, Model BSY-Super-S-375. It had a 375 horsepower engine and was capable of digging a trench up to 36 inches wide and as deep as 20 feet plus. In 1984, the machine, without extras, cost approximately $570,000.00.

After excavation of the shallow bench, the trenching machine was positioned along the trench line and the drainage tubing was snaked through the top of a boot attached to the digging mechanism. The tubing exited out the bottom of the boot and the leading end was connected to the short section of PVC of the valve assembly, using a watertight, flexible rubber coupling. The excavation of the trench and the placement of the drainage tubing was now ready to begin.

The trenching machine excavated the trench to the required depth and grade, laid the tubing at the specified depths and evenly distributed the select granular material around the tubing all in one operation. Both the tubing and granular material were fed through the boot attached to the digging mechanism. The tubing was fed from a large spool at the rear of the trenching machine. The digging mechanism was similar to that used on conventional trenching machines, but larger and more powerful.

The digging mechanism could be disconnected from the boot whenever necessary to reposition the machine or to remove obstacles. The tubing was fed through a large conduit in the center of the boot, which separated the tubing from the granular material while inside the boot. The conduit was curved at the bottom of the boot to facilitate laying the pipe on a horizontal plane. A dual laser guidance system was employed to insure accurate depths and to maintain uniform slopes to within 15/100 of a foot. The granular material was placed in the hopper portion of the boot, i.e., that portion outside of the conduit through which the tubing was fed. Loading of the hopper was accomplished with front-end loaders or excavators. The granular material was gravity placed from the boot and was distributed under, around and over the tubing.

Material excavated by the trenching machine was deposited alongside the trench. This material was removed daily with the use of a front-end loader and was transported to the designated excess soil disposal area on site.

Note: As the trenching machine was excavating and placing the first trench, it became obvious the further away the machine moved from the dewatered sump area, the more difficult it was for the machine to excavate and place the tubing. Finally, the tubing broke, and it was decided the same type of dewatering performed at the sump area had to be performed along the entire trench line to permit operation of the trench machine as intended. Therefore, a well-point system was installed upgradient of the trench that ran the entire length of the trench. After installation of the well-point system and the subsequent dewatering, the trenching machine worked much better and was able to excavate and place all five trenches. See Problems/Analysis for more discussion relative to dewatering.

Near the completion of the trench excavation, i.e., at the end of the trench where the flushing riser was to be installed, the tubing was curved upwards at a gradual rise to avoid a 45-degree connection, or elbow, which could not be accommodated by the trenching machine. The tubing was cut and the trenching machine was driven away from the trench area. The area where the tubing curved upward was excavated using an excavator/backhoe to expose the tubing, and the trench shield that was previously used to install the collection sump was placed around the tubing. A section of solid high-density polyethylene pipe was attached to the tubing using a flexible coupling. This section of solid pipe acted as both the lower portion of the flushing riser and as a transition between the flexible tubing and the section of solid Schedule 80 PVC pipe that was the final section of the flushing riser. The PVC pipe was connected to the solid high density polyethylene pipe with a flexible coupling also. Once all the connections were made, the trench shield was removed and backfilling around the flushing riser was performed.

At this point, additional select granular material was backfilled into the open trench to bring the top elevation of granular material to approximately 3 1/2 feet below grade. A layer of filter cloth was then placed on top of the granular material to filter out sediments and provide structural support for the clay backfill that was specified to be placed on top of the granular material. The clay material was then placed on the filter cloth in 8-inch lifts and was compacted with a dozer. Final thickness of the clay material was 30 inches. Concurrent with this operation was the backfilling of the shallow bench excavation. Once the backfilling of the clay material and the bench excavation was complete, the site was graded to facilitate proper drainage. A drilling crew then installed the piezometer approximately midway between the collection sump and the flushing riser, taking soil samples to insure the piezometer was within the confines of the trench. Finally, six inches of topsoil was placed on top of the disturbed areas, and these areas were seeded, fertilized and mulched.

PROBLEMS/ANALYSIS

A major problem associated with the use of the trenching machine at the Millcreek site was the machine's inability to trench through in-situ soil without requiring the entire length of trench to be dewatered to a depth equal to or greater than the bottom elevation of the trench. Visual classifications of the material at the trenches ranged from very loose gravel, sand and silt to medium dense gravel, sand and silt to very dense gravel, sand and silt. Blow counts experienced during test borings ranged from 1/6 inches to 50/2 inches, with the overwhelming majority less than 15/6 inches. The borings also indicated the site was nearly saturated just below the surface.

During the course of construction, another contractor that specializes in placing trenches using a trenching machine was contacted. The contractor's representative stated there had been cases in the past when the trenching machine could not place the tubing without dewatering. The frequency of this occurrence, though, was less than 1% of all projects. No definite reason for the trenching machine's failure to perform was provided.

After considerable analysis of the experiences at the Millcreek site, the most logical reasoning behind the trenching machine's failure to perform without dewatering was the excessive hydrostatic pressure created by the high water table and the mixture of in-situ silty materials. The mixture of soils and ground water created enough pressure at the bottom of the trenching machine boot that it pinched the tubing against the side of the curved section of conduit and prohibited the tubing from being placed without excessive resistance. This same hydrostatic pressure also displaced the granular material intended to encompass the tubing, thereby contaminating the sand filter pack.

A well-point system installed along the entire length of trench on the upgradient side eliminated the hydrostatic pressure problem and did permit the installation of the trenches as intended via the trenching machine. Yet the well-point solution negated one of the supposed benefits of the trenching machine, i.e., the installation of a subdrainage system without the need for dewatering.

Another difficulty encountered during the installation of the trenches was "untrenchable" material. Untrenchable material was defined as material that could not be excavated with the trenching machine. During negotiations, it was agreed the contractor would not be liable for costs associated with removing untrenchable material, and that any untrenchable material would be considered a differing site condition and a modification to the contract would be executed to compensate the contractor. Through the course of construction, untrenchable material was encountered in four of the five trenches. The untrenchable material was glacial till that was at a higher elevation than what was expected from interpretations of the boring logs. Since the intent of the design was for the trenches to be constructed just above the glacial till, the bottom elevations of the trenches were raised just enough to clear the glacial till.

Once it became evident during the initial trenching operations that the glacial till was at elevations that were higher than anticipated, the Government directed the contractor to drill test borings along the projected locations of the trenches that had yet to be excavated to pinpoint, if possible, the top elevations of the glacial till. This approach proved invaluable in that it did accurately locate the glacial till, and it enabled the contractor to adjust the trenching machine depth to avoid the untrenchable material, thereby eliminating potential impacts and delay costs.

Due to either the untrenchable material or the excessive hydrostatic pressure at the bottom of the trenching machine, there were several instances when the tubing was crushed, stretched or broken. This occurred on one occasion even after the extensive well-point dewatering system was installed. The operators of the trenching machine knew the tubing was damaged on the basis of the reaction of the tubing and trenching machine itself.

When the tubing became damaged, the contractor had to implement a construction procedure similar to that employed in installing the flushing riser. This procedure included excavating with a conventional excavator/backhoe to expose the damaged tubing, installing the trench shield, cutting away the damaged tubing, connecting the undamaged tubing to the leading end of the tubing that was protruding from the bottom of the trenching machine boot, using a flexible coupling, and concurrently removing the trench shield while backfilling with select granular material.

Obviously, this procedure was time-consuming, hazardous, and costly, and it was in the best interest of all parties to avoid, as much as possible, creating situations that could exacerbate the damage to the tubing. This rationale was the basis for the Government's directive to drill test borings along the trench lines in an attempt to ascertain the exact locations of the till material.

After construction of the trenches was completed, a series of pump tests were conducted and another problem surfaced. Several of the trenches exhibited an abnormally high hydraulic gradient between the collection sump and the piezometers. The contractor was directed to redrill some of the piezometers to insure they were within the confines of the trenches. Redrilling and the associated soil sampling indicated the original piezometers were located within the trenches, but the trenches themselves were partially contaminated with in-situ materials. One theory on how this siltation occurred is that during backfilling through the trenching machine boot, the discharged granular material, since it was discharged solely through the force of gravity, began bridging and created gaps which were filled by in-situ materials once dewatering was discontinued. A theoretical h solution to this problem is to attach an external vibrator to the trenching machine boot which would consolidate the granular material enough to minimize or eliminate any bridging within the backfill. This approach was not used on this site and it is not known whether this would effectively eliminate the bridging problem.

Another problem associated with the trench system was the valve stem. During backfilling operations, one of the valve stems was dislodged from its seat on the plug valve which rendered the valve inoperable. This unfortunate occurrence will eventually result in some repair and/or replacement work, but the extent is unknown at this time because the contractor is currently seeking approval to abandon the plug valve and install a knife-gate valve within the collection sump. In hindsight, a separate manhole for the plug valve or a manhole large enough to accommodate the plug valve and the future duplex submersible pumps would have eliminated this problem and would have provided a means of accessing the valve for future maintenance or replacement.

CONCLUSION

Under compatible subsurface conditions, ground water extraction trenches can be installed more safely and cost effectively by using a continuous trenching machine in lieu of a conventional trenching method. The key issue is the compatibility of the subsurface conditions. It is imperative that the designer conduct a thorough investigation and analysis of the subsurface conditions before specifying the trenching machine as the method for installing collection trenches. Several recommendations for owners/designers contemplating the use of a trenching machine are listed below:

1. Drill test borings along the entire length of trench to determine whether any of the in-situ material within the trench line is untrenchable, i.e., too dense to be excavated by the trenching machine.

2. Analyze the drill logs to ascertain whether dewatering of the site is required prior to trenching. The experience at the Millcreek site shows that a site containing intermixed sands, silts and gravels of varying densities, as opposed to a site with more uniform materials, may not be conducive to use of the trenching machine without extensive dewatering. However, even with extensive analysis, it may not be possible to determine whether or not the trenching machine could work without dewatering. The only true measure would be to conduct a pilot test, using the trenching machine at the site. The cost of this approach may discourage owners from selecting this method of

trench construction, but the potential cost savings associated with the trenching machine could justify the additional design costs. Also, the contract could be worded to place some of the risk on the contractor by making it the contractor's responsibility for dewatering the site, regardless of the method used. Furthermore, even if extensive dewatering is required, the potential cost savings and reduction in safety hazards achieved by eliminating the need for massive excavations, sheeting and confined space entry techniques may still justify the use of the trenching machine.

3. Specify means of insuring consolidation of the granular filter pack material to minimize or eliminate siltation within the trench. The trench width is extremely narrow (14") and it is imperative that the trench backfill be kept as clean as possible, since there is little room for error. The use of external vibrators is a possibility, as well as specifying drilling of test borings through the trench as soon as portions of the trench are placed, and prior to discontinuing dewatering, if it is required. This approach may provide the on-site construction managers with some assurance that no bridging has occurred, and in the event it has, it allows the contractor a chance to correct any deficiencies prior to final backfilling of the trench.

4. Allow sufficient time between contracts in the event the remedial activity is broken down into separate phased contracts. With the trenching machine method, there is no opportunity for visual inspection of the backfill and drainage tubing, and, therefore, there is the potential for extensive corrective construction in the event portions of the trench are found to be deficient. Specifying operating tests/inspections such as dye tests, in-line video surveillance, etc. during construction may minimize impacts and conflicts with follow-on contractors since the deficiencies, if any, could be positively identified while the trench construction contractor is still on-site.

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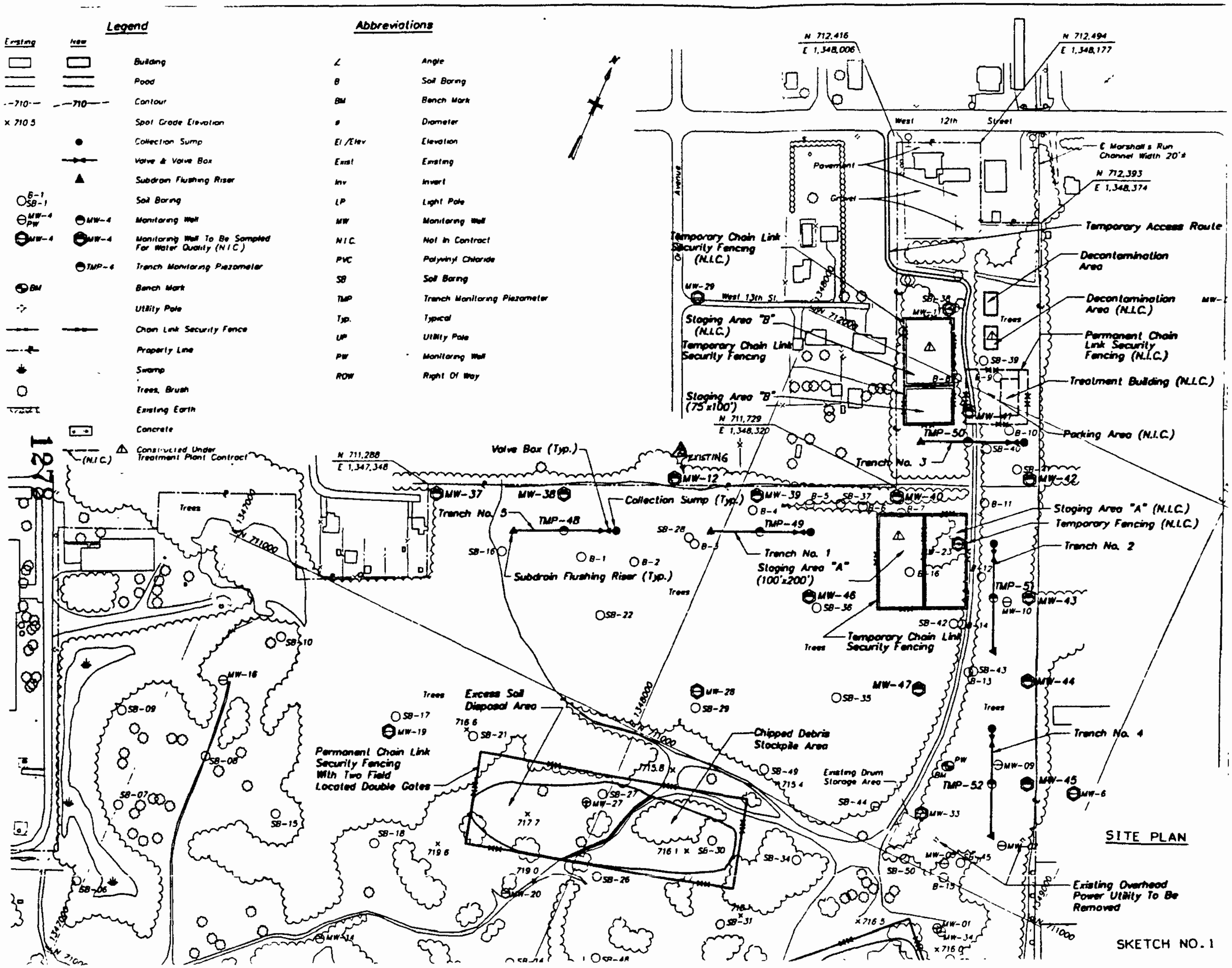
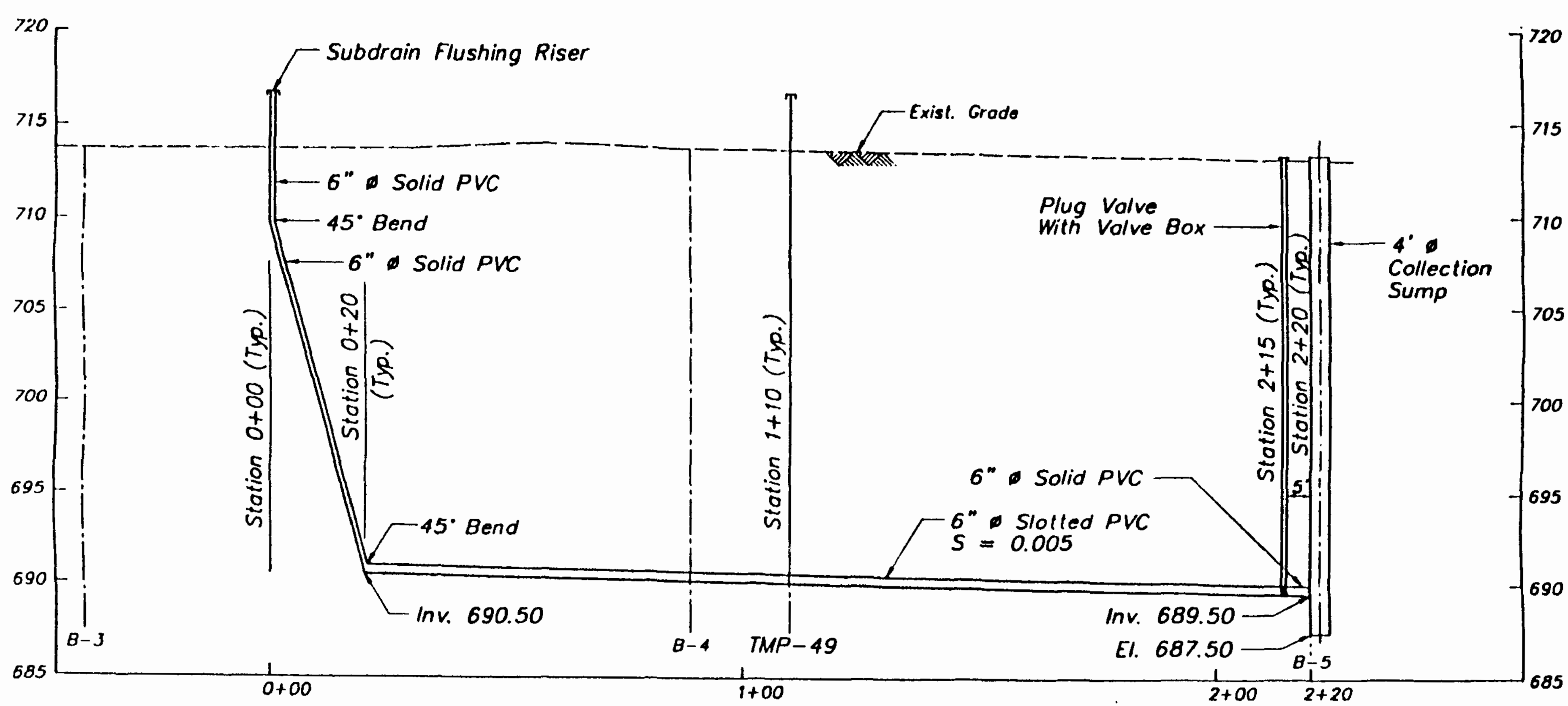

Legend
Existing
New
Building
Road
Contour
Spot Grade Elevation
Collection Sump
Valve & Valve Box
Subdrain Flushing Riser
Soil Boring
Monitoring Well
Monitoring Well To Be Sampled For Water Quality (N.I.C.)
Trench Monitoring Piezometer
Bench Mark
Utility Pole
Chain Link Security Fence
Property Line
Swamp
Trees, Brush
Existing Earth
Concrete
Constructed Under Treatment Plant Contract
(N.I.C.)
Abbreviations
Angle
Soil Boring
Bench Mark
Diameter
El./Elev. Elevation
Exist. Existing
Inv. Invert
LP Light Pole
MW Monitoring Well
N.I.C. Not In Contract
PVC Polyvinyl Chloride
SB Soil Boring
TMP Trench Monitoring Piezometer
Typ. Typical
UP Utility Pole
PW Monitoring Well
ROW Right Of Way
N 712,416
E 1,348,006
N 712,494
E 1,348,177
West 12th Street
Pavement
Gravel
Avenue
€ Marshall's Run Channel Width 20'±
N 712,393
E 1,348,374
Temporary Access Route
Temporary Chain Link Security Fencing (N.I.C.)
Decontamination Area
Decontamination Area (N.I.C.)
Permanent Chain Link Security Fencing (N.I.C.)
West 13th St.
Staging Area "B" (N.I.C.)
Temporary Chain Link Security Fencing
Treatment Building (N.I.C.)
Staging Area "B" (75'x100')
N 711,729
E 1,348,320
Parking Area (N.I.C.)
Trench No. 3
Valve Box (Typ.)
Existing
N 711,288
E 1,347,348
Trees
Collection Sump (Typ.)
Trench No. 5
Staging Area "A" (N.I.C.)
Temporary Fencing (N.I.C.)
Trench No. 2
Trench No. 1
Staging Area "A" (100'x200')
Subdrain Flushing Riser (Typ.)
Temporary Chain Link Security Fencing
Excess Soil Disposal Area
Chipped Debris Stockpile Area
Trench No. 4
Permanent Chain Link Security Fencing With Two Field Located Double Gates
Existing Drum Storage Area
Existing Overhead Power Utility To Be Removed
MW-37
MW-38
MW-39
MW-40
MW-42
MW-43
MW-44
MW-45
MW-46
MW-47
MW-12
MW-16
MW-19
MW-20
MW-27
MW-28
MW-29
MW-33
TMP-48
TMP-49
TMP-50
TMP-51
TMP-52
SB-22
SB-35
SB-36
SB-42
SB-43
SB-44
SB-49
SITE PLAN
SKETCH NO. 1



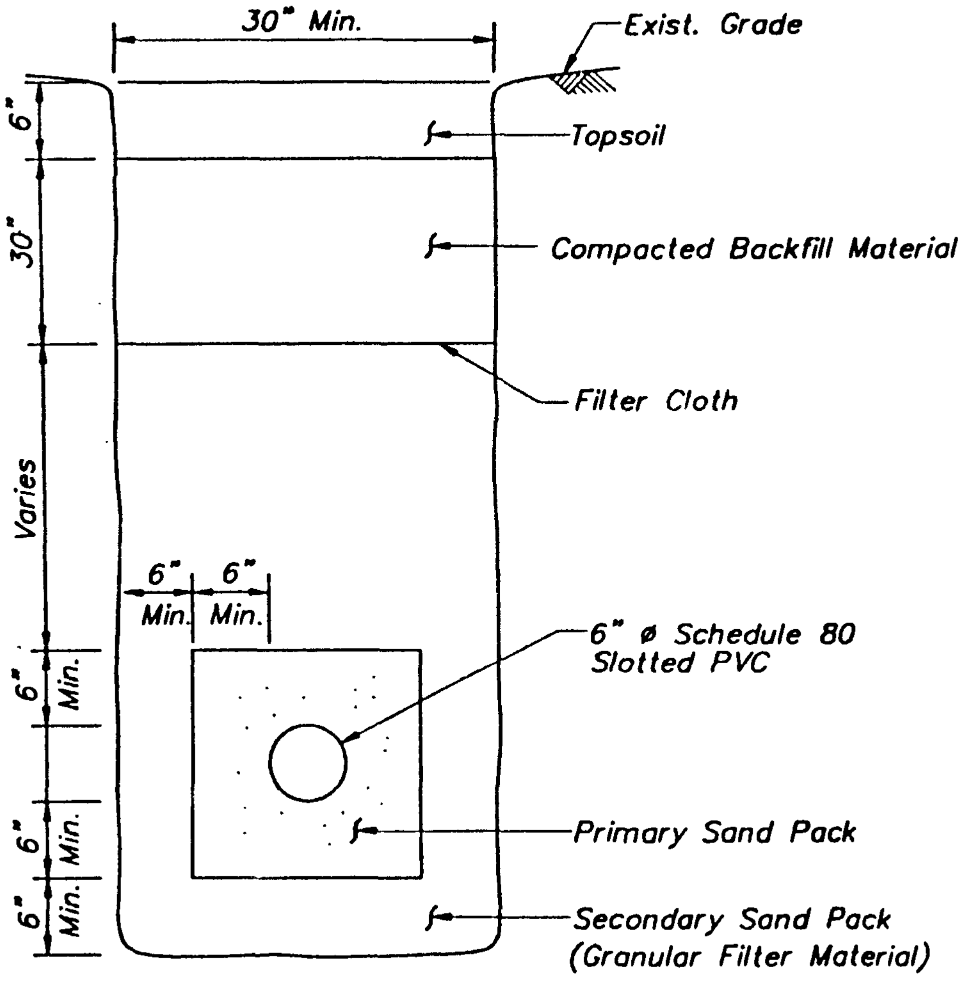
PROFILE-TRENCH NO. 1 ORIGINAL DESIGN

1279

NOTE: THE ONLY CHANGE MADE IN THE REVISED DESIGN WAS THE CHANGE IN MATERIAL COMPOSITION FROM PVC PIPE TO HDPE TUBING. THE VERTICAL SECTION OF THE FLUSHING RISER AND THE SECTION BETWEEN THE PLUG VALVE AND THE SUMP REMAINED PVC.

SKETCH NO. 2

1280



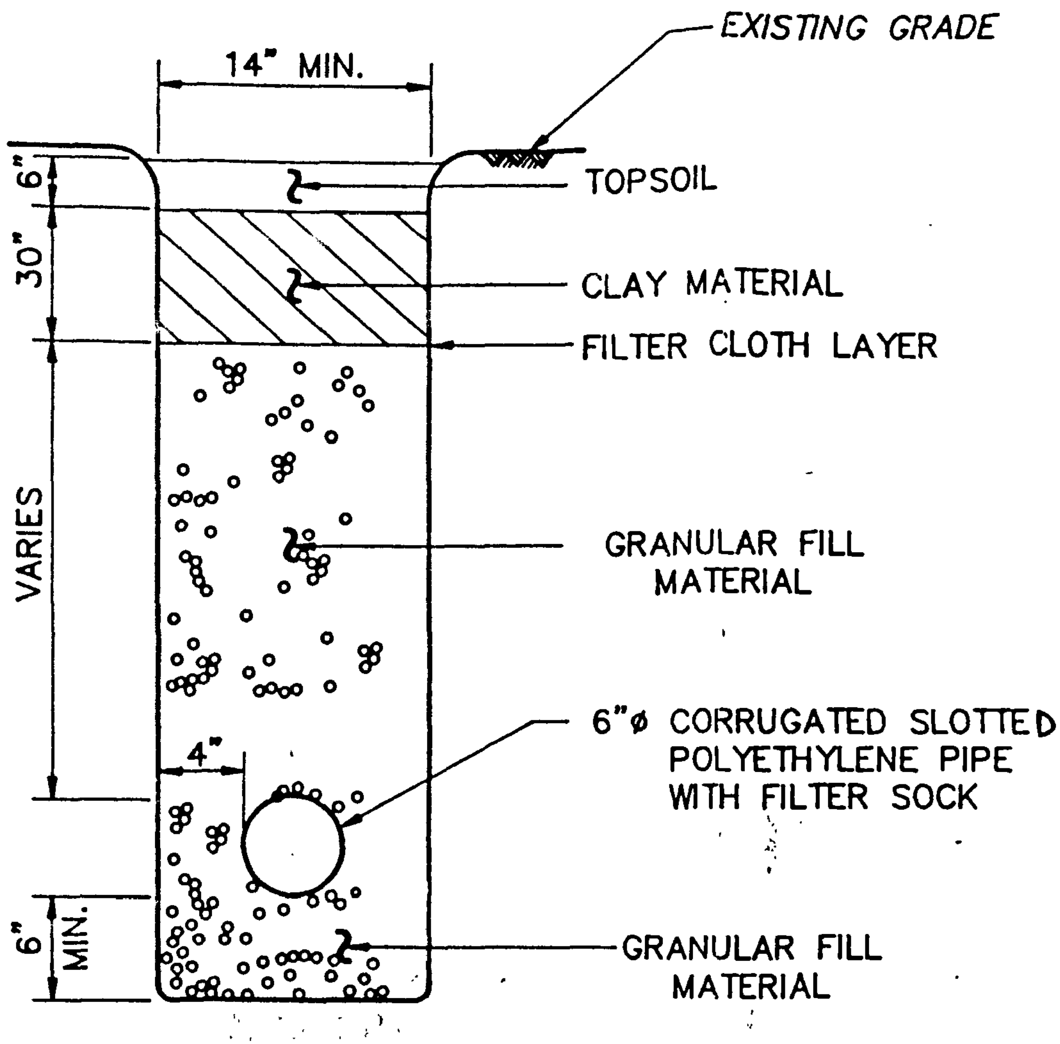
TRENCH BEDDING DETAIL

Not To Scale

ORIGINAL DESIGN

SKETCH NO. 3

1281



TRENCH BEDDING DETAIL

NOT TO SCALE

REVISED DESIGN

SKETCH NO. 4

1282

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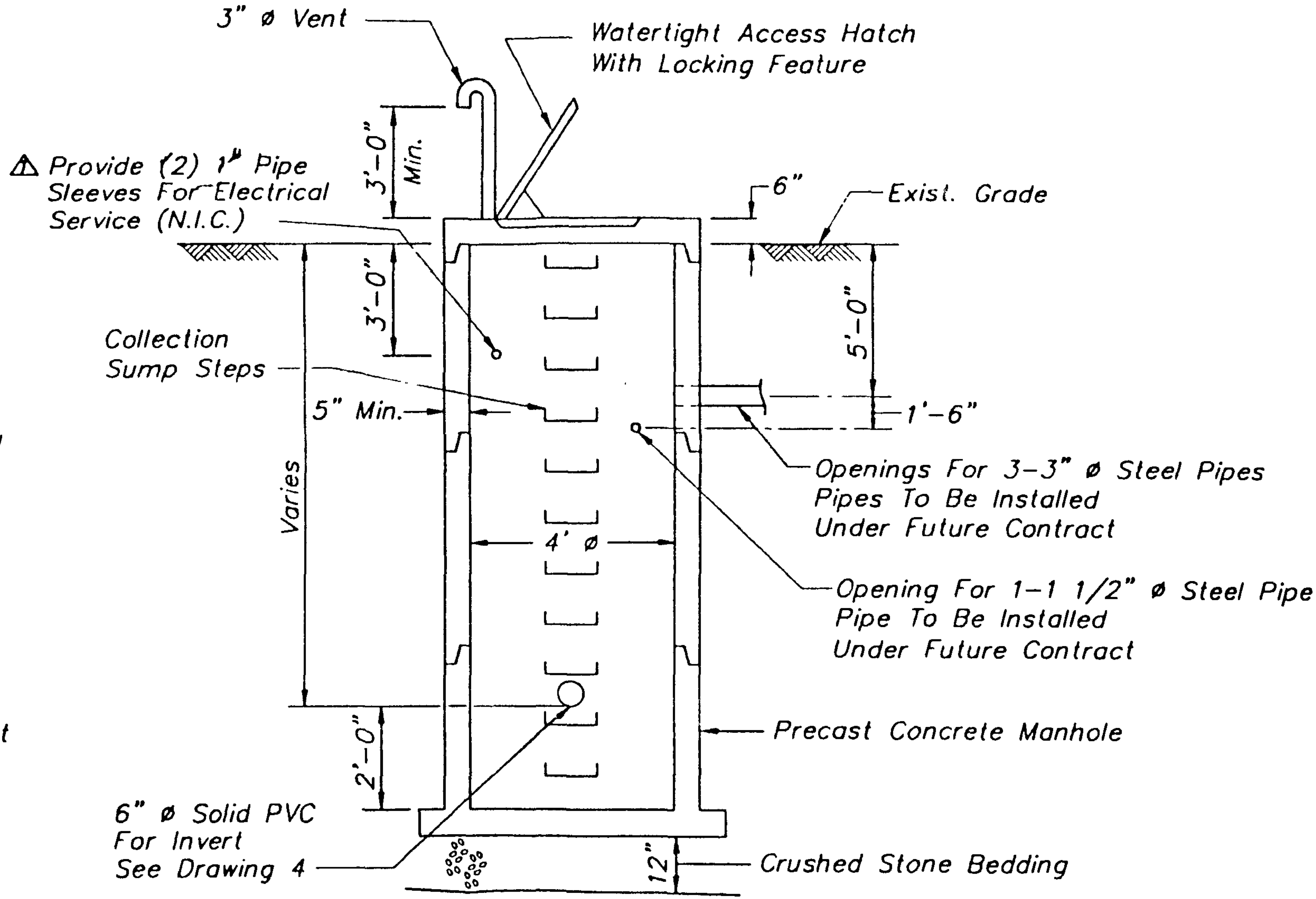


COLLECTION SUMP DETAIL

Not To Scale

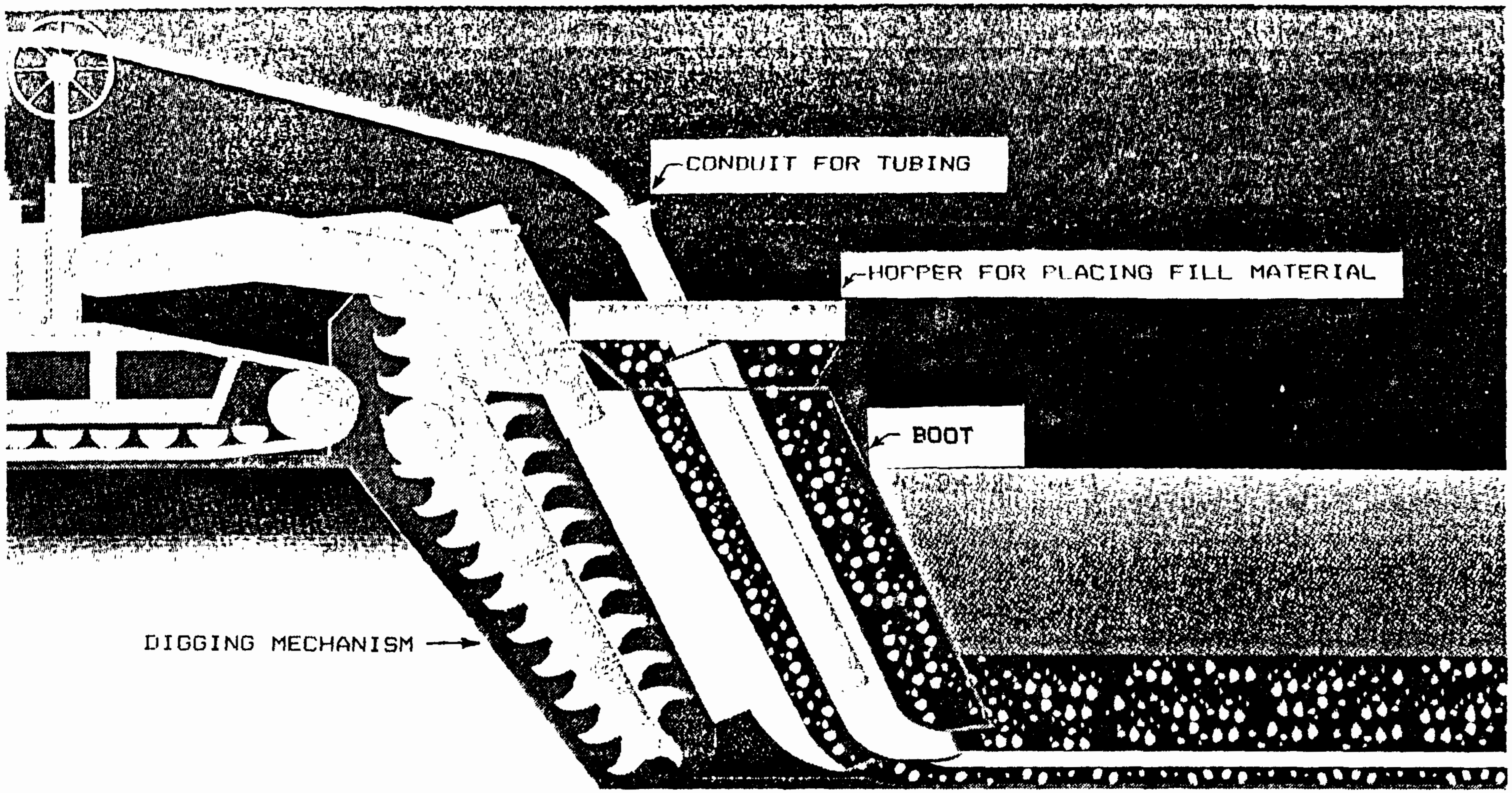
SKETCH NO. 5

1283

STEENBERGEN/HOLLANDDRAIN TRENCHER, MODEL BSY-SUPER-S-375, 1984

SKETCH NO. 6

1281



SECTION THROUGH TRENCHER

SKETCH NO. 7

EUROPEAN SOIL WASHING FOR U.S. APPLICATIONS

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INTRODUCTION

The purpose of this paper is to present the details of the introduction of a new soil treatment technology to the U.S. market. For the purposes of this presentation, I would like to introduce a concept of three tiers of contaminated soil treatment; traditional treatment technologies, alternative treatment technologies,and emerging treatment technologies. Traditional treatment consists of landfilling, incineration, and stabilization. Alternative technologies consist of low-temperature thermal treatment, bioremediation, vapor extraction, and physical screening and separation to achieve volume reduction...the essence of soil washing. Emerging technologies currently include in-situ vitrification, RF processes, dechlorination, and possibly some extraction techniques. This paper focuses on the alternative technologies. One of the most important lessons we have learned over the past decade is that no single technology provides a broad enough capability to solve all the soil situations that we encounter - - the key to feasible and cost-effective site solutions is the ability to optimize the use of reasonable alternatives in a site-specific matrix of use.

The EPA has recognized this need and particularly with SARA, emphasized the importance of "on-site" treatment technologies. This policy was initially stimulated through the development of the SITES program and most recently expanded by the formation of the Technology Innovation Office (TIO).

Still, all technologies have their limitations. The limitations that are most commonly encountered are:

- The volume of soil is too big or too small.
- The contaminants species and/or concentration is not process compatible.
- Organics and inorganics cannot be handled in the same treatment train.
- The process has little or no commercial operations experience.

This presentation is intended to provide a description of a commercial soil-washing facility operating in Holland for the past seven years and to demonstrate how many limitations can be overcome with this system.

BACKGROUND

About the same time as the EPA began an active review of European technologies, Geraghty & Miller spent about one year evaluating various soil treatment facilities operating in The Netherlands, Germany, France, Italy, and the U.K. This search led us to meet the operational group of Heidemij, headquartered in Arnhem, The Netherlands. Heidemij is an environmental consulting, management, and remediation firm over 100 years old and the market leader in The Netherlands in soil washing and bioremediation. Heidemij has strong research roots in the Dutch university system and has applied that resource to real field implementation. Heidemij currently operates bench scale, pilot, and commercial soil-washing facilities in Holland, and last year treated more than 150,000 tons of contaminated soil. The USEPA has visited the Heidemij facilities on many occasions and has prepared papers providing technology comparisons.

This background led Geraghty & Miller to establish a Joint Venture with Heidemij and, together, we are actively marketing the capability, conducting treatability studies, and performing in-field trials.

DISCUSSION

The objective of the Geraghty & Miller Joint Venture is to contract, own, and operate mobile treatment equipment to manage contaminated soils with a wide range of soil properties and contaminant types. The first venture process offered in the U.S. is soil washing. Soil washing provides a practical method whereby the entire soil volume can be understood to separate clean materials from contaminated fractions, and then to direct appropriate treatment at the contaminated portion. The process depends on the ability to effect substantial volume reductions and then to place "clean" soil back on site or to effect beneficial reuse in construction grade materials meeting applicable specifications.

PROCESS DESCRIPTION

PARTICLE SIZE/CONTAMINANT RELATIONSHIP

The Heidemij Soil Wash Process is based upon the fact that a discrete relationship exists between soil particle size and contaminant residence. The nature of this phenomenon is a result of many factors, including the manner in which the waste was disposed, the site soil matrix, the specific contaminants, the soil cation exchange capacity, particle zeta potential, and dynamic stresses placed on the materials at the site. The first step in evaluating the potential application of soil washing at a particular site is to quantify this particle size/contaminant relationship. It is not necessary to understand all the geochemical forces on the material, but simply to perform a standard sieving analysis and to analyze target fractions. Generally, remedial site soils will exist in five primary "fractions":

- **Gross Oversize.** This material is >8" and consists of concrete rubble, tree stumps and branches, scrap steel, and tires.

- **Oversize.** Material in this fraction is >2"(500mm) but <8". This fraction will consist of gravel, cobbles, shredded wood, and slags.

- **Large, Coarse-Grained Soils.** This material is in the range of 1/4" to 2" and is composed of sands and gravels.

- **Coarse-Grained Soils.** This material resides in the range of 40-60 microns up to 1/4" and is sand.

- **Fine-Grained Materials.** Clays and silts with an average particle size of less than 40-60 microns.

Once these particle size fractions have been identified and quantified, the "percent finer" particle size distribution curve is constructed. Each resulting target fraction is then analyzed chemically for appropriate contaminants. The selection of the analytical menu, of course, will be dependent upon existing information, the history of the site, and understanding of the contaminants of concern. The worst case, where no information exists, will require a full quantitation of each of the particle-size fractions. This analytical work does not need to be conducted with the extensive QA/QC that we have grown used to on investigation projects. Level III data (in accordance with the EPA's Draft Treatability Study Guidance Document) is acceptable at this point. The data is reviewed and then an overlay of the data on the particle-size distribution curve is prepared. The understanding of this step is the real key to soil washing, for in most cases, at least one of the fractions will not be contaminated. The challenge and capability of the soil wash system is to separate the uncontaminated fraction(s), and then to direct appropriate treatment at the contaminated fractions.

PROCESS OVERVIEW

The process is constructed completely of standard, proven equipment, most of which has been used for decades in the mining business. The waste pile is excavated and a working pile is created. The Gross Oversize and Oversize fractions are separated individually using mechanical screening techniques, while the coarse and fine-grained split is obtained with the creative use of hydrocyclones. If required, the coarse-grained materials (the sands and gravels) are treated by froth-flotation techniques. The fine-grained materials are more difficult to treat and will be handled by dewatering, biological, or extraction processes.

The basic soil-wash treatment plant is modular, and easily transportable. The plant is extremely flexible and can be configured to handle a very wide range of needs from simple volume reduction to sophisticated treatment trains. The "basic" plant has a throughput capacity of 20 tons per hour (tph) and in a full treatment mode requires about 1.5 acres of laydown space. On a typical site, the facility area will be graded, a liner placed on the plant area, and run-on and run-off controls provided. The plant does not require any special foundation or support work. All equipment is on engineered skids with quick disconnects and flexible hosing connections as a basic design feature. If the remedial site is extremely remote, and roads need to be built into the area of contamination, then that clearly expands the scope of the mobilization activities. The plant's primary utility requirements are water and electrical power. Water is completely recycled in the system, and therefore no discharge is required, but make-up water at the rate of approximately 25 gallons per minute (gpm) is necessary. The 20 tph plant has approximately 1,000 connected horsepower and can operate from an organic mobile generator if commercial 440, 3-phase power is not available.

The soil wash system can be used on a very wide range of contaminant species, including heavy metals, semi-volatile organics, including PCBs and pesticides. If volatile organics are included in the waste stream, the material will either be pre-treated by removing the VOCs with a thermal screw, or the entire system may be operated in an enclosed working space with complete air emissions control.

Remember, the plant consists of four major sub-systems:

- Screening
- Separation
- Froth Flotation
- Sludge Management

A schematic diagram of the plant is attached as Figure 1. Also remember that the plant will be generating three residual products that will be managed:

1. Oversize and Gross Oversize material (usually clean)

2. Clean sand (to be beneficially reused)

3. A sludge cake to be appropriately disposed at a permitted TSD (this is where the contaminants finally reside)

THE SECRET IS TO RECYCLE THE OVERSIZE, REUSE THE CLEAN SOIL, AND TO KEEP THE SLUDGE CAKE VOLUME AS SMALL AS POSSIBLE.

Each of the sub-systems will now be explained.

<u>Screening</u>

As mentioned above, a working pile is excavated in the field. This working pile must first be screened to remove the Gross Oversize fraction. This will normally be accomplished using a hopper mounted with a vibrating Grizzly. If annoying hopper blockage results, it may be necessary to substitute a Kombi screen or Trommel screen to provide a more uninterrupted step. Gross Oversize material is periodically removed from the hopper area and staged for recycling. The "fall through", or the material that is now <8", is conveyed to the next mechanical screening unit, which will generally consist of a double decked vibrated screen with stacking conveyors. The double-decked screen will have two flow paths: 1) an oversize material that is >2" and, 2) a fall-through that is directed by conveyor to the wet-screening unit.

Wet screening is applied to the stream of soil <2". High-pressure water nozzles attack the influent stream, breaking up small clods, dropping out pea-sized gravel, and forming the slurry that is now pumped to the Separation Sub-system.

<u>Separation</u>

The heart of the Heidemij soil wash system, and the area where extensive experience has been developed, is the creative use of hydrocyclones. Conceptually, the use of hydrocyclones is simple: the influent soil/water slurry is pumped to the cyclone and the slurry enters tangentially. In the cyclone, open to atmospheric pressure, the coarse-grained sands are spun out of the bottom, while the fine-grained materials and water are ejected from the top of the unit.

Several details need to be pointed out regarding the special use of the hydrocyclones in this system. First, the cyclones have field-adjustable cone and barrel components such that the "cut-point" interface between coarse and fine-grained materials can be modified consistent with treatment needs. This is extremely important in achieving the smallest volume of sludge cake requiring off-site disposal. Secondly, the hydrocyclones can be arranged in many flow-path configurations depending upon the interface needs and the goal of minimizing coarse-grained carryover into the fines.

Depending upon the soil to be treated, it may also be beneficial to utilize gravity separators on either or both of the coarse/fine fractions. Typical applications might include the removal of a floating organic layer or, at the other end of the density spectrum, dropping lead out from the soil-treatment stream.

Coarse Fraction Treatment

The underflow from the hydrocyclones contains the coarse-grained materials. When treatment is required for this fraction, it is accomplished using proven air flotation treatment units.

The first important decision that must be made in this sub-system is the selection of a surfactant. The selection, made from scores of alternatives, has one objective: the surfactant, when contacted properly with the contaminant/soil mass, reduces the surface tension binding the contaminant to the sand and allows the contaminants to "float" into a healthy froth which is then removed from the surface of the air-flotation tank. The selection of the appropriate surfactant is made during the treatability study at the bench-scale level.

The air-flotation tank is a long, rectangular tank that is mixed with the use of mechanical aerators and diffused air. Retention time is typically about 30 minutes, but can be adjusted on the treatment unit.

The flotation units require operator experience to obtain optimal performance. Primary control parameters are surfactant dosing, slurry flow rate, air flow rate, and the height of the overflow weir.

Two streams, the overflow froth, and the underflow sand, are the effluents from the treatment unit. The froth is concentrated and usually directed to the sludge management belt filter press where it is dewatered into a 50-60% solids cake. If, however, the contaminants from the coarse and fine-grained fractions are not compatible, then it may not be wise to send the froth to the filter press, but to manage it separately. The underflow from the flotation unit (the sand) is now directed to sand dewatering screens - the dry sand represents the "clean" material that will be reused, the water is recycled back to the wet screening section.

Sludge Management

The overflow from the hydrocyclone, consisting of fine-grained materials and water is now pumped to the sludge management subsystem. As mentioned earlier, the fines represent the most difficult fraction to treat, as a result of complex binding and attachment dynamics and mechanisms. If the distribution of fines to coarse is favorable, it is feasible to simply treat the fines similar to a wastewater sludge by polymer addition, sedimentation, thickening, and dewatering. If the fines/coarse ratio is not that favorable, it may be necessary to consider more sophisticated treatment. Of course, this upgraded treatment will depend upon the contaminants of concern, but it may include biological degradation or metals extraction.

In the primary case (simple treatment), the hydrocyclone overflow is pumped to the sedimentation area, currently consisting of banked Lamella clarifiers. An appropriate polymer has been selected in lab jar testing, and is dosed prior to introduction to the Lamella. The clarified solids are directed to a sludge thickener, while the water overflow is returned to the wet screening area for reuse. The thickened solids are then pumped to the belt filter press, or, more accurately, a pressurized belt filter press. This unit is one of the most important in the entire process in terms of selection. A 15-20% solids influent is converted into a 50-60% dry solids filter cake. This cake contains the target contaminants and therefore must be managed by disposal at a properly permitted off-site disposal facility, depending upon the specific contaminants and their status in regard to current land bans.

Residuals Management

The important decision that must be made in selecting a soil-wash system is the manner in which the residuals from the treatment system will be managed. Remember, there are three primary residuals to be handled:

- The Oversize and Gross Oversize Material
- The Clean Coarse-Grained Material (The Sand)
- The Fine-Grained Material (The Sludge Cake)

For the oversize material, efforts will be taken to reuse the material. Wood and wood products can be shredded, in many areas this material can be used as a supplemental fuel in co-generation facilities. Steel scrap can be sold to mini-mills, and concrete rubble can be crushed for use as aggregate in concrete production.

The clean sand can be used as select backfill, and can usually be returned directly to the area of excavation. If the site conditions do not require the area of excavation to be regraded, the clean material can be used as a construction grade material for other development uses on site, such as roadways or concrete. In some states, with California leading the way, this "clean" material can be sold for off-site uses after meeting certain criteria.

The fine-grained materials, recall that here is where the contaminants reside, will require disposal off-site at a permitted RCRA Treatment, Disposal, or Storage Facility (TSDF). When the job is initially scoped we will make solid determinations regarding the type of disposal or treatment facility that will be required for the specific fine-grained residuals from the site. This scoping decision will usually be limited to a decision between a hazardous waste landfill or a fixed-base incinerator. This decision will hinge upon the determination as to the status of the specific waste(s) with regard to the Land Disposal Restrictions (LDRs), commonly known as the land bans.

QUALITY CONTROL SAMPLING AND ANALYSIS

Naturally, any decisions in both the selection, qualification, handling, and disposal of treated residuals will be made using analytically quantified information. The specific parameters to be quantified, and the analytical methods to be employed will be made on a site-specific basis. This decision will be made after an understanding of the previous work performed, the nature of the regulatory requirements at the site, and the client/contractor strategy to be followed.

In most cases, routine quality analyses will be performed on the project site relying on GC and AA techniques. Periodic sampling and analyses will be performed on the treated residuals to verify product quality and the compliance with treatment objectives.

OPERATIONS AND STAFFING

The soil wash plant is relatively easy to operate. The flexibility of the plant is such that it need not be kept running 24 hours per day, as is the case with an incinerator, for example. Currently, the Dutch operate the plant on a 5 day per week/2 shift per day basis. Preventive and routine maintenance is performed on Saturday and the plant is shut down on Sunday. Since only pumps, conveyors, and support equipment are operated, the air flotation unit is the only sub-system that requires any extraordinary care. If schedule or production requires, however, 7 days per week/3 shifts per day schedules can be worked.

The field operation is headed up by a Plant Manager, who is supported by a Plant Engineer, Site Safety Officer, and a mechanical/electrical technician, the four of whom work the day shift. The shift crews (two or three depending upon production requirements) each consist of a Shift Foreman, a flotation unit operator, a belt filter press operator, and two laborers. All plant personnel are trained in the requirements of OSHA 1910.120 and all participate in the routine medical monitoring program.

Since this venture represents the use of a new technology to the U.S., the plant operations staff will be supplemented by trained and experienced operators from Holland during the first year of operation.

THE REGULATORY SITUATION

The success of soil washing will be measured by the ability of the system to meet specific treatability/cleanup standards. Projects will be regulated, in most cases, by either CERCLA, RCRA, or specific state law. In the case of CERCLA, no specific permit is required, but all the normal requirements of a permit must be documented and met. When the soil-washing remedy is specified in the Record of Decision (ROD)...as it has been in seven RODs as of Mid-April, 1991...the permits form no barrier to implementation.

RCRA projects have recently become much more flexible to the use of innovative technologies through the Corrective Action Program. An owner/operator can apply for a temporary permit to use an innovative method for 180 days and renew for another 180-day period. (Most projects can be completed in this one year period.)

States are also moving ahead rapidly to implement practical remedial projects. The State of California, for example, is promulgating policies to permit the treatment and incorporation of treated residual materials into asphaltic and construction grade materials.

TREATABILITY STUDIES

Every project will commence with a treatability study. The purpose of the study is to understand the particle size/contaminant relationship, to confirm a process for the treatment of the waste of concern, and to price the service. The treatability study consists of four phases:

Phase I: "Representative" samples are collected from the site. This determination of representativeness is important to the client and contractor since this agreement is the basis of treatment and pricing decisions. Where possible, we believe that it is very useful for the client and the contractor to participate mutually in this "representativeness" decision. The samples are managed with proper controls, and can be analyzed at the client's facility if the proper staff and resources are available, at the Geraghty & Miller Treatability Laboratory in Tampa, Florida, or at the Heidemij Treatability Laboratory in Waalwijk, The Netherlands. The analyses to be performed include, first, the sieve analysis and the construction of the percent Finer Curve. Then, the target particle-size fraction samples are chemically analyzed for the required contaminant menu. This phase usually takes about four weeks and costs between $3,000 and $5,000 depending upon the analytical requirements. The Phase I results represent a good "Go/No Go" point, for this information will allow a reasonable decision to be made regarding the feasibility of soil washing.

Phase II: The next step is to perform bench-scale investigations to confirm specific unit operations. Specifically, screening, hydrocycloning, air flotation, and filter pressing studies will be conducted to select treatment units, and to determine surfactant, polymer, flow rate, and throughput requirements. This phase of the treatability study will be conducted in The Netherlands. In this phase of work, direct equipment and professional support will be provided by the Mineral Processing staff and the extensive facility at the Technical University of Delft (The Netherlands). This is a long-term, funded relationship between Heidemij and TUD that has proven invaluable in keeping the team at the forefront of soil treatment. This study will generally take about four weeks to conduct, will result in the confirmation of a process flow diagram, confirmation of treatment capabilities, and will cost $15,000 to $25,000 depending upon the nature of the soil to be treated and the resulting process treatment train.

Phase III: When necessary, a pilot treatment plant will be tailored from existing plants at two locations to run the specified treatment train with actual site soils. The pilot plant facilities consist of the full range of required treatment units and have the capacity to run studies at the level of one ton per hour. While these studies will be normally conducted in Holland, the USEPA has anticipated the need to ship soils out of the U.S. and has provided guidelines and requirements in 40 CFR 263. (PCB materials cannot be shipped out of the U.S.) The scope of the pilot study and the location where it will be conducted depend directly on the size and complexity of the project. Where a site situation matches closely to current experience, it may not be necessary to even conduct a pilot level study. The team can, where necessary, assemble a pilot treatment facility at the U.S. site. The cost of the pilot study involves so many variables, that no good guidelines can be given without understanding the specific site requirements.

Phase IV: After the completion of the required studies, a report will be prepared documenting the investigation activities and providing conclusions regarding the findings. The report will provide the confirmed process flow diagram and the general specifications for the actual facility. The report will commit to a unit treatment price and specify any particular contractual qualifications. The document is intended to provide all the technical information required to negotiate a services agreement.

COSTS

Comparison costs of other forms of on-site treatment are shown in Table 1. A summary of the unit treatment price, broken down by major cost components, and at several different volume points, is presented in Table 2.

KEYS TO A SUCCESSFUL PROJECT

What makes a successful remediation project? Of course, many things, but for soil washing here are the key issues to consider:

1. Begin with an open relationship between client and contractor. One thing is certain....the project understanding we start out with will certainly change during the conduct of the work. It is extremely important that a relationship of reasonable trust exists at the beginning of the job and be nurtured through the ensuing work.

2. The size of the job should be considered, since on-site technology applications are directly dependent upon volume as an economic fact. For a soil washing job to compete on a project where all "normal" remedial alternatives are open, a volume of more than 20,000 tons is required. On projects where "normal" alternatives are limited by unusual site conditions or wastes, then that minimum volume may decrease.

3. The particle size/contaminant relationship is central to the selection of soil washing. The better the natural distribution of coarse and fine-grained materials, the more economical soil washing becomes. Remember, soil washing is not a set, rigid treatment train, but is modified specifically for the actual wastes to be treated. Also, keep in mind that very substantial volume reductions can be obtained by understanding the particle size/contaminant relationship and merely screening and separating wastes for the most appropriate treatment.

4. The understanding of the regulatory situation is very important. The EPA is in strong support of innovative, on-site technologies. BUT, that does not mean that any special consideration or permitting support emerges from this supporting position. The position of the State regulators is very important in selecting on-site approaches, and this position must be factored directly into the client's remedial strategy.

BENEFITS OF SOIL WASHING

The benefits of soil washing are substantial and are:

- The system is exceptionally cost-effective since it can focus treatment only on the appropriate fractions, rather than treating the entire waste stream.

- The system can treat both organics and inorganics in the same treatment stream.

- The soil washing system is a true volume reduction option and directly supports the recycle and reuse of site materials.

- The system is consistent with the current EPA directives and policies requiring on-site, innovative treatment.

- Since there is no air emission or wastewater discharge, the system is easier to permit than traditional remedial alternatives.

WHAT DO YOU NEED TO DO TO GET STARTED?

Please contact Mr. Michael J. Mann, Mr. Jack Peabody, or Ms. Jill Besch at (800) 676-1921 to discuss your specific site situation. We will be happy to provide direct information regarding your needs, arrange a site visit, if appropriate, and respond in writing to requests for proposal. As stated above, each site requires a treatability study, a study that can be tailored to the needs of your project, conducted in a staged process, and by using existing site information.

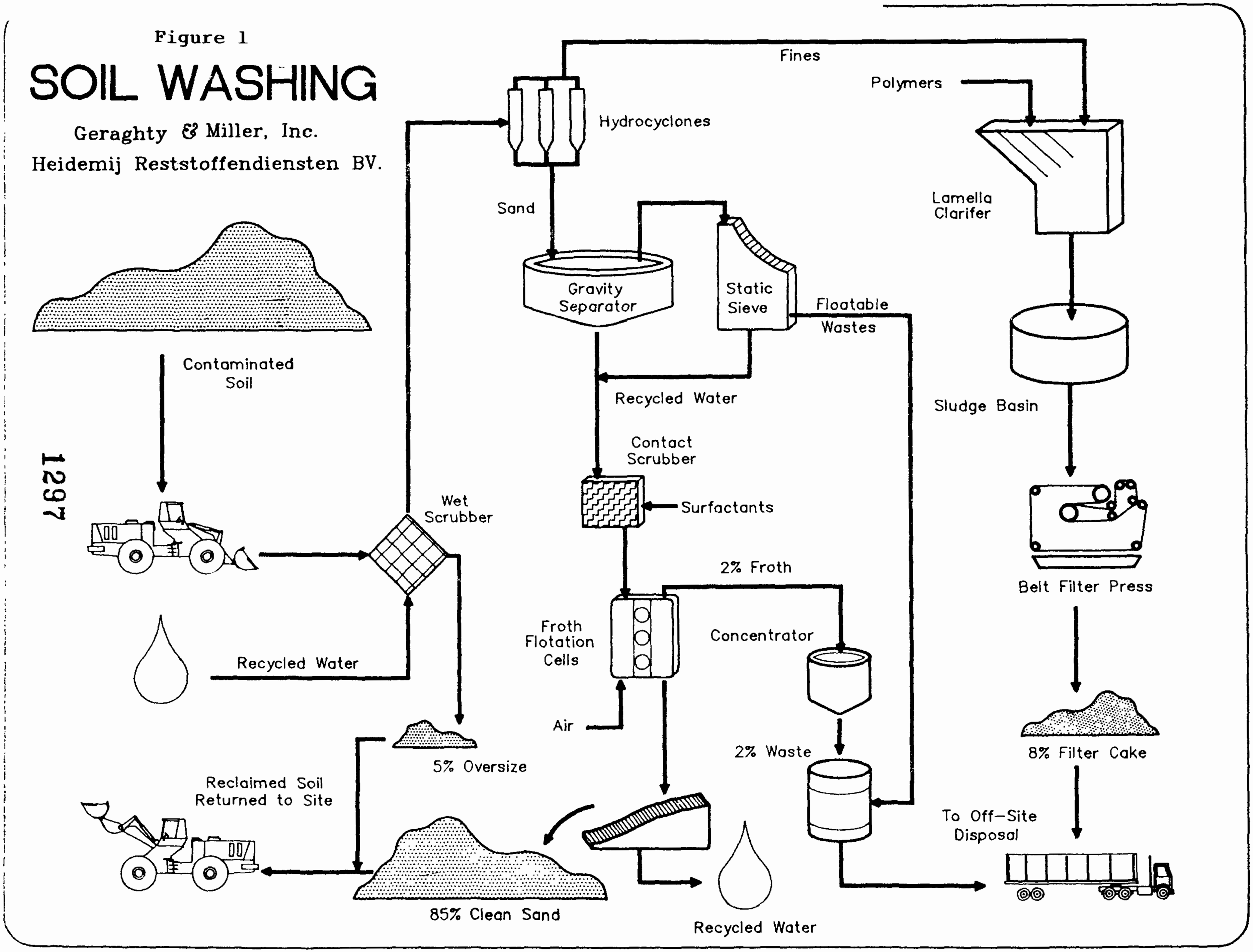
Figure 1
SOIL WASHING
Geraghty & Miller, Inc.
Heidemij Reststoffendiensten BV.
Contaminated Soil
Recycled Water
Wet Scrubber
Hydrocyclones
Fines
Polymers
Sand
Gravity Separator
Static Sieve
Floatable Wastes
Lamella Clarifer
Sludge Basin
Recycled Water
Contact Scrubber
Surfactants
Belt Filter Press
2% Froth
Froth Flotation Cells
Concentrator
Air
2% Waste
8% Filter Cake
5% Oversize
Reclaimed Soil Returned to Site
To Off-Site Disposal
85% Clean Sand
Recycled Water

TABLE 1

COMPARISON OF ON-SITE REMEDIAL TECHNOLOGIES

	Cost/yd	Waste Handled Organic	Waste Handled Inorganic	Permitting
Incineration	600-2000	yes	no	RCRA, air and NPDES
In-situ vitrification	350-400	yes	yes	Land ban restrictions
Low temperature thermal treatment	200-250	yes	no	air
Chemical treatment, (solvent extraction, BEST, KPEG)	250-300	yes	no	NPDES
Soil washing	150-200	yes	yes	none
Bioremediation	75-100	yes	no	none
Stabilization/solidification	20-100	yes	yes	Land ban restrictions
Vapor extraction/soil venting	2-5	yes	no	air

TABLE 2

SOIL WASHING COSTS
($ Cubic Yard)

Item	Volume (cubic yards) 20,000	40,000	60,000	100,000
Capital Depreciation	65	38	28	20
MOB/demob	5	3	2	2
Labor	25	15	12	9
Back-up	3	2	2	1
Chemicals	15	15	15	15
Maintenance	8	4	4	3
Equipment upgrade	12	9	8	7
Safety equipment	3	3	3	3
Utilities	6	6	6	6
Material handling	5	5	5	5
Management/engineering	20	13	10	8
Overhead	9	8	5	3
Process testing	22	11	8	4
Off-site disposal	15	15	15	15
Site preparation	0	0	0	0
TOTALS	$ 213	$ 147	$ 123	$ 101

REMEDIAL DESIGN PROCEDURES FOR RCRA/CERCLA FINAL COVERS

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I. INTRODUCTION

The design of RCRA/CERCLA final covers requires a systematic process that begins with the collection of predesign data and ends with a set of plans and specifications for construction of the project. The remedial design procedures presented in this paper were developed over the past several years and are based upon the following experiences:

* Performance of in-house designs
* Reviews of Architect-Engineer (AE) designs
* Lessons learned from construction
* Training Short Courses:

  - Clay Liners and Covers for Waste Disposal Facilities/University of Texas at Austin
  - Designing with Geosynthetics/Drexel University
  - HELP Model/U.S. Army Corps of Engineers
  - Etc.

* Seminars

  - EPA: Design and Construction of RCRA/CERCLA Final Covers (Summer 1990)
  - 4th GRI Seminar: Landfill Closures (Dec 1990)
  - Etc.
* Supplier presentations
* EPA Technical Guidance Documents
* and from the many technical references noted herein

The target audience for this paper is the project engineer or technical manager who is responsible for producing plans and specifications for the construction of a final cover.

II. PREDESIGN REQUIREMENTS

In order to proceed from the Record of Decision (ROD) into preparing plans and specifications for the construction of a final cover, it is normally necessary to conduct predesign surveys and investigations to fill data gaps. The existing data base available from the Remedial Investigation (RI), the Feasibility Study (FS) and any other available documents must be reviewed before scoping a predesign effort. The following predesign information is normally required to design a final cover:

A. **Field Surveys and Record Searches.**

1. **Topographic Surveys.** Topographic surveys of the project site are required at one foot contour intervals. One foot contour intervals are desirable for final covers because of the thin component layers (24" clay barrier) and flat slopes involved with the design. The topographic mapping should be accurate within ± 0.1 foot in all dimensions. The topographic survey should be mapped on the Computer Aided Design and Drafting (CADD) system. All surface features such as utilities, ponds, fences, trees, streams, ditches, water, etc., should be delineated on the mapping. The topographic mapping needs to be referenced to the horizontal and vertical control used to perform the survey. The surveys should also identify the coordinates and elevations of existing wells, drill holes, piezometers and any predesign activities such as trenching and borings.

2. **Aerial Photography (Historic Photo Chronology).** A record search should be made to obtain a chronology of historic aerial photographs. Historic aerial photographs can be used to help identify the nature and extent of the landfill. This information is used to help define the limits of the final cover and aid in the cover design.

3. **Horizontal and Vertical Control.** Three permanent control monuments need to be established. The monuments should be strategically located to be used for, but not destroyed by, new site construction. The monuments should be assigned state plane coordinates and/or be tied to the horizontal grid used in previous studies. The vertical datum should be sea level elevations. The control monuments should be described and tied to references.

4. **Boundary Surveys and Property Search.** Boundary surveys shall be performed for all properties or parcels within the project construction and access limits. The boundary survey traverses should be tied to the sites horizontal control. All corners and evidence shall be identified on a traverse plat. A property search is also required which identifies the property owners of all affected and adjacent parcels of land. This information is used to prepare right-of-way and construction limit drawings.

5. **Monitoring Baseline Surveys.** For some projects, it is desirable to perform surveys to establish the baseline to monitor design concerns such as settlement and slope movement.

6. **Utilities Search.** All on-site above and below ground utilities need to be identified and located on plan sheets. The utility search should consist of an on-site inspection, a flat file search and contacts with utility companies. The location of all on-site utilities should include horizontal alignment, depth or height, type, sizes and the Utility company contact and telephone number.

7. **As-built Drawings Search.** Rarely are design or as-built drawings available for CERCLA sites. However; it is prudent to conduct a record search for any design, operational or as-built information that can help identify the nature and extent of the landfill or contaminated area.

B. **Geological Subsurface Investigations.** After the existing data base within the RI/FS and all other available documents regarding subsurface information has been reviewed, the geological subsurface investigations can then be scoped. The purposes of conducting geological subsurfaces investigations during the predesign phase are described as follows:

1. **Define Limits of Landfill.**

It is imperative to properly define the limits of the landfill which is to be covered. In many situations, the extent of the landfill is not clearly visible due to cover soil placed over the landfill in the past and subsequently overgrown by vegetation. The limits of the landfill can be tentatively defined by first conducting an electromagnetic conductivity (EM) survey (if the landfill is suspected to contain metals) or a soil gas survey (if the landfill is suspected to contained organic material). Test pits should then be excavated around the perimeter of the suspected landfill area to verify landfill boundaries as estimated by the EM or soil gas surveys. The test pits shall be excavated radially away from the landfill until the boundary is identified. Historic aerial photos can aid in trying to delineate the landfill boundary. The horizontal coordinates and vertical elevations of the EM, soil gas surveys, and trenching need to be surveyed and recorded.

2. **Characterize Site and Borrow Area Soils.**

The geotechnical characteristics of the soil at the site and at potential borrow sources need to be determined. Soil characteristics are required to determine the suitability of the material for use in the various layers of the cover system and for use in the settlement and stability analyses. The soil characteristics are determined by drilling (or trenching), sampling and testing the material. For certain soil parameters, the cone penetrometer, standard penetration test, vane shear test and other in-situ tests can be used to estimate to soil properties.

3. **Material Excavatability.**

When a project feature such as a leachate collection trench requires excavation, profile sheets should be included in the drawings informing the contractor of subsurface conditions and excavation limits. The information required includes soil or rock type, water table and leachate levels, soil moisture content, soil horizons and bedrock profiles, rock hardness and rippability.

4. **Methane and Landfill Gas Presence.**

Soil gas surveys on the ground or landfill surface and soil gas probes can be installed into the landfill proper to investigate the presence of methane and other volatile organic vapors within the landfill.

5. **Landfill Composition.**

Sometimes it is necessary to excavate actual landfill refuse in order to minimize earthwork or to locate leachate collection trenches. If this is the case, then the landfill composition should be determined during the predesign effort in order to inform the contractor of subsurface conditions.

6. **Leachate Levels.**

Landfills are normally quite pervious and can have large void spaces creating significant amounts of leachate. Landfills have their own distinct internal drainage characteristics. During predesign activities, the surface of the landfill should be inspected in order to locate leachate seepage exit areas. Leachate seeps should be surveyed and mapped. Piezometers can be installed in landfill to identify leachate gradients and flow paths. This information is used to design and locate leachate collection systems.

7. **Define Ground Water Conditions.**

Observations wells and piezometers are normally installed during the RI/FS process. It is normally necessary to define water levels, gradients, water chemistry prior to constructing a final cover to define baseline conditions.

C. **Laboratory Geotechnical Testing Requirements.** The following geotechnical tests are normally required to assess the suitability of borrow sources for use in the cover layers and to perform the stability and settlement analyses:

* Soil Classifications
  - Mechanical Analysis
  - Hydrometer Analysis
  - Atterberg Limits
* Moisture Content
* Standard (or Modified) Proctor Compaction Test
* Permeability Tests
* Density Tests
* Dispersive Clay Tests (Borrow Material)
* Soil Strength (Shear Tests)
* Consolidation Tests (for Settlement Analysis)
* Direct Shear Tests for all Final Cover Interfaces

D. **Chemical Data Quality Management.**

Chemical testing is required to determine if there is a presence of methane or other volatile organic vapors. Chemical testing is also required to ensure that borrow sources are not contaminated (TCLP test) and to determine ground water and leachate chemistry.

E. **Map Data Base.**

USGS Quadrangle Maps in both the 7.5 minute series and the 1:250,000 scale are useful design aids. Separates can be obtained from the USGS for both these map types and can be used to make site and location maps.

F. **Field Pilot Studies.**

Test fills can be conducted as a component of predesign or as part of construction to verify or determine design assumptions. The landfill refuse material can be preloaded to obtain short term settlement values or stability parameters. Test fills can be used to determine or verify construction methods such as the placement of select fill on the geosynthetics. Tests fills can be used to design or verify the stability of the final cover layer interfaces under worst-case conditions. Test fills can be used to determine the minimum random fill thickness required to provide a firm foundation to allow proper compaction of the low-permeability clay layer. Constructability and safety issues such as the placement of random fill on steep landfill sideslopes can be assessed with test fills. The large scale field performance of final cover components such as the in-situ (large scale) permeability of the clay barrier layer can be verified with a test fill.

III. DESIGN CONSIDERATIONS

The EPA Technical Guidance Document titled Final Covers on Hazardous Waste Landfills and Surface Impoundments, dated July 1989 (EPA/530-SW-89-047) <1> provides design guidance on final covers for hazardous waste units. The design guidance presented in that document satisfies the requirements of 40 CFR 264 and 265 Subparts G (closure and post-closure), K (surface impoundments), and N (landfills). The EPA emphasizes that their recommendations are guidance only and not regulations. The EPA also acknowledges that other final cover designs may be acceptable, depending upon site-specific conditions and upon a determination by the Agency that an alternative design adequately fulfills the regulatory requirements. The following design considerations adhere to the EPA's recommendations and reflect additional design requirements.

A. Final Cover System Component Layers.

1. Vegetative Cover. The top layer in a final cover is the vegetative cover. The primary purpose of the vegetative cover is to resist wind and water erosion. The vegetative cover minimizes the infiltration of surface water into the lower layers of the cover system and maximizes evapotranspiration. The vegetative cover also functions in the long term to enhance aesthetics and to promote a self-sustaining ecosystem on top of the cover <2>.

The EPA <1> recommends that the vegetative cover meet the following design specifications:

* Locally adapted perennial plants
* Resistant to drought and temperature extremes
* Roots that will not disrupt the low-permeability layer
* Capable of thriving in low-nutrient soil with minimum nutrient addition
* Sufficient plant density to minimize cover soil erosion to no more than 2 tons/acre/year (5.5 MT/ha/yr), calculated using the USDA Universal Soil Loss Equation <3>
* Capable of surviving and functioning with little or no maintenance

The final cover should be built on slopes no steeper than 1V : 3H for maintenance purposes. Equipment necessary to plant and maintain vegetation cannot operate safely on steeper slopes <2>. This minimum slope recommendation compares to a slope of 2V on 5H which the Corps of Engineers uses as the steepest slope that can be conveniently traversed with conventional mowing equipment <4>.

It is important to note that in many cases, landfill gas must be contained and controlled to prevent gases from migrating into the root zone of the vegetative cover and killing the plants.

The EPA has developed "expert systems" which are computer programs that "mimic" the knowledge and decision making processes of a human expert. An expert system titled Vegetative Cover Advisor (Veg Cov) analyzes the properties of the topsoil and subsoil, examines the appropriateness of plant species, preforms use analysis, examines general requirements, and writes a conclusion report. This system can be used to verify or aid in the design of the vegetative cover, topsoil, and select fill.

For sites located in arid regions or final covers with steep sideslopes (steeper than 1V:4H), an armor system can be used as an alternative to vegetative cover <2>. Alternative designs could consist of cobbles, gabion structures, concrete caps, asphaltic cement caps and chemical sealant caps.

2. **Soil Cover (Top Soil).** Below the vegetative cover is top soil which is required to support the vegetative cover. The top soil shall have a minimum thickness of 6 inches and shall be representative of soils in the site vicinity that produce heavy growths of crops, grass or other vegetation. The top soil must be free of contamination. The final top slope, after allowance for settling and subsidence, should have a slope of at least 3 percent, but not greater than 5 percent in order to facilitate runoff while minimizing erosion <1>.

For cover sideslopes greater than 5 percent, erosion caused from surface runoff is likely to occur unless erosion controls such as terraces, gabion structures, riprap, or erosion control mats are designed. As stated previously, the EPA <1> recommends that slopes and vegetative cover be designed to prevent the formation of erosion rills and gullies such that total erosion is limited to less than 2.0 tons/acre/year as determined by the Universal Soil Loss Equation. In addition, temporary erosion control measures are required during construction and post construction until permanent vegetation is in place.

3. **Select Fill.** Below the six inch thick top soil layer is the select fill layer. The purpose of the select fill is to provide a soil that is capable of sustaining the vegetative cover through dry periods and protect the underlying geosynthetics and clay barrier layer from the elements (frost penetration and desication). The select fill also provides water holding capacity to attenuate rainfall infiltration to the underlying drainage layer.

When designing clay barrier cover systems, the thickness of the select fill should be a minimum of 24 inches (including 6" of top soil) or equal to the maximum frost depth, whichever depth is greatest. The select fill must also be free of contamination The select fill material should be of medium textured soils such as loam soils for both function and constructability. Loam soils are capable of supporting the root systems of the vegetative cover and providing water holding capacity. Sandy soils are undesirable because the material has low water retention and loses nutrients by leaching. Cohesionless sands and silts are also undesirable because these materials have been known to cause severe clogging of underlying geotextile filters. Clayey soil types are more fertile than sandy soils but cohesive soils, especially highly plastic clays tend to pond water, and are difficult to place on the underlying geosynthetics. The best materials that are cohesive but not highly plastic and include SM-SC (sandy silt-sandy clay), SC (sandy clay), ML-CL (silt-lean clay) and CL (lean clay) as classified according to the Unified Soil Classification System. The maximum particle size should not exceed 3/8 inch so as not to puncture or damage the geotextile. It should be noted that the determination of the select fill soil type will ultimately depend upon the availability of economical borrow sources.

Constructability issues are critical when placing the select fill on the geosynthetics. Specifying soil types that are not highly plastic clays assures the select fill material can be placed in homogeneous layers. The select fill material should be placed starting at the toe of the cover working up the slope and parallel to the toe. The first layer of select fill should be placed in a thick loose lift of 15"-18" in depth. Equipment should not be driven or pulled directly on any underlying geosynthetics. Equipment is allowed on areas underlain by the geotextile only after the first layer of select fill has been placed. The select fill should not be dropped or dumped onto the geosynthetics from a height greater than 12 inches. The select fill should be placed onto the geosynthetics by dropping (not pushing) the fill from a small tracked-dozer similar to a Caterpillar Model D4 or D6. To protect the geosynthetics, achieve a stable structure, and to enhance the soil's ability to support the vegetative cover, select fill should be compacted with only minimum effort. Generally, traffic compaction using placement equipment is sufficient. Select fill should be placed when the geosynthetics are fully contracted (i.e. during cooler periods of the day) to prevent excessive thermal stresses in the geosynthetics. This is more critical for polyethylene products which have a relatively high coefficient of thermal expansion. The geosynthetics must be anchored at the top of the slope before placement of select fill. The select fill should not be stockpiled on the final cover in heights greater than 24 inches. The exposed geosynthetics should be covered as quickly as possible to reduce the potential for damage from ultraviolet radiation, wind, temperature extremes, and on-going construction activities <5>.

A test section should be constructed before full scale placement of select fill is allowed on the geosynthetics. The contractor should demonstrate that their placement method and equipment used will not damage the geosynthetics.

4. **Filter Layer.** A filter layer is normally required between the select fill soil cover and the underlying drainage layer. The filter layer insures consistent drainage properties by preventing migration of fine graded soil particles into the void spaces of the drainage layer below. The filter layer consists of either a geotextile or a series of graded granular materials.

a. **Geotextile Filter Fabric Alternative.** Adequate performance of the filter layer depends on several factors. Once the select fill soil type is specified, the geotextile is chosen based upon the following design criteria: 1) the fabric must retain the soil (retention criteria); 2) the fabric must allow surface infiltration to permeate through the fabric into the drainage layer (permeability criteria); and 3) the fabric must not clog over time (clogging criteria). In addition, 4) the fabric must survive the installation process, placement of select fill upon it, and long term loading from the select fill surcharge (survivability criteria), and 5) the fabric must be compatible with surface water (compatibility criteria) <6> <7>. The fabric could also be designed to withstand a tensile force (tensile criteria) since the material is normally tied into an anchor trench and could be secured by drainage benches. Design references and procedures for these criteria are presented as follows:

1) **Retention Criteria.** To prevent the migration of soil particles from the select fill into the drainage layer, the voids in the

geotextile filter must be small enough to retain the soil on the top side of the fabric. It is the coarser soil fraction that must be initially retained. The coarser soil fraction eventually blocks the finer sized particles <6>. Koerner <6> presents several approaches to determine apparent opening size (AOS) of the fabric based upon the particle size distribution of the soil to be retained. The most conservative method presented by Koerner is after Giroud <8>. Giroud predicts the apparent opening size of the geotextile based upon the following soil characteristics: relative density; coefficient of uniformity and the soil particle size corresponding to 50% finer. Giroud's method as represented by Koerner is displayed in table 2.14 on page 122 of reference <6>. Giroud's method is applicable to cohesionless soil types. When the select fill is highly cohesive and consists of primarily clay materials, the above referenced relationships are not applicable because the particle size of clay (0.002 mm) is far smaller than the apparent opening size of any geotextile. For cohesive soils, the Omaha District uses a geotextile filter with an Apparent Opening Size (AOS) no finer than the U.S. Standard Sieve No. 100 and no coarser than the U.S. Standard Sieve No. 70 to separate the select fill from the drainage layer <9>.

2) **Permeability criteria.** <6> <8> The geotextile filter must have an Apparent Opening Size fine enough to retain the select fill but yet open or permeable enough to allow surface water infiltration to pass through the filter into the underlying drainage layer. Therefore, it is necessary to determine the cross-plane permeability (k) of the fabric. In addition, since geotextiles deform under load the thickness (t) of the fabric is accounted for in a term called permittivity (Y) where: $Y=k/t$

The permeability and permittivity values of the filter are determined by using ASTM Method D4491, Water Permeability of Geotextiles by Permittivity. The values of these parameters for geotextiles range over several orders of magnitude as presented below <6>:

Permittivity (Y)=from 0.02 to 2.2/seconds

Permeability (k)=from 0.0008 to 0.23 cm/s

The flow rate through the geotextile as measured by its permittivity (Y), is selected to be greater than the flow from the select fill times a factor of safety, usually 10 or greater <7>. The flow rate through the select fill can be obtained from the HELP model or from the site-specific water balance. The coefficient of permeability (k) of the geotextile can also be checked to verify the k value of the fabric is greater than the k value of the soil.

3) **Clogging Criteria <6>.** The filter fabric becomes clogged when the soil particles embed within the fabric structure. Clogging of the filter fabric prevents surface water infiltration from being able to enter the drainage layer. Koerner <6> states that the likelihood of complete soil clogging of geotextile filters can be prevented by:

* avoiding cohesionless sands and silts as select fill;
* avoiding gap-graded particle size distributions in select fill; and
* avoiding high hydraulic gradients.

If these situations cannot be avoided, then the specified select fill material and geotextile filter can be tested together using either a gradient ratio test <12> or long term flow test <13>.

4) **Survivability Criteria.** The geotextile filter must survive the installation process to perform effectively <7>. The geotextile must be durable enough to withstand a Caterpillar Model D6 working on loose lifts thicknesses of 15 inches (see paragraph III. A.3 Select Fill). The Specifications for Geotextiles developed by Task Force #25 (AASHTO-ABC-ARBTA) <11> specifies the physical properties required for various degrees of survivability. For final covers as presented above, the geotextile requires a "High" degree of fabric survivability with the following minimum property values: Grab strength ≈ 180 lbs; Puncture Strength = 75 lbs, Burst Strength ≈290 psi and Trap Tear ≈ 50 lbs.

5) **Compatibility Criteria.** The compatibility between surface water infiltration and the geotextile filter is generally not critical and does not normally require compatibility testing (EPA 9090).

6) **Tensile Criteria.** The geotextile fabric can be designed to withstand tensile forces if the material is tied into an anchor trench and secured by drainage benches. A heavy woven fabric with a high modulus of elasticity should be specified for the filter material if the fabric is to be designed to withstand tensile forces. In addition, the fabric would have to be sewn in the field in lieu of just overlapping the material.

b. **Graded Granular Filter Alternative.** A series of graded granular filter layers can be used as an alternative to a geotextile filter. The granular layers must be graded both to prevent piping and to maintain permeability. Criteria for granular filter layers can be found in Cedergren <14> and the U.S. Army Corps of Engineers, Engineering Manual for Seepage Analysis and Control for Dams <15>.

5. **Drainage Layer.** The primary functions of the drainage layer are to intercept water that infiltrates the select fill and then convey the water out from beneath the cover. The drainage layer should be designed to minimize the amount and residence time of water being in contact with the low-permeability layer, thus decreasing the potential for leachate generation. The drainage layer must slope to an exit drain and discharge away from the toe of the cover. The drainage layer can consist of either a geonet or 12 inches of granular material <1>.

a. **Geonet Alternative.**

1) **EPA Recommendations.** The EPA <1> identifies the following parameters which should be addressed in assessing geonet drainage materials:

* hydraulic transmissivity (the rate at which liquid can be removed) should be no less than $3 X 10^{-5}$ meters squared per second.
* compressibility (the ability to maintain open pore space and thus transmissivity, under expected overburden);
* deformation characteristics (the ability to conform to changes in shape of the surrounding materials);
* mechanical compatibility with the FML (the tendency for the drainage material and the FML to deform each other);
* useful life of the system; and
* ability to resist physical, chemical and biological clogging.

2) **Koerner's Design-by-Function Concept.** Koerner <6> <16> presents the following design criteria which reflects in part the EPA requirements addressed above:

* **Compatibility.** As with the geotextile, the compatibility between surface water infiltration and the geonet is generally not critical and does not normally require compatibility testing (EPA 9090).

* **Crush Strength.** The geonet must be able to withstand normal pressures from the dead load of the select fill material and live loads from construction and maintenance activities. In order to avoid rib "lay-down" and/or creep deformation, the normal pressure capability of the geonet must be increased by a factor of safety over the design value. The Geosynthetic Research Institutes Test Method GN-1 <18> can be used to determine the allowable normal pressure. The normal stress on a geonet from the select fill for a cover design is light as compared to a landfill bottom liner and usually should not be a critical cover design parameter.

* **Flow Capability.** <6> The geonet must be able to convey the designed flow rate which is determined from the HELP Model or from the site-specific water balance. The allowable flow rate is the quantity for which the geonet can convey by planar flow or by it's transmissivity. The transmissivity of the geonet is determined by using ASTM D4716. The laboratory test flow should reflect the proper normal load and hydraulic gradient. Since laboratory tests yields the ultimate flow rate, Koerner <6> recommends that the laboratory flow rate be reduced before use in design. Koerner reduces the ultimate flow rate to reflect items not adequately assessed in the laboratory test. The items include preliminary factors of safety adjustments for the following: elastic deformation, or intrusion of the adjacent geosynthetics into the geonet's core space; creep deformation of the geonet and adjacent geosynthetics into the geonet's core space; chemical clogging and/or precipitation of chemicals in the geonet's core space; and biological clogging in the geonet's core space. A final factor of safety is also used where the required flow rate must be less than the allowable flow rate. Refer to Koerner <6>, pages 350 to 352 for the preliminary factor of safety values and further discussion.

* **Minimum Slope.** The EPA <1> states for gravel drainage layers, particularly where unusually long slopes are required, slopes greater than three percent may be necessary. This concern is especially true for geonets because of the thin depth of the material.

b. **Granular Material Alternative.** The EPA <1> also describes a 12 inch minimum thickness drainage layer alternative. The 12 inch thickness allows for both transport of drainage and protection of the low-permeability geomembrane barrier (FML) during construction. Slopes of 3% or greater are recommended. The EPA specifies the granular drainage material have a hydraulic conductivity of no less than 1 x 10^{-2} cm/sec and a hydraulic transmissivity no less than 3 x 10^{-5} meters squared per second at the time of installation. The granular material should be no coarser than 3/8 inch, and classified as SP and consist of smooth rounded particles. A hydrologic and hydraulic analysis is still required to verify the layer adequacy.

6. **Low-permeability Layer.** As per the EPA <1>, the final cover system is required by 40 CFR 264.228, 264.310, and 265.310 to provide long-term minimization of migration of liquids through the closed land disposal

unit and to have a permeability less than or equal to the permeability of the bottom liner system or natural subsoils present. The EPA has interpreted this to mean that the cover should contain a geomembrane (FML)/soil composite layer similar in concept (but not necessarily identical construction materials) to the composite bottom liner detailed in "Minimum Technology Guidance on Double Liner Systems for Landfills and Surface Impoundments -- Design, Construction and Operation" (EPA). The two components (FML and soil) of the low-permeability layer recommended in this document are considered to function as one system. They should be designed, constructed, and operated to maximize removal of water by the overlying drainage layer and to minimize infiltration of water into the waste. The low-permeability layer should require little or no maintenance during and after the post-closure period.

a. **Geomembrane Barrier Component (FML).**

1) **EPA Recommendations <1>.** The FML component of the low-permeability layer is located above the clay barrier. The EPA recommends the FML component have the following characteristics:

* The FML should be located below the maximum depth of frost penetration.
* The FML should be at least 20 mils (0.5 mm) in thickness, but some units and/or some FML materials may require a greater thickness to prevent failure under potential stress of the post-closure care period, or during construction. The Agency recognizes that some types of FMLs must be thicker to accommodate unique seamability requirements, or to increase long-term durability (e.g., increase resistance to puncture). It should be noted that the Corps of Engineers Missouri River Division <19> recommends the FML be a minimum of 40 mils based upon seamability (burn outs) and survivability during construction.
* The surface of the FML should have a minimum 3 percent slope after allowance for settlement.
* There should be no surface unevenness, local depressions, or small mounding that create depressions capable of containing or otherwise impeding the rapid flow and drainage of infiltrating water.
* The Agency recommends the use of material and seam specifications such as those in "Lining of Waste Containment and other Impoundment Facilities" (EPA, 1987).
* The FML should be protected by an overlying drainage layer of at least 30 cm (12 in.) of soil material no coarser than 3/8-inch (0.95-mm) particle size, Unified Soil Classification System (USCS) SP sand, free of rock, fractured stone, debris, cobbles, rubbish, roots, and sudden changes in grade (slope) that may impair the FML. The overlying drainage layer should suffice as bedding in most cases, but care should be taken that any included drainage pipes are not placed in a way that will damage the FML.
* The FML should be in direct contact with the underlying compacted soil component and should be installed on a smoothed soil surface.
* The number of penetrations of the FML by designed structures (e.g., gas vents) should be minimized. Where penetrations are necessary, the FML should be sealed securely around the structure.

* Bridging or similar stressed conditions in the FML should be avoided by providing slack allowances for temperature-induced shrinkage of the FML during installation and during the period prior to placement of the protective layer or drainage layer.
* Slack should not be excessive to the extent that folds are created that later may crack.

2) **Koerner's Design-by-Function Concept.** Koerner <6> <16> presents the following FML design criteria:

* **FML Compatibility and Material Selection.** As with the other geosynthetics, the compatibility between surface water infiltration and the FML is generally not critical and does not normally require compatibility testing (EPA 9090). The FML is located on top of the clay barrier layer which consists of uncontaminated fill material. The compatibility between the underlying soil is also generally not critical. The FML does need to be chemically compatible with landfill gases.

Recent Omaha District designs have specified VLDPE over HDPE as the geomembrane material type. VLDPE is easy to install, has higher friction properties and conforms better to surface topographic changes such as the drainage terraces than does HDPE.

* **Vapor Transmission (Water and Methane).** Water vapor transmission is determined by ASTM D96. The corresponding coefficient of permeability (k) can be then be determined for the geomembrane type and thickness. When the landfill cover is also used to contain methane gas, methane vapor rates can be evaluated by ASTM D1434 and D814.

* **Biaxial Stresses via Subsidence.** The FML will need to withstand stress induced into the material from differential settlement. The allowable stress is determined from GM4 Three Dimensional Geomembrane Tension Test <18>. The required stress is determined after the settlement amount has been estimated and is dependent upon the following parameters: the unit weight of cover soil; the height of cover soil; the depth of differential settlement; the width of settlement depression; and the thickness of the liner. Refer to Koerner <18>, page 39 for further discussion.

* **Planer Stresses via Tension.** The FML would have to withstand tensile forces if the coefficient of friction of the upper layer (geonet/FML or geotextile/FML) is greater than the FML/clay interface. The tensile force in this case would also be dependent upon the length of slope and width. Refer to Koerner <18>, page 40 for further discussion.

b. Clay Barrier Component.

1) **EPA Recommendations <1>.** The clay barrier layer is located directly below the geomembrane. The EPA recommends the clay barrier layer have the following characteristics:

* The soil should be at least 24 inches of compacted, low-permeability soil with an in-place saturated hydraulic conductivity of 1×10^{-7} cm/sec or less.
* The compated soil must be free of clods, rock, fractured stone, debris, cobble, rubbish, and roots, etc., that would increase

the hydraulic conductivity or serve to promote preferential water flow paths.

* The upper surface of the compacted soil (which is in contact with the FML) should have a minimum slope of 3 percent after allowance for settlement.

* The soil layer should be constructed so that it will be entirely below the maximum depth of frost penetration upon completion of the cover system.

2) Design Considerations.

* Composite Action. The clay barrier layer is located directly below the geomembrane (FML) to create a composite liner system. The advantage of the composite liner design is that by putting a fine grain material beneath the FML, the impact of imperfections or holes in the FML can be reduced by many orders of magnitude <2>. In order to achieve composite action, the FML must be direct contact with the clay barrier layer.

* **Permeability Requirement.** As stated previously, the EPA <1> recommends a low-permeability soil with an in-place saturated hydraulic conductivity of 1×10^{-7} cm/sec or less. In addition to meeting the permeability requirement, the Omaha District has been specifying the clay liner be constructed of materials classified (as per ASTM D 2487) as either CL, CH or SC having a plasticity index (PI) of not less than 15. Daniel <36> warns that clays with a high PI may be a constructability problem. The clayer layer should not contain debris, roots, organic or frozen materials, stones or clods having a maximum dimension larger than one inch.

* **Thickness Requirement.** As previously stated, the EPA <1> recommends the clay barrier layer be at least 24 inches thick. Daniel <36> presents the relationship between the hydraulic conductivity versus the thickness of the liner for both good and excellent construction methods. The relationship indicates that the 24 inches is an absolute minimum thickness and greater depths should be considered. The minimum thickness of 24 inches is based upon constructability considerations and the ability to provide uniformity in overall permeability.

* **Frost Depth Requirement.** The drainage layer, the FML and the clay barrier layer should all be located below the maximum frost depth penetration. Freeze-thaw cycles adversely increases the permeability characteristic of the clay barrier layer. Freeze-thaw cycles could also effect the interface friction between the clay/FML contact and other interfaces.

* **Desication Cracking.** Desication cracking adversely increases the permeability characteristic of the clay barrier layer. The potential for desication of clay materials depends upon the following factors: Clay-size particle content, the soil properties such as plastic limit, liquid limit and plastic index, depth of soil cover, clay barrier moisture content and compaction history, climate, moisture content and the soil type of the adjacent random fill.

* **Settlement.** Daniel <36> recommends not placing a permanent low-permeability cover on unstabilized waste that will undergo large settlements. Daniel recommends interim fill to preconsolidate the refuse before the final cover is placed. Richardson <35> recommends an allowable subsidence (differential strain between inflection points) of no more than 1%

for the clay layer. Daniel <36> emphasizes the need for composite liners for covers placed on waste that will undergo settlement.

7. **Gas Collector and Removal System.** Degradation of solid organic waste materials in a landfill generates gases, primarily of which is carbon dioxide (CO_2) and methane (CH_4). The carbon dioxide is heavier than air and will move downward. The methane however, being lighter than air will move upward and collect at the bottom of low-permeability geomembrane (FML) barrier <2>. The potential impacts of gas generation are as follows <30>:

* **Explosion hazard.** Methane gas can migrate laterally and vertically and has caused explosions in structures adjacent to and on landfills.
* **Vegetation distress.** Landfill gases must be controlled before they penetrate into the vegetative cover layer. If uncontrolled, the gases could distress the vegetation resulting in subsequent erosion of the cover <22>.
* **Odor.** Landfill gases generate nuisance odors. Odor becomes a design parameter if the landfill is located adjacent to any existing or potential developments. Nuisance odors can be a public perception issue and can effect property values.
* **Physical disruption of cover components.** Landfill gases if not properly controlled, can generate uplift forces against FML and clay low-permeability layers. Uplift forces can disrupt the clay layer and stretch and bubble the FML which adversely results in increased permeability properties of the layers.
* **Toxic Vapors.** Landfill gases can be toxic. Toxicity is a design parameter when determing venting or treatment requirements.

a. **Gas Migration <30>.** After a final cover is placed, gas production can occur at high rates for years and can continue at lesser rates for centuries. Gas migration occurs by two processes. Convection is flow induced by pressure gradients formed by gas production in layers surrounded by low permeability or saturated layers. Convection is also induced by buoyancy forces since methane is lighter than air. Diffusion is flow induced by concentration gradients formed by production of methane and carbon dioxide at concentrations greater than in the surrounding air. Gas migration rates are affected by the type and age of refuse material, the final cover design, refuse temperature and moisture content. Vertical or lateral migration paths for gas movement are influenced by the final cover design and the presence of migration corridors and or barriers. Migration corridors include sand and gravel lenses, void spaces, cracks, fissures, utility conduits, drain culverts and buried lines. Barriers to gas migration include clay deposits and high and perched water tables. Saturated or frozen surface layers promote lateral migration of landfill gases.

b. **EPA Recommendations.** The function of a gas collection system is to protect the structural integrity of the final cover from uplift forces from the gas pressure and to protect the environment and public from the hazardous effects of the gas. The EPA <1> offers the following design recommendations based upon engineering judgment for a gas vent layer:

* The layer should be a minimum of 30 cm (12 in.) thick and should be located between the low-permeability soil liner and the waste layer.

* Materials used in construction of the gas vent layer should be coarse-grained, porous materials such as those used in the drainage layer.

* Geosynthetic materials may be substituted for granular materials in the vent layer if equivalent performance can be shown.

* Venting to an exterior collection point for disposal or treatment should be provided by means such as horizontal perforated pipes, patterned laterally throughout the gas vent layer, which channel gases to vertical risers.

* The number of vertical risers through the cover should be minimized and located at high points in the cross-section, and designed to prevent water infiltration through and around them.

c. **Gas Control Systems.** Gas control systems consist of a collection, conveyence and outlet component. Gas control systems are designed to be either passively vented to the atmosphere or as an active system where the landfill gas is mechanically extracted to the surface. At the landfill surface, the gases are either dispersed into the atmosphere, collected or treated. All components of the gas control system must consist of materials that are compatible with methane gas. Alternative gas control systems are described below:

1) **Passive Blanket and Liner Systems.** A continuous blanket gas collection system consisting of either 12 inches of granular fill or of a geosynthetic material is located below the clay barrier layer. Filter layers may be required above and below the continuous blanket. Linear trenches excavated into the refuse backfilled with granular material can also be used as a collector component. The granular or geosynthetic gas collection material should have a permeability coefficent (k) of 1 cm/sec or greater <36>. Gases are conveyed or removed from the granular blanket or trench collector in horizontal perforated pipes which are connected to vertical outlet vent pipes. Continuous blanket and trench gas control systems are normally passive where the gas is forced through the system by pressure gradients and buoyancy forces. The thickness of the select fill overburden must be chosen such that the soil weight exceeds the anticipated gas pressure <32>. The vertical outlet vent pipes for passive systems need to be located at the highest elevation of the gas collection blanket to allow maximum evacuation of the gas <1>. The vent pipes should be anchored to the barrier layer (FML) in a way that ensures watertightness but allows for some movement should there be differential settlement (see penetration discussion). The number of vent pipes should be minimized and are normally spaced abouth 200 feet apart (1 per acre) <36>. The vent pipe depth should be minimized to avoid stress concentrations at the boot connection. Linear gas collection systems should only be used for verly low expected gas production rates <30>. When the refuse material does contain suspecting gas producing material but off-site migration of the gas is not a specific concern, the passive continuous blanket gas control system can be used to protect the integrity of the final cover.

Feeney <32> describes a constructability problem which the Omaha District has also encountered at several projects. Passive systems relying on granular blanket (or trench) collector systems may not function until the geomembrane is completely covered with soil. Prior to placement of the geomembrane, landfill gas exits the landfill through the path of least resistance. The path of least resistant is sometimes through the cover soils and clay barrier layer and not through the gas control system. When the geomembrane is placed, gas collects under the material where a bubble can form and the geomembrane is damaged or eventually ruptures. Feeney recommends a method of avoiding this problem is to leave temporary vents in the geomembrane so that the landfill gas is dissipated rather than allowed to collect beneath the liner. The vents should be progressively sealed immediately prior to the placement of soil cover over the vent.

2) **Well Extraction Systems.** Gas extraction wells (perforated vertical collection pipes) can be drilled and placed penetrating to the bottom of the refuse. Gas extraction wells can be either active or passive. Active extraction wells used in conjunction with barriers create negative pressure zones to extract gas <30>. Wells are useful for layered landfills where vertical migration is impeded. Active gas control systems are more effective than passive blanket systems. Active well systems with perimeter barriers should be considered when there is nearby development and the off-site (lateral) migration of methane gas is either an environmental or safety concern and when the refuse material is highly organic and will generate large amounts of gas. Gas monitoring stations should be located outside the perimeter of the landfill situated between any development or area of concern. Gas monitoring stations can be used in conjunction with any gas control system active or passive. Gas monitoring stations <30> should be spaced every 1000 feet and be able to detect 25% of the lower explosive limit of methane. The monitoring stations are similiar to piezometers and extend to the maximum refuse depth.

The boot connection detail is critical for wells that penetrate completely or deeply into the refuse material. The well itself being ridsid and anchored into firmer and more compact material will not settle as much as the landfill surface. This differential movement will create stress concentrating at the boot connection and can cause the FML to tear away from the rent pipe (see penetration discussion).

8. **Random Fill.** Random fill is placed directly on the refuse material covering the entire aerial extent of the landfill. Random fill is used to bring the cover to proper grade and elevation reflecting the settlement and stability analyses and drainage and minimum fill requirements.

Prior to the placement of the random fill material, the landfill surface must be cleared of vegetative cover and proof-rolled. In certain circumstances, limited excavation and reshaping the landfill surface can minimize the volume of random fill material required which could result in substantial cost savings. Excavation into the landfill material requires specific safety considerations and is normally avoided if possible. Random fill can be either cohesionless or cohesive depending of the availability of materials. Materials which are unsuitable for use as random fill include debris, roots, brush, sod, organic or frozen materials and soils classified (according to ASTM 2487) as either MH, PT, OH and OL. The random fill is placed in lift thicknesses of 8 inches for cohesive materials and 12 inches for cohesionless materials. Density of the random fill is controlled by the standard procter test (ASTM D 698) for cohesive soils and the relative density test (ASTM D 4253) for cohesionless materials. Specific density requirements are not used for the bottom two layers of random fill placed. A procedure specification is used for the bottom two layers identifying a minimum number of passes of compaction equipment. A specific density in the first few lifts may not be possible due to a soft and compressable landfill surface. The random fill layer must have a minimum thickness to provide a firm foundation to allow adequate compaction of the low-permeability clay layer. A test fill may be required to determine this thickness. The Omaha District has been specifying that the measurement and payment method for random fill be by the ton. This assures that the contractor is payed for all fill placement noting the refuse consolidation and foundation settlement are likely to occur.

9. **Refuse or Contaminated Material.** A final cover can be placed over landfill refuse material or contaminated natural soils. Landfill refuse materials can consist of municipal or industrial wastes or be construction debris. The nature and extent of the waste material significantly effects the final cover design. The settlement and stability analyses, the gas and leachate control systems are all effected by the landfill composition. A final cover over natural soils that are contaminated is easier to design than a cover over a landfill. Traditional soil geotechnical sampling and testing can be used to characterize the properties of the soil required for design. Whereas, the geotechnics of landfill materials are normally highly variable within an individual site and the geotechnical properties of waste materials are very difficult to quantify.

10. **Optional Layers.**

a. **Biotic Protection Barrier.** The Omaha District has no experience with the operation and effectiveness of constructed biotic barrier layers. To reiterate EPA <1> guidance documents, plant roots or burrowing animals may disrupt the integrity of the drainage and low-permeability layers. Physical barriers, such as layers of cobbles or coarse gravel beneath the select fill, and chemical barriers, have been proposed to discourage or reduce the threat of biointrusion. Long term monitoring and evaluation of constructed final covers is required in various locations of the country to assess actual damage to the drainage and low-permeability layers from biointrusion.

b. **Geogrid Reinforcement <33>.** The geosynthetic liner layer interfaces normally control the design sideslopes of a cover. The interface friction angles between adjacent geosynthetics or between the geosynthetics and adjacent soil can range between 8^{o} to 25^{o} <33>. Cover sideslopes of 1V:4H (14^{o}) and steeper could readily have stability problems at the cover layer interfaces. Geogrids can be used to reinforce soils to provide stability to cover sideslopes.

c. **Geocomposite Alternatives.** There is a wide range of geocomposite materials available where various geosynthetic layers are factory-bonded together in one unit. Koerner <6> describes the various forms of geocomposites noting that the type of geocomposite is controlled by the function required, such as; seperation, reinforcement, filtration, drainage, and moisture barriers.

B. **Settlement Analysis.** Without the proper design considerations, settlement of the landfill and the underlying natural foundation material can damage or compromise the integrity of the final cover <25>. Excessive differential settlement could cause the following failure scenarios:

* Severe cracking of the clay barrier resulting in the loss of the impermeable characteristic of the layer.
* Steepened sideslopes resulting in slope stability failures.
* Induced tensile stresses in the FML and other geosynthetics.
* Stress concentrations at the penetration connections (i.e. gas vent boots to FML) resulting in the shearing or tearing of the FML.

* The flatter (3% to 5%) landfill slopes can change significantly with time, negating careful contouring and drainage provisions. The result could be failure of the drainage layer or vegetative cover.
* Disruption of the leachate or gas collection systems.

The major mechanisms of refuse settlement are as follows: <27> <28>

* The mechanical consolidation or void ratio reduction by distortions, bending, crushing, and material reorientation.
* Raveling or the movement at fines into large voids.
* Physical-chemical changes from corrosion, oxidation and combustion.
* Bio-chemical decomposition from fermentation and decay.

The refuse settles from both its own weight and the final cover components.

If the natural foundation material under the waste fill is composed of clayey soil types, the foundation consolidation will contribute to the overall settlement of the final cover. Traditional settlement analyses based upon on-site soil characteristics and loading conditions can be used to estimate the foundation component of the settlement of the final cover. It is important to note that many clean-up sites have a combination of remedial technologies.

Ground water pump and treatment systems are often coupled with a RCRA/CERCLA final cover. In this case, the effects of the ground water extraction system on foundation settlement must also be determined.

The factors affecting the magnitude of settlement are many and are often influenced by each other <27>. These factors include:

* refuse type or characterization (i.e. construction debris vs. municipal wastes)
* refuse density or void ratio
* content of decomposable materials
* waste fill depths
* weight of final cover components
* stress history (landfill operational history)
* leachate levels
* environmental factors such as moisture content, temperature, and gases present
* water table location

Sowers <28>, Yen and Scanlon <29> and others have developed methods to estimate the settlement refuse of material. Mechanical settlement occurs rapidly and is complete in essentially a month <28> and is a function of compression index (related to the void ratio) of the refuse material and the consolidation pressures. The combination of mechanical secondary compression, physical/chemical action, and bio-chemical decay causes settlement to continue with time. The rate of this secondary settlement is a function of the secondary compression. Predesign information, such as historic settlement surveys of the landfill surface is extremely useful in verifying design assumptions.

When either settlement of the waste fill or foundation is critical, pre-loading or surcharging can be used to preconsolidate. After time, the surcharge fill can be reshaped and the final cover components completed. Large scale pilot tests may be necessary.

C. Stability Considerations. Final covers over landfills or contaminated soils must remain stable through the 30 year design life and beyond. All portions of the system must be stable including the natural foundation materials below and beyond the landfill, the refuse material and the multi-layered components of the cover. Slope stability failures could be catastrophic both economically and environmentally.

Stability analysis of landfills and final covers are complicated in part by the following issues:

* The geological conditions at any site are unique.
* The geotechnics of the landfill materials are normally highly variable within an individual site and also vary with time. In addition, geotechnical investigations of landfills are rarely undertaken and quantification of the geotechnical properties of waste materials is very difficult <20>.

* Design procedures and guidance have not kept pace with the rapid development of the wide variety of new materials used in cover designs. <21>
* There are sometimes a lack of adequate test data and test methods to confidently allow the use of new materials.

The following stability issues should be addressed in a cover design:

1) Cover Component Interfaces. During the past two years over two dozen cover failures have occurred in the United States as a result of surface sliding on geomembrane or other low friction interfaces of the cover system <33>. The geosynthetic liner layer interfaces normally control the design sideslopes of a cover rather than the stability of the waste fill mass or foundation. The frictional resistance of all layer interfaces must be analyzed. The controlling interfaces will likely be the geonet/FML geonet/geotextile or FML/clay. Inclusion of a geotextile bedding beneath the drainage layer can be used to increase friction values and to prevent intrusion, by deformation, of the FML into the net or grid of the drainage layer <1>. Geocomposite systems and textured geomembranes can be used to improvement frictional resistance. The sliding resistance of the interface layers must take into account long term creep of the geosynthetics. The stability of the material interfaces should be designed based upon frictional resistance between the material interfaces plus a factor of safety. The geosynthetic components of final covers should not be designed in tension. With proper detailing and material selection, the stabilizing effects of anchor trenches and drainage benches can add to margin of safety and prevent localized and long term failures.

It is imperative that design analyses be based upon friction values that are specifically determined for each project using samples of actual materials and reflecting representative placement, loading, and wetting conditions <23>. For example, interfaces between the geomembranes and compacted clay may be critical, and their shearing resistance may also be extremely sensitive to the compaction conditions <23>. Clay barriers are compacted at high moisture contents being wet of the line of optimum. Soils compacted to the wet of optimum have lower friction values than the same material compacted with lesser water contents. Another issue is the effect of a film of water that develops between the geomembrane and the clay interface such that there is a possibility that increased pore pressures could result with a corresponding reduction strength. The interface wetting effects, consolidation conditions, grid orientations, and the surface texture and cleanliness of geomembranes may all affect frictional resistance <23>.

2. **Waste Fill Mass and Foundation Stability.** After the slopes are selected based upon layer interface friction requirements, the overall stability of the waste fill mass and foundation need to be analyzed. Traditional slope stability methods can be used to assess foundation stability. It is difficult to determine the geotechnical characteristics of refuse material. Observation of existing slopes of the refuse and back calculating available strengths have been used in determining the slope stability of landfill masses <24>. Seismic considerations should be addressed where applicable in the slope stability evaluation.

3. **Other Stability Issues.** Boschuk <22> in his review of more than 20 cover failures, identifies several other stability issues not described above. The effects of seepage forces resulting from infiltration in the select fill layer needs to be considered in cover designs. The effects of desiccation cracking and the corresponding transfer in load to the geosynthetics is a possible stability concern. Boschuk <22> continues noting that static shear strength parameters do not address seismic conditions, freeze/thaw effects, long-term rainfall events, biological and soil clogging, construction stress, and long-term stress relaxation and creep and stress transfer in geotextiles. Gas uplift forces under geomembranes can further reduce stability. Leachate trapped under the low-permeability layers of the final cover can create a hydrostatic pressure head which can reduce stability or fail the cover. Tension cracks in the select fill can allow a direct path for surface runoff to infiltrate the soil in sufficient quantities where hydrostatic pressures build up leading to instability of the soil cover.

D. **Grading Requirements.** The grading plan(s) for the final cover can be developed after the following design considerations have been completed:

* Topographic mapping of the landfill area and beyond is available.
* The limits of the landfill have been defined.
* After considering health and safety requirements, can the landfill material be partially graded to minimize random fill?
* Minimum fill requirements and layer thicknesses have been determined.
* The maximum or design sideslope has been determined based upon the stability analyses.
* The initial settlement analyses has been estimated.
* The drainage terraces have been sized, spaced and sloped to drain.
* Gabion drop structures have been sized and located.

Development of the grading plan is an iterative process where settlement is a function of fill height but fill height is not known until the final grading plan is complete. The grading plan should be well defined by horizontal and vertical control such that the cover grades can be staked in the field without any scaling from the drawings. The final slopes must reflect minimum grade requirements of 3-5% (after settlement) to accommodate both internal and surface drainage requirements. The final slopes must reflect the stability analysis. Maximum slopes should not exceed grades steeper than 1V: 3H to assure maintenance safety. The grading plan should also identify perimeter ditches. Grading plans are normally developed for the top of random fill, the top of the clay barrier layer and for the top of top soil. Each of these layers should be surveyed after construction. Development of the grading plan of the random fill must meet the above criteria while <u>minimizing</u> fill quantities.

E. **Hydrologic and Hydraulic Design Considerations.**

1. **HELP Modeling.** After the final cover layers have been tentatively selected, the Hydrologic Evaluation of Landfill Performance (HELP II) Model <10> can be used to assess the amount of infiltration which would penetrate into the refuse material. The Model also predicts amounts of surface runoff, subsurface drainage and leachate that results from operation of the final cover. The program models the effects of hydrologic processes including precipitation, surface storage, runoff, infiltration, percolation, evapotranspiration, soil moisture storage, and lateral drainage using a quasi-two-dimensional approach <10> <31>.

2. **Cap Internal Drainage.**

a. **Infiltration Drainage.** The final cover's internal drainage system consists of a drainage layer, a perforated pipe collection and conveyance system and exit or toe drains. Perforated collection pipes with point source outlets should be used instead of a continuous outlet at the toe of the final cover.

b. **Leachate Control.** As stated in the predesign discussion, landfills are normally quite pervious and can have significant amounts of leachate. Leachate seeps exiting from the landfill surface need to be identified and located during predesign activities. A leachate collection blanket being either granular fill or a geonet coupled with a conveyance pipe and outlet is required to control leachate levels. Uncontrolled leachate levels can build-up hydrostatic pressures behind the low-permeability layers resulting in decreased stability of the cover system or failure.

3. **Final Cover Surface Drainage and Erosion Control.** Proper design of a final cover includes assuring that surface runoff is drained off of the cover in a manner where erosion of the cover materials is controlled. Erosion of the final cover is controlled by the vegetative cover (discussed previously), drainage terraces and armored drop structures. The surface drainage system must be capable of conveying runoff across the cover without creating rills and gullies. The erosion control features should be designed so that little long term maintenance is required. In non-level terrain, diversion structures should be installed to prevent the run-on of surface water onto the cover <1>. Temporary erosion control measures during construction such as silt fences and straw bales is integral to any design.

a. **Terraces.** Slopes greater than 5 percent, are likely to promote erosion unless controls are included in the design <1>. Terraces are used to reduce erosion, reduce sediment content in runoff water, intercept and conduct surface runoff of a nonerosive velocity to a stable outlet or drop structure. The Omaha District has been specifying terraces that are 10 feet wide with a reverse slope of 1V:10H being one foot deep. A hydrologic evaluation is required to determine the surface runoff from the cover. The terrace should have enough capacity to control the design runoff event (25 year to 100 year rainfall frequency). The maximum flow velocity must be analyzed. Flow velocity is dependent upon channel slope and discharge quantities. The maximum nonerosive flow velocity for average soils is 2 feet per second. Riprap, erosion control mats and gabions can be used to armor the sideslope and bottom of terraces in order to resist erosive flow velocities. The length of drainage terraces is controlled by capacity and the nonerosive velocity requirement. The maximum spacing between terraces can be determined with the Universal soil loss equation <3>. The Soil Conservation Service <34> has developed methods to determine the maximum vertical spacing between terraces.

b. **Drop Structures.** All terraces must have adequate outlets <34>. Terraces normally discharge into central collection ditches or drop structures that drop down the steep sideslope of a cover. Depending upon the gradient of the cover sideslope, the drop structure will be constructed of either erosion control mats, riprap or gabions. As with the terraces, the drop structures have to be hydraulically sized and designed. A stilling basin at the bottom of the drop structure being at the toe of the final cover will be required to dissipate flow velocities in order to discharge the surface runoff off-site. Drop structures or perimeter ditches may also be required at the abutment contacts if surface runoff is directed from off-site towards the final cover.

c. **Off-site Discharge.** It is important to note, that if a final cover functions as designed, there will be an increase in both the total volume and the peak discharge of surface runoff leaving the site. The impact to the receiving stream of increasing runoff volumes and peak discharges off of the final cover should be a design consideration.

d. **Floodplain Considerations.** Several issues should be considered if a portion of the final cover is located in a floodplain. First, does the fill material of the final cover encroach into the zoned 100 year floodway such that river stages are raised over one foot and flood damages are induced? Second, could streambank erosion attack the fill material of the final cover such that streambank erosion control measures are needed?

F. **Borrow Areas.** The availability of on-site borrow materials should be evaluated in the Feasibility Study or Predesign stages. On-site borrow will normally result in substantial cost savings over off-site materials. Off-site materials must normally be purchased by the contractor and hauled to the site. On-site borrow avoids both of these costs. In addition, hauling large quantities of materials to the project location normally stresses transporation routes and is usually a public concern. If on-site borrow is availabile, predesign investigations are requried to map the area and define the nature and extent of the borrow source. A borrow area grading plan is required in the plans along with profiles showing excavation limits and subsurface features. Haul roads from the borrow site to the landfill location must also be assessed. Borrow areas can be used to mitigate wetlands or other environmental resources.

G. **Cover Penetrations.** Penetrations through the flexible geomembrane by rigid and relatively fixed gas vents, drainage pipes, leachate collection clean-out risers, piezomenters, monitoring wells and other structures should be minimized. Where a penetration is necessary, it is essential to obtain a secure, liquid-tight seal between the structuure and the geomembrane to prevent leakage of water around the structure <1>. The connection of the flexible geomembrane to fixed and rigid structures must also be flexible because differential settlement or any downslope movement of the cover soil will create stress at the connection resulting in either the streching or tearing of the geomembrane. The geomembrane boots that are currently used to connect the geomembrane to structures do not allow for such movement. As Jaros <5> notes, for CERCLA landfills, where the location, rate, and magnitude of differential settlements are unknown, additional emphasis is required in designing more flexible connections.

H. **Instrumentation requirements for Post Closure Monitoring <35>.** The monitoring time frame for a RCRA closure is 30 years. Key monitoring parameters include groundwater, leachate generation, air quality, gas lateral migration, settlement, slope stability, surface erosion, biotic intrusion and cover effectiveness. It is necessary to incorporate the proper instrumentation into the cover design and construction in order to monitor these parameters of concern. Baseline conditions must be measured either prior to or immediately after construction depending upon the parameter of concern. Consistent and accurate record keeping during the post closure period is essential.

Ground Water monitoring wells are normally placed both up and down gradient from the landfill and final cover. Baseline index parameters are taken prior to construction of the final cover. The ground water is sampled and monitored during the post closure period. It may also be necessary to abandon or raise existing monitoring wells where fill material will cover the wells.

Leachate seep discharge areas should be monitored at the collection discharge outlets for flow quantity versus time. Leachate seep discharge should decrease with time unless there is a failure in the low-permeability liner system. The concentration of leachate with time can also be monitored. Piezometers can be installed to monitored leachate levels beneath the final cover.

Landfill gas concentrations should be monitored for both the underground lateral movement of the gas and for air quality at the vent outlet locations. Regarding the underground lateral movement of gas, gas monitoring stations should be located around the perimeter of the landfill between any development or area of concern. The lower explosive limit of gas is the parameter of concern. The monitoring stations should be in place prior to placement of the low-permeability layers. The sampling frequency should be at least twice a day when the FML is being placed or when the ground is frozen. Air quality should be monitored on the final cover surface for toxic landfill gases emitted from the vent system. The contaminatnt levels of methane and other landfill gasses should be monitored with time and compared to the threshold limit values of the contaminants. For passive systems, internal gas pressures may be a parameter of concern. Pressure cells can be used to measure gas pressures.

Subsidence is a critical parameter to monitor because of the unseen damage differential settlement can cause to the clay barrier, the FML and other geosynthetics, penetration connections, drainage provisions, slope stability and to the leachate and gas collection systems. Normally settlement markers are installed on the final cover above the FML to monitor surface settlement. Methods are available to monitor foundation settlement and refuse settlement, if required. However, instrumentation needed to monitor these parameters requires intrusive effects into the refuse and cover penetrations.

Slope stability can be monitored with visual inspection, surface movement markers and possibly inclinometers. Inclinometers are used to measure horizontal movements with depth. Installation of a inclinometer would require a cover penetration and should be used only where stability considerations are critical. Movement markers should be located on the steepest slopes of the final cover and surveyed annually to the nearest one-hundreth of a foot.

The vegetative cover, drainage terraces, ditches and drop structures should be inspected annually in order to assure that there are no formations of erosion rills and gullies. The final cover surface should also be inspected for biotic intrusion and volunteer vegetation.

The effectiveness of the final cover is dependent upon the long-term operation of the drainage system and low-permeability layers. The outlets of the drainage system can be monitored. Lysimeters can be installed below the low-permeability layers to spot monitor leakage. Piezometers monitoring leachate levels should drop with time. The ground water wells (water quality) ultimately monitor the overall effectiveness of the final cover.

IV. SPECIAL FEATURES

There are many other features that must be addressed during the design of a final cover. These features are an integral component of a final cover design. Items such as the acquistion of construction easements and project right-of-way are critical and time consuming. These special features are identified below:

A. Decontamination Facilities
B. Access Routes (Road and Rail)
   1. Video tape of existing roads
   2. Traffic regulation requirements
      a. Load limits on public access routes
      b. Highway safety
   3. Cap perimeter road
   4. Maintenance requirements during construction
   5. Road surface rehabilitation requirements after construction
   6. Access requirements after construction

C. Staging Areas

   1. Support facilities (i.e. construction trailers, lay-down areas, etc.)
   2. Parking areas

D. Security Fencing
E. Utilities

   1. Existing location and availability
   2. Utility relocation considerations

F. Easements and Right-Of-Way Requirements
G. Phasing Requirements (Order of Work)
H. Operation and Maintenance Requirements
I. Demolition (if required)
J. Material Handling
K. Chemical Quality Data Management
L. Health & Safety

M. Project Camera
N. Pre and Post Construction Aerial Photos
O. Disposal of Cleared, Grubbed and Demolished Material (Hazardous or Not)

V. POTENTIAL LIST OF DRAWINGS

The following is a list of drawings that would normally be included in a set of plans for the construction of a final cover:

Cover Sheet
Index of Drawings
Vicinity Map (Large Scale and State map)
Location Map (Small Scale-Nearest Town to Project)
Existing Site Conditions Including Utilities
General Plan
Contractor Access Plan
Horizontal and Vertical Control
Demolition Plan (If Required)
Safety Work Zone Plan (Site Control Plan)
Cap Initial Grading Plan
Cap Low Permeability Clay Liner Grading Plan
Cap Final Grading Plan
Erosion Control Plan (Temporary)
Cap Cross Sections
Gabion Channel Cross Sections and Details
Cap Detail Drawings; Anchor Trench, Collection Pipes and Toe Drains.
Gas Vent, Settlement Monument, Benchmark and Penetration Details
Wash-Down Area Cross-Sections and Details
Monitoring Well Details
Leachate Control Plan and Details
Piezometer Details
Chain Link Fence Details
Borrow Area Grading Plan, Sections and Soil Test Data
Boring Location Plan
Record of Borings (Geological Profile Sheets)
New Utility Drawings (If Required)
New Access Road Profiles and Sections (If Required)
Project Right-of-way Map

VI. POTENTIAL LIST OF SPECIFICATION SECTIONS The following is a list of specification sections that would normally be included in a set of specifications for the construction of a final cover.

DIVISION 1 GENERAL REQUIREMENTS

01100 Special Clauses
01200 Warranty of Construction
01201 On-Site Camera
01300 Environmental Protection
01401 Safety, Health and Emergency Response
01402 Chemical Quality Management
01500 Decontamination and Disposal
01501 Summary of Work
01600 Temporary Utilities and Controls
01610 Support Facilities
01620 Security

01700 Measurement and Payment (Optional-Can Be In Technical Specifications)

DIVISION 2 SITE WORK

02050 Demolition (If Required)
02060 Well Abandonment (If Required)
02100 Clearing and Grubbing
02150 Hazardous Material Excavation and Handling (If Required)
02210 Grading
02215 Geotextile Filter
02220 Test Fill Sections
02222 Wire Mesh Gabions
02243 Crushed Rock Surfacing (If Required)
02244 Low Permeability Clay Liner
02246 Flexible Membrane Liner for Cap Systems (FML)
02248 Cap System Drainage Layer (Gravel Option)
02250 High Density Polyethylene Drainage Net (Geonet Option)
02251 Geogrid Reinforcement Material (If Required)
02252 Gas Venting System (If Required)
02420 Temporary Erosion and Sediment Controls
02435 Permanent Surface Water Controls
02444 Chain Link Security Fence and Gates
02475 Sodding (If Required)
02480 Seeding
02600 Roadways and Parking Areas
02900 Site Maintenance
02910 Monitoring Wells
02913 Demobilization and Project Close Out
02915 Piezometers
02920 Post-Construction Maintenance Activities

VII. **DESIGN ANALYSIS.** A design analysis in prepared to document design assumptions and procedures for all project features.

VIII. **QUANTITY TABULATION SHEET**

Item	Measurement
1. Seeding	Acres
2. Top Soil	Cubic Yards or Tons
3. Select Fill	Cubic Yards or Tons
4. Filter Layer	
a. Geotextile Fabric Alternative	Square Yards
b. Graded Granular Layer Alternative	Tons
5. Drainage Layer	
a. Geonet Alternative	Square Yards
b. Gravel Layer Alternative	Tons

6. Synthetic Barrier Layer	Square Yards
7. Clay Barrier Layer	Cubic Yards
8. Gas Control System	
a. Collection System	
1) Granular blanket option	Tons
2) Granular trench option	Tons
3) Geosynthetic material option	Tons
4) Wells option	Linear Feet
b. Pipe Conveyence	Linear Feet
c. Vertical Vent Pipes	Lump Sum/Each
d. Treatment System	Lump Sum
9. Random Fill	Tons
10. Clearing	Acres
11. Proof-rolling lLandfill Surface	Acres
12. Landfill Excavation or reshaping	Cubic Yards
13. Decontamination Facility	Lump Sum
14. Security Fencing	
15. Operation and Maintenance	Linear Feet
16. All Other Items	Lump Sum

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The Challenge of Treating Superfund Soils: Recent Experiences

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The treatment of Superfund soils is a challenging technical issue that is currently being addressed by a variety of different groups and programs within EPA. The Superfund Amendments and Reauthorization Act (SARA) of 1986 specifies a preference for permanent treatment of waste sources such as soil and there is a further preference for the selection and use of innovative technologies to accomplish permanent reduction in toxicity, mobility, or volume.

This paper covers five related areas presenting a total picture of this challenging issue including:

- Why is treating soils a Superfund priority?
- What unique considerations of these soils make their treatment challenging?
- What technologies will be effective at treating Superfund soils?
- What are the considerations for selecting treatment technologies for Superfund sites?
- What technology transfer mechanisms exist regarding soil treatment technologies?

Superfund soils have unique physical characteristics compared to the characteristics and requirements for the treatment/disposal of other industrial process wastes. The need to treat these contaminated soils has led to interesting research and demonstrations of treatment technologies.

This paper discusses currently available and innovative treatment technologies including low temperature thermal desorption, chemical extraction, bioremediation, soil washing, stabilization, and high temperature thermal treatment. In addition to a summary of how each technology is employed, both the applicability as well as the problems experienced with each technology are summarized and supplemented with examples from recent and ongoing Superfund treatment experiences. Sponsors of completed or ongoing treatability tests will be asked to submit data for the data base being developed for an EPA project.

INTRODUCTION

Section 3004(m) of the Resource Conservation and Recovery Act (RCRA) mandates that the EPA require treatment of hazardous wastes prior to land disposal. Known as the "Land Disposal Restrictions" (LDRs), these regulations may apply to hazardous industrial process wastes as well as contaminated soil, sludge and debris from Superfund and RCRA facilities that are destined for land disposal.

The 1989 Superfund Management Review (also known as the 90-Day Study) by the Office of Solid Waste and Emergency Response (OSWER) acknowledged that Superfund response actions may not be able to meet existing RCRA treatment standards based on "best demonstrated available technology" (BDAT) under the LDRs. The existing LDR regulations may limit the potential treatment technologies available for Superfund clean-ups, with technologies such as soil washing, stabilization, and biological treatment, being precluded because they may not meet the highest level of performance required by LDRs. In contrast, the 90-Day Study encouraged the greater use of innovative technologies and urged the reduction of non-technical barriers, such as regulatory and policy constraints, that inhibit the use of treatment technologies, while preserving the intent and spirit of applicable RCRA regulations.

OSWER recognized the potential limitation on treatment technologies for Superfund actions and developed a process to use LDR treatability variances for soil and debris. Guidance was issued to the Regions through the Superfund LDR Guide 6A, "Obtaining a Soil and Debris Treatability Variance for Remedial Actions," (OSWER Directive 9347.3-06FS) in July 1989 and revised in September 1990 (1). Superfund LDR Guide 6B, "Obtaining a Soil and Debris Treatability Variance for Removal Actions," (OSWER Directive 9347.3-07FS) was issued in December 1989 and revised in September 1990 (2). These guides describe the treatability variance process, include alternate treatment levels to be obtained under treatability variances, and identify treatment technologies which have achieved the recommended levels.

A memorandum issued on November 30, 1989 by OSWER entitled the "Analysis of Treatability Data for Soil and Debris: Evaluation of Land Ban Impact on Use of Superfund Treatment Technologies," (OSWER Directive 9380.3-04) provides support for decisions by the Regions to use treatability variances, when appropriate (3). The analysis identifies some of the key technical considerations to be evaluated in obtaining a treatability variance.

OSWER recognizes that the use of treatability variances represents an interim approach and is actively in the process of acquiring additional data for developing separate treatment standards for contaminated soil and debris.

The collection of data which supports the development of regulations for contaminated soil and debris is a joint effort by the OSWER's Office of Emergency and Remedial Response (OERR), Office of Solid Waste (OSW), and Technology Innovation Office (TIO), and the Office of Research and Development (ORD) Risk Reduction Engineering Laboratory (RREL). The initial data collection effort by the OERR that produced the data for the development of the treatability variance levels also identified the types of data needed to develop treatment standards for soil. These initial data are summarized in the "Summary of Treatment Technology Effectiveness for Contaminated Soil" (4). This paper describes both the conclusions drawn by OERR to date as well as the unique considerations of soil treatment which the Superfund program is investigating further. Ongoing research activities are also described.

ANALYSIS OF TREATMENT EFFECTIVENESS

OERR launched an extensive effort in 1987 and 1988 to collect existing data on the treatment of soil, sludge, debris, and related environmental media. The results from several hundred studies were collected and reviewed.

All applicable treatment information from the best documented studies was extracted, loaded into a data base, and analyzed to determine the effectiveness of technologies to treat different chemical groups (4).

Based on this analysis, a number of technologies commonly used in the Superfund program provide substantial reduction in mobility and toxicity of wastes as required in Section 121 of the Superfund Amendments and Reauthorization Act (SARA) of 1986. For example:

- Thermal destruction has been effective on all organic compounds, usually accomplishing well over 99% reduction of organics.

- Although the data indicate that PCBs, dioxins, furans, and other aromatic compounds have been dechlorinated to approximately 80%, more recent data indicate that removal efficiencies may approach 99.9%.

- Bioremediation successfully treats many halogenated aliphatic compounds, non-halogenated aromatics, heterocyclics, and other polar compounds with removal efficiencies in excess of 99%.

- Removal efficiencies for low temperature thermal desorption have been demonstrated with averages up to 99% for non-polar halogenated aromatics and with treatment often exceeding 90% for other polar organics.

- Soil washing and chemical extraction data on organic compounds indicate average removal efficiencies of approximately 90% for polar non-halogenated organics and 99% for halogenated aromatics, with treatment often exceeding 90% for polynuclear aromatics. The soil washing process, with optimized solvent selection, has demonstrated removal efficiencies often exceeding 90% for volatile and non-volatile metals.

- Immobilization can achieve average reductions in mobility of 93% for volatile metals, with reductions in mobility often exceeding 90% for non-volatile metals. Immobilization processes, while not actually destroying the organic compounds, reduce the mobility of contaminants an average of 99% for polynuclear aromatic compounds. Immobilization may not effectively stabilize some organic compounds, such as volatile organics, and the long-term effectiveness of immobilization of organics is under evaluation.

CONCLUSIONS REGARDING SOIL TREATMENT TECHNOLOGY EFFECTIVENESS

Contaminated soils can be treated via three basic mechanisms: (1) destruction of the contaminants through alteration to a less toxic compound; e.g., thermal destruction, dechlorination, bioremediation; (2) physical transfer and concentration of the contaminants to another waste stream for subsequent treatment or recovery; e.g., low temperature thermal desorption and chemical extraction, soil washing; and (3) permanent bonding of the contaminants within a stabilized matrix to prevent future leaching; e.g., immobilization and vitrification. In general, the destruction technologies are effective in reducing the toxicity of many organic contaminants. The physical transfer technologies reduce the toxicity and often the volume of selected organic and inorganic contaminants. While the bonding technologies are most effective at reducing the mobility and, therefore, the toxicity of inorganic contaminants, some increasing effectiveness is being demonstrated on selected organic contaminants as well. Figure 1 presents a summary of these basic conceptual conclusions. A more detailed discussion follows.

The technologies that have been widely demonstrated on soils are thermal destruction for organic contaminants and immobilization for inorganic contaminants. While these two technologies may be highly effective in treating particular classes of compounds, neither provides an ideal solution to complex mixtures of organic and inorganic contaminants, which are common at Superfund sites. The inherent difficulty in treating contaminants in a soil matrix, where waste conveyance and mixing are in themselves complicated unit operations, contributes to the need to find special solutions. Other

Contaminant	Technology		
	Destruction	Physical Transfer	Stabilization
Volatile Organics	●	●	✖
Semi-Volatile Organics	●	◒	◒
Metals	✖	◒	●

● Demonstrated Effectiveness

✖ Not Effective, Not Advised

◒ Potential Effectiveness (More Data Required)

Figure 1. Soil Treatment Effectiveness - Conceptual Approach

issues, such as landfill capacity and cost, cross-media impacts, and natural resource conservation, also support the need to develop and use
alternative and innovative treatment technologies for contaminated soil.

Because of EPA's ultimate goal of developing LDRs for contaminated soil and debris, this study evaluates a number of treatment options that are applicable to excavated soils. In-situ soil techniques, such as some types of bioremediation, soil vapor extraction, in-situ immobilization, and combined ground water and vadose zone soil treatment were not included in the scope of this evaluation. In-situ techniques should also be considered when researching remediation measures for a contaminated soil problem. When in-situ technologies are used at Superfund sites, the LDRs may not be applicable because the waste has not been excavated and subsequently "placed" in a landfill or other RCRA unit.

Based upon the data collected and evaluated by OERR from more than 200 soil treatment tests, conclusions were developed regarding the effectiveness of six soil treatment technology groups for each of eleven contaminant treatability groups. For destruction and physical transfer technologies applied to organic contaminants, the removal efficiency was analyzed. This evaluation factor was replaced by the reduction in mobility for the following technologies: immobilization, chemical extraction, and soil washing. The principles of operation and the effectiveness of treatment on organic and inorganic contaminants are presented below.

THERMAL DESTRUCTION

Principle of Operation

- o Thermal destruction uses high temperatures to incinerate and destroy hazardous wastes, usually by converting the contaminants to carbon dioxide, water, and other combustion products in the presence of oxygen.

Effectiveness on Organics

- o This technology has been proven effective on all organic compounds, usually accomplishing well over 99% removal.
- o Thermal destruction technologies are equally effective on halogenated, non-halogenated, nitrated, aliphatic, aromatic, and polynuclear compounds.
- o Incineration of nitrated compounds such as trinitrotoluene (TNT) may generate large quantities of nitrous oxides.

Effectiveness on Inorganics

- o Thermal destruction is not an effective technology for treating soils contaminated with high concentrations of some metals.
- o High concentrations of volatile metal compounds (lead) present a significant emissions problem, which cannot be effectively contained by conventional scrubbers or electrostatic precipitators due to the small particle size of metal-containing particulates.
- o Non-volatile metals (copper) tend to remain in the soil when exposed to thermal destruction; however, they may slag and foul the equipment.

DECHLORINATION

Principle of Operation

- o Chemical dechlorination is a process that involves the removal of chlorine atoms from chlorinated aromatic molecules by alkali metals, glycoxides, and hydrogen and hydroxyl radicals. This destruction process converts the more toxic compounds into less toxic products. The transformation of contaminants within the soil produces compounds that are more readily degradable. An evaluation of the end products is necessary to determine whether further treatment is required.

Effectiveness on Organics

- o PCBs, dioxins, furans, and other aromatic compounds (such as pentachlorophenol) have been dechlorinated to approximately 80% removal, with more recent data indicating that removal efficiencies may approach 99.9%.

- o Recent limited laboratory data have confirmed the applicability to other halogenated compounds including straight-chain aliphatics (such as tetrachloroethene). The removal of chlorine from aliphatics generally involves the removal of hydrogen.

- o Recently acquired data for halogenated cyclic aliphatics (such as dieldrin) indicate that dechlorination will be effective on these compounds as well.

- o When non-halogenated compounds or lower molecular weight halogenated compounds are subjected to this process, volatilization may occur.

Effectiveness on Inorganics

- o Dechlorination is not designed to treat metals. High concentrations of reactive metals (such as aluminum), under very alkaline conditions can increase the chemical requirements and may affect the dechlorination process.

BIOREMEDIATION

Principle of Operation

- o Bioremediation is a destruction process that uses soil microorganisms including bacteria, fungi, and yeasts to chemically degrade organic contaminants.

Effectiveness on Organics

- o Bioremediation appears to successfully treat many halogenated aliphatic compounds (1,1-dichloroethane), non-halogenated aromatics (benzene), heterocyclics (pyridine), and other polar compounds (phenol) with removal efficiencies in excess of 99%; however, the high removal implied by the available data may be a result of volatilization in addition to bioremediation.
- o More complex halogenated (p,p'-DDT), nitrated (triazine), and polynuclear aromatic (phenanthrene) compounds exhibited lower removal efficiencies, ranging from approximately 50% to 87%.

- o Poly-halogenated compounds may be toxic to many microorganisms.

Effectiveness on Inorganics

- o Bioremediation is not effective on metals.
- o Metal salts may be inhibitory or toxic to many microorganisms.

LOW TEMPERATURE THERMAL DESORPTION

Principle of Operation

- o Low temperature thermal desorption is a physical transfer process that uses air, heat, and/or mechanical agitation to volatilize contaminants into a gas stream, where the contaminants are then subjected to further treatment. The degree of volatility of the compound
rather than the type of substituted group is the limiting factor in this process.

Effectiveness on Organics

- o Removal efficiencies have been demonstrated by these units at bench, pilot, and full scales, ranging from approximately 65% for polynuclear aromatics (naphthalene), to 82% for other polar organics (acetone) and 99% for non-polar halogenated aromatics (chlorobenzene).

Effectiveness on Inorganics

- o Low temperature thermal desorption is not generally effective on metals.
- o Only mercury has the potential to be volatilized at the operating temperatures of this technology.

CHEMICAL EXTRACTION AND SOIL WASHING

Principle of Operation

- o Chemical extraction and soil washing are physical transfer processes in which contaminants are disassociated from the soil, becoming dissolved or suspended in a liquid solvent. This liquid waste stream then undergoes subsequent treatment to remove the contaminants and the solvent is recycled, if possible.
- o Soil washing uses water as the solvent to separate the clay particles, which contain the majority of the contaminants, from the sand fraction.
- o Chemical extraction processes use a solvent which separates the contaminants from the soil particles and dissolves the contaminant in the solvent.

Effectiveness on Organics

- o The majority of the available soil washing data on organic compounds indicates removal efficiencies of approximately 90% for polar non-halogenated organics (phenol) to 99% for halogenated aromatics (chlorobenzene), with lower values of approximately 71% for PCBs to 82% for polynuclear aromatics (anthracene).

- o The reported effectiveness for these compounds could be due in part to volatilization for compounds with higher vapor pressures (such as acetone).

- o This process is least effective for some of the less volatile and less water soluble aromatic compounds.

Effectiveness on Inorganics

- o The chemical extraction process, with optimized solvent selection, has demonstrated removal efficiencies of 85% to 89% for volatile metals (lead) and non-volatile metals (copper), respectively.

IMMOBILIZATION

Principle of Operation

- o Immobilization processes reduce the mobility of contaminants by stabilizing them within the soil matrix, without causing significant contaminant destruction or transfer to another medium.

- o Volatile organics will often volatilize during treatment, therefore an effort should be made to drive off these compounds in conjunction with an emission control system.

Effectiveness on Organics

- o Reductions in mobility for organics range from 61% for halogenated phenols (pentachlorophenol) to 99% for polynuclear aromatic compounds (anthracene).

- o Immobilization is also effective (84% reduction) on halogenated aliphatics (1,2-dichloroethane).

- o Some organic mobility reductions of the more volatile compounds may actually be removals as a direct result of volatilization during the exothermic mixing process and throughout the curing period.

- o The immobilization of organics is currently under investigation, including an evaluation of the applicability of analytical protocols (EP, TCLP, total analysis) for predicting long-term effectiveness of immobilization of organics. The preliminary available data indicate that significant bonding takes place between some organic contaminants and certain organophilic species in the binding matrix; however, immobilization may not effectively stabilize some organic compounds, such as volatile organics.

Effectiveness on Inorganics

- o Immobilization can accomplish reductions in mobility of 81% for non-volatile metals (nickel) to 93% for volatile metals (lead).

The effectiveness of the six technologies to treat soil was classified as having demonstrated effectiveness, potential effectiveness, or no expected effectiveness for the eleven contaminant groups (Figure 2). The ratings were based on removal efficiency, scale of operation, and potential for adverse effects as follows:

- o Demonstrated Effectiveness: A significant percentage of the data, at least 20%, is from pilot or full scale operations, the average removal efficiency for all of the data exceeds 90%, and there are at least ten data pairs.

- o Potential Effectiveness: The average removal efficiency for all of the data exceeds 70%.

- o No Expected Effectiveness: The average removal efficiency for all of the data is less than 70% and no interference from the contaminants in the soil is expected.

- o No Expected Effectiveness: Potential adverse effects to the environment or the treatment process may occur. For example, high concentrations of metals may interfere with biological treatment.

In some cases, a different rating was selected when additional qualitative information and engineering judgment warranted. Two ratings were selected if the compounds within a treatability group were so variable that a range of conclusions could be drawn for a particular technology.

Although some of the data upon which the analysis is based have limited quality assurance (QA) information, the data, nevertheless, do indicate potential effectiveness (at least 90% to 99% reduction of concentration or mobility of hazardous constituents) of treatment technologies to treat Superfund wastes. Some reductions in organic concentrations or organic mobility of more volatile compounds may actually represent the removal of those compounds as a direct result of volatilization. Technologies where this is most likely to occur include dechlorination, bioremediation, soil washing, or immobilization, and consideration of appropriate emission controls is required. Percentage removal reductions (removal efficiencies) are not always a good measure of effectiveness, especially when high concentrations remain in the residuals. Some of the performance observations are based upon a relatively small number of data points and may not extrapolate well to the broad array of soils requiring treatment.

QUANTIFYING TECHNOLOGY EFFECTIVENESS AND LIMITATIONS

TECHNOLOGY LIMITATIONS

A variety of potential limitations to the effective treatment of Superfund wastes were identified in the analyses of data from OERR's original survey. The EPA offices of OERR, OSW, TIO, and ORD are now working together to identify technology limitations and their impact on technology effectiveness.

The data suggest that the treatment of soil and debris with organic contamination, by technologies other than thermal destruction, will not be able to consistently achieve BDAT standards previously developed for industrial process wastes. The difficulty in treating soil and debris is a direct result of the levels of contaminants, the types/combinations of contaminants, the type of matrix, particle size, and other physical and chemical characteristics of the soil and debris.

TECHNOLOGY / TREATABILITY GROUP	THERMAL DESTRUCTION	DECHLORINATION	BIOREMEDIATION [4]	LOW TEMPERATURE THERMAL DESORPTION	CHEMICAL EXTRACTION AND SOIL WASHING	IMMOBILIZATION [4]
NON-POLAR HALOGENATED AROMATICS (W01)	●	◒	◒ [3]	● ◒	◒	◒
PCBs, HALOGENATED DIOXINS, FURANS, AND THEIR PRECURSORS (W02)	●	◒	◒ [3]	◒ [1]	◒	◒ [1]
HALOGENATED PHENOLS, CRESOLS, AMINES, THIOLS, AND OTHER POLAR AROMATICS (W03)	● [3]	◒	◒	◒	◒	◒ [3]
HALOGENATED ALIPHATIC COMPOUNDS (W04)	●	◒ [2]	◒ [2]	●	◒	◒ [2]
HALOGENATED CYCLIC ALIPHATICS, ETHERS, ESTERS, AND KETONES (W05)	●	◒ [1]	◒ [1]	○ [1]	◒ [1]	◒ [1]
NITRATED COMPOUNDS (W06)	●	○ [1]	◒	○ [1]	◒	◒ [1]
HETEROCYCLICS AND SIMPLE NON-HALOGENATED AROMATICS (W07)	●	○ [2]	◒ [2]	●	◒	◒ [2]
POLYNUCLEAR AROMATICS (W08)	●	○ [2]	◒	○	◒	◒
OTHER POLAR NON-HALOGENATED ORGANIC COMPOUNDS (W09)	●	○ [2]	◒ [2]	◒	◒	◒ [2]
NON-VOLATILE METALS (W10)	○ [1]	○ [1]	○ X [1]	○ [1]	◒	● [3]
VOLATILE METALS (W11)	X [1]	○ [1]	○ X [1]	○ [1]	◒	●

● Demonstrated Effectiveness
◒ Potential Effectiveness
○ No Expected Effectiveness (no expected interference to process)
X No Expected Effectiveness (potential adverse effects to environment or process)

1 Data were not available for this treatability group. Conclusions are drawn from data for compounds with similar physical and chemical characteristics.
2 High removal efficiencies implied by the data may be due to volatilization or soil washing.
3 The predicted effectiveness may be different than the data imply, due to limitations in the test conditions.
4 These technologies may have limited applicability to high levels of organics.

Figure 2. Predicted Treatment Effectiveness for Contaminated Soil

The residual concentrations in contaminated soil treated by technologies other than thermal destruction is highly dependent upon the concentrations in the untreated soil. Therefore, when evaluating technologies other than thermal destruction, the ability of those technologies to treat high concentrations of organics should be considered. The number and types of contaminants must also be carefully screened. Organic and inorganic contaminants may require different treatment technologies, thus requiring a treatment train. In some cases, different technologies may be necessary for soils and sludges.
In addition, the distribution of contaminants often is also very non-homogeneous and is dependent on patterns of contaminant deposition and transport.

The complex nature of solid waste matrices, such as contaminated soil from a Superfund site, severely complicates the treatment process. Soil is a non-homogeneous living medium, and the proportion of clay, organic matter, silt, sand, debris, and other constituents can affect the treatability of a contaminated soil. For example, the complex bonding forces that are exhibited by various soil fractions, particularly clays and organic matter, can be difficult to counteract and can affect the treatability of contaminated soil. To further complicate these circumstances, the age of many of these sites has allowed significant opportunity for environmental weathering of the contaminants and the medium.

Collectively, these conditions make the treatment of contaminated soil, weathered contaminated ("old") sludge, and debris a formidable technical challenge. EPA intends to quantify the effects of these factors, and the approach is to analyze the existing treatment data for the effects of these factors. Specific parameters affecting performance will be identified from existing data; parameters include: soil morphology (particle size distribution), clay content, permeability, total organic carbon, cation exchange capacity and as many as twenty other parameters. Differences in treatment performance among different technologies, contaminants and soil and debris types will be investigated.

SUPERFUND DATA COLLECTION AND RESEARCH APPROACH

EPA is in the process of developing the final regulations for contaminated soil and debris, and the Superfund program has a second important goal--timely and thorough technology transfer. The initiatives EPA has taken involve collecting all existing information on the treatment of soil and debris to supplement the first data collection effort and conducting experimental tests, when necessary, to better understand the process (Figure 3). The EPA OERR, ORD, OSW, and TIO are working together in these efforts due to the complexity of effectively treating soil and debris. Discussion of the initiatives follows.

Existing Data Collection

The targets for existing soil and debris treatment data include recent EPA remedial/removal actions, Department of Defense (DOD) and Department of Energy (DOE) actions, Superfund Innovative Technology Evaluation (SITE) program demonstrations, underground storage tank (UST) corrective actions, and activities conducted by private research organizations and vendors. The information that is being requested includes data on performance as well as other information important for technology transfer. Parameters of interest include: contaminants treated, scale of the test, measured contaminant concentrations before and after treatment, quality control (QC) protocols, design and operating parameters of the treatment system, methods to improve performance and problems encountered in treatment. The information that is collected will be entered in the Superfund Soil Data Management System, (DMS) designed specifically for storing and managing this information.

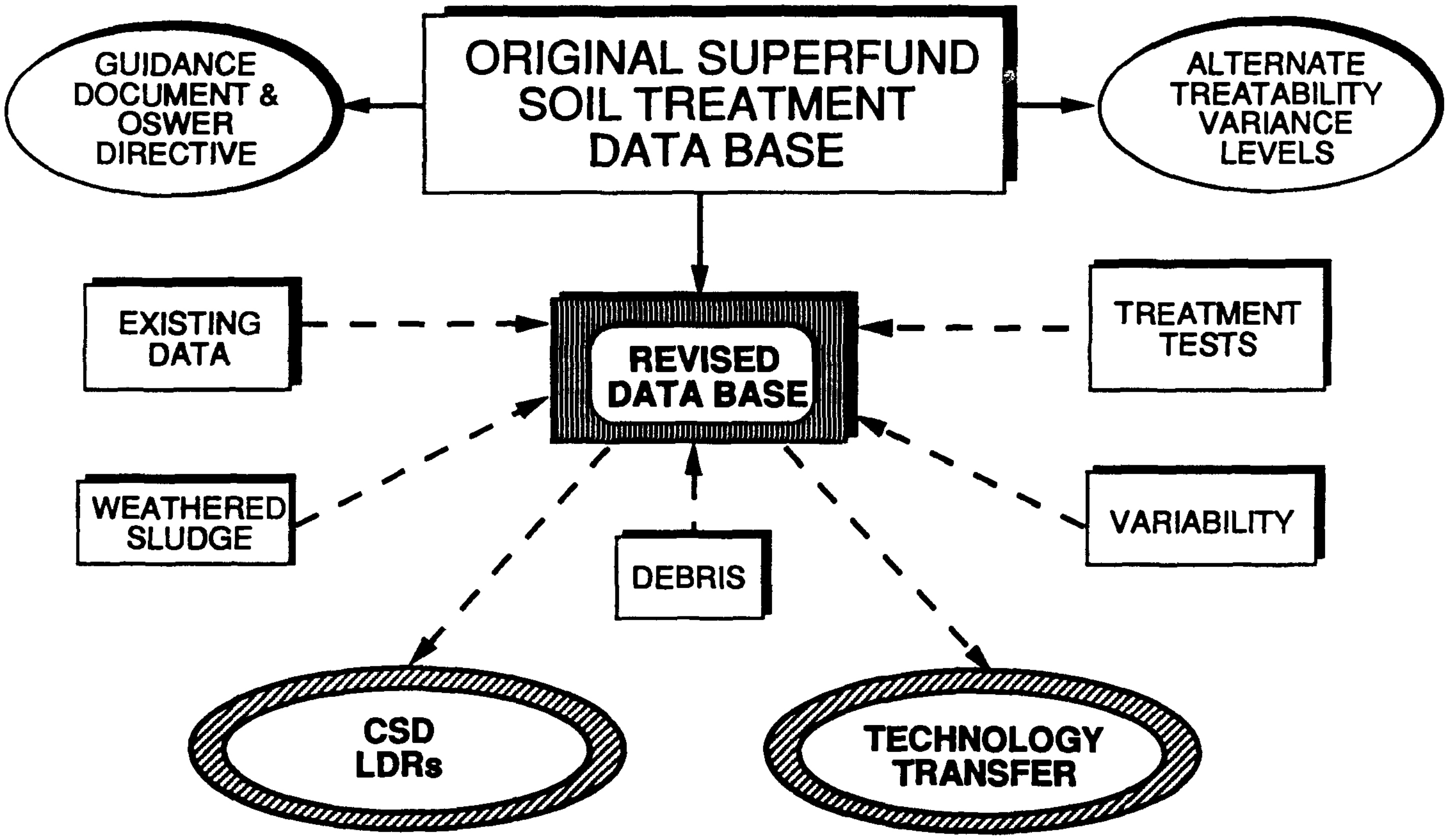

Figure 3. Superfund Data Collection and Research Approach

Soil Treatment Tests

The treatment tests that are being performed are tests on soils, contaminants, and technologies that lacked adequate treatment performance data where the technologies would be available for treating contaminated soil and debris (CSD). Twelve treatment tests are currently planned on eight different Superfund soils representing different soil types, contaminant types and concentrations, and treatment technologies.

Because the variability of the soil matrix may have significant effects on the ability of a technology to perform, EPA is especially interested in testing the effects of soil morphology or composition on treatment technology performance. Preliminary data indicate that clayey soils are treated less effectively than silty or sandy soils by some technologies. To evaluate this finding, pilot-scale treatability tests will be conducted on three different soil types - sandy, silty, and clayey from the eight different Superfund sites. Data generated from these treatability tests and the available treatment data will be used to investigate the effect of soil type on treatment effectiveness.

The technologies that will be tested include slurry bioremediation, low temperature thermal desorption, chemical extraction, soil washing, and stabilization. The technologies will be applied to different types of contaminants as well. Soils with significant levels of polynuclear aromatic hydrocarbons (PAHs), pentachlorophenols, volatile organics, PCBs and metals, will be tested. The stabilization technology may be tested as both a primary technology and as a secondary treatment process for residuals.

The treatability tests will be conducted according to the EPA "Quality Assurance Program Plan for Characterization Sampling and Treatment Tests Conducted for the Contaminated Soil and Debris Program" (5) and site specific Sampling and Analysis Plans. The individual sampling plans specify holding times, analytical methods, chain of custody, and quality control measures, such as blanks and spikes. The tests will include measurements of contaminant concentrations before and after treatment, and measurements of the waste characteristics that affect the performance of soil treatment technologies. Examples of waste characteristics that affect treatment performance include but are not limited to moisture content, oxidation/reduction potential, and particle size distribution; the parameters that affect performance are listed in the QA Program Plan.

OERR recognizes that much of the soil and debris from Superfund sites contains mixtures of contaminants and that individual contaminants may need to be treated differently. Treatment trains may be utilized in these cases. EPA wants to know the types of technologies applied to mixtures of contaminants and the effectiveness of the system. The major source of this type of data will be from existing treatability data, however, several of the planned treatment tests may also involve treatment trains. The treatment trains used in the tests will be a technology for treating the organic contaminants followed by stabilization to treat the inorganics (metals) remaining in the soil residues.

Debris Treatment

Parallel with the effort to collect data on soil is an effort to collect existing information on the characterization and treatment of debris. The first data collection effort obtained very limited data on debris treatment. The studies indicated that debris could constitute as much as fifty percent of the contaminated media, such as might be found at a wood preserving site. OERR also recognized that the sampling procedures used to provide representative samples of debris contamination were not well documented. Recognizing the importance of debris, EPA has implemented a comprehensive review of debris sampling, analysis and treatment approaches. Some characteristics of debris that may affect treatment include permeability and destructibility. The potential treatment technologies that have been identified for debris to date are destruction, extraction, and immobilization.

Weathered Contaminated Sludge

The OERR data survey identified the existence of large quantities of weathered contaminated or "old" sludges on Superfund sites. These sludges have aged or weathered, and are different than typical RCRA sludges. The data on "old" sludge indicated that sludges are not consistently defined in the literature. Furthermore, these sludges, when identified, had higher concentrations of contaminants than soils, and as a result, did not meet treatability variance levels as frequently as soil. Of the OERR survey data, 55% of the sludge treatment tests met variance levels, while 78% of the soil treatment tests met variance levels. These results indicate that weathered contaminated sludge may require separate treatment standards. In order to quantify the treatability of sludges for regulatory development purposes, more data will be collected on the characteristics and treatability of sludges. Existing data will be collected as part of the data collection effort, and characterization tests will be conducted on sludges from Superfund sites to obtain the physical and chemical characteristics of weathered contaminated sludge. A focused symposium will also be convened to discuss this timely topic and to compile the experiences of others who have dealt with these wastes.

Variability

An additional factor which influences treatment performance is homogenization of the waste, whether through materials handling, preprocessing, and or mixing within the treatment system. The previous OERR data survey indicated that the degree of homogenization achieved can have important effects on treatment performance and therefore the issue is being evaluated in the current research approach.

A critical element in soil treatment is materials handling. Special approaches to waste transfer throughout the treatment system are particularly important for solids and viscous sludges, where traditional conveyance methods are frequently ineffective. Slugs of material or debris tend to jam treatment equipment, resulting in breakage, downtime, and the potential for uncontrolled releases to the environment.

The preprocessing of waste to maximize homogeneity and modify the waste characteristics is also important to successful treatment technology operation. Any treatment technology will operate most efficiently and cost effectively when it is designed and utilized to treat a homogeneous waste with a narrow range of physical/chemical characteristics. If contaminant types and concentrations, waste viscosity, BTU content, moisture content, acidity, alkalinity, etc., vary widely, control of the system can be difficult and costly to maintain. Many of these waste characteristics can be modified and improved with appropriate preprocessing.

In addition, the most effective technology performance is achieved when the soil particle size is small and the maximum amount of surface area is exposed. This condition facilitates adequate contact between the contaminant sorption sites and the driving force of the technology (i.e., microorganism, solvent, warm air, etc.). The key to achieving this contact, and subsequent contaminant destruction, transfer to another medium, or bonding, is often achieved only through significant mixing, either before entering or within the treatment unit.

Materials handling, preprocessing, and mixing technologies with potential application to contaminated soil are currently in use in industries such as construction, agriculture, and mining. All of these industries routinely handle large quantities of soil or rock. The use of technologies from these industries should be considered during all soil remediation activities. Materials handling, preprocessing, and treatment unit mixing techniques should also be incorporated in treatability testing programs.

The results of such tests will better define the range of waste characteristics which the full-scale technology will have to treat.

To further investigate this important issue, EPA is performing mixing studies performed on various uncontaminated soils. The tests are designed to quantify the mixing of soil and test the effects of soil homogeneity on treatment performance. A selection of soil types, mixing equipment scales, and moisture contents, representative of different treatment technologies, will be combined to provide a matrix of samples commonly encountered during treatment. Mixing experiments will be conducted on three types of uncontaminated soil (clayey, silty, and sandy) at three mixer scales (bench, pilot, and full) and at three moisture contents (field dry, liquid limit, and plastic limit) to establish trends in the degree of mixing as a function of soil type, scale, and moisture content, representative of different treatment technologies. Similarly, treatment and mixing tests will be performed on contaminated soil at the pilot scale on a select set of samples from this matrix. Data generated from these tests could be used to establish a correlation between treatment effectiveness and degree of mixing.

CONCLUSIONS

EPA has launched a comprehensive and aggressive effort to facilitate technology transfer and to develop LDR regulations based upon best demonstrated available technologies for treating soil and debris. The technical issues that need to be considered in the development of LDR regulations for soil and debris have been identified and are being investigated in research programs and by analyses of existing data.

Timely and complete technology transfer is an important EPA Superfund goal and in addition to collecting data and developing land disposal restriction regulations for contaminated soil and debris. Therefore, EPA will continue to seek and evaluate all treatment results, and evaluate the results for both regulatory development and technology transfer. In this vein, the data and conclusions presented in this paper represent the most current information available in the Superfund program. EPA recognizes that with each additional treatment test performed, more valuable information will be generated regardless of whether the test was successful or not.

It is important that the research, remediation, and vendor experts have an opportunity to participate in the EPA Superfund technology transfer activities as well as in the development of the land disposal restriction regulations for contaminated soil and debris. Two options exist for this participation. First, EPA requests that all available information on the treatment of contaminated soil, sludges, and debris be forwarded to EPA or to CDM FEDERAL PROGRAMS CORPORATION. Second, public participation in the regulatory development process through response to upcoming Federal Register Notices is also encouraged.

The data, experience, and opinions of members of the hazardous waste treatment community. will be valuable additions to the crucial technology transfer and regulatory development efforts. Participation in this process is strongly encouraged and will be greatly appreciated. Please send all available information and any comments or suggestions to EPA OERR or to CDM FEDERAL PROGRAMS CORPORATION at the following addresses:

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Tower Chemical: Remedial Design
For
A Small But Complex NPL Site

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INTRODUCTION

The goal of this paper is to describe one NPL remedial design project and share the circumstances surrounding a few key issues that arose during the effort. The design project was for the Tower Chemical site near Clermont, Florida (near Orlando). The design phase was completed in August 1990, under the REM III contract and will be entering a competitive bidding phase for Remedial Action (RA) in mid-1991, under the ARCS IV contract.

Several unanticipated aspects of the design resulted in a bumpy ride to completion, only a few of which will be discussed in this paper. Two technical issues and one contracting issue are described in some detail, and conclusions regarding their resolution are provided. The technical issues were: 1) accommodate a seven-fold increase in the estimate of contaminated soil requiring remediation, and; 2) provide a biddable design document which takes into consideration the limited data used to determine the quantity of contaminated soil. The contracting issue was one of whether or not to divide the design into two parts, a water treatment system contract document and a thermal treatment system contract document.

BACKGROUND

The Tower Chemical Company site is an abandoned pesticide manufacturing facility located near Clermont, Florida (see Figure 1). From 1957 to 1981, manufacture of pesticides resulted in disposal of residues that contaminated soil and groundwater with various contaminants including DDT, dicofol, xylenes, chromium, nickel and lead. Site investigations conducted by the United States Environmental Protection Agency (EPA) and Florida Department of Environmental Regulation (FDER) resulted in the site being included in the National Priority List in 1981. In 1983, an

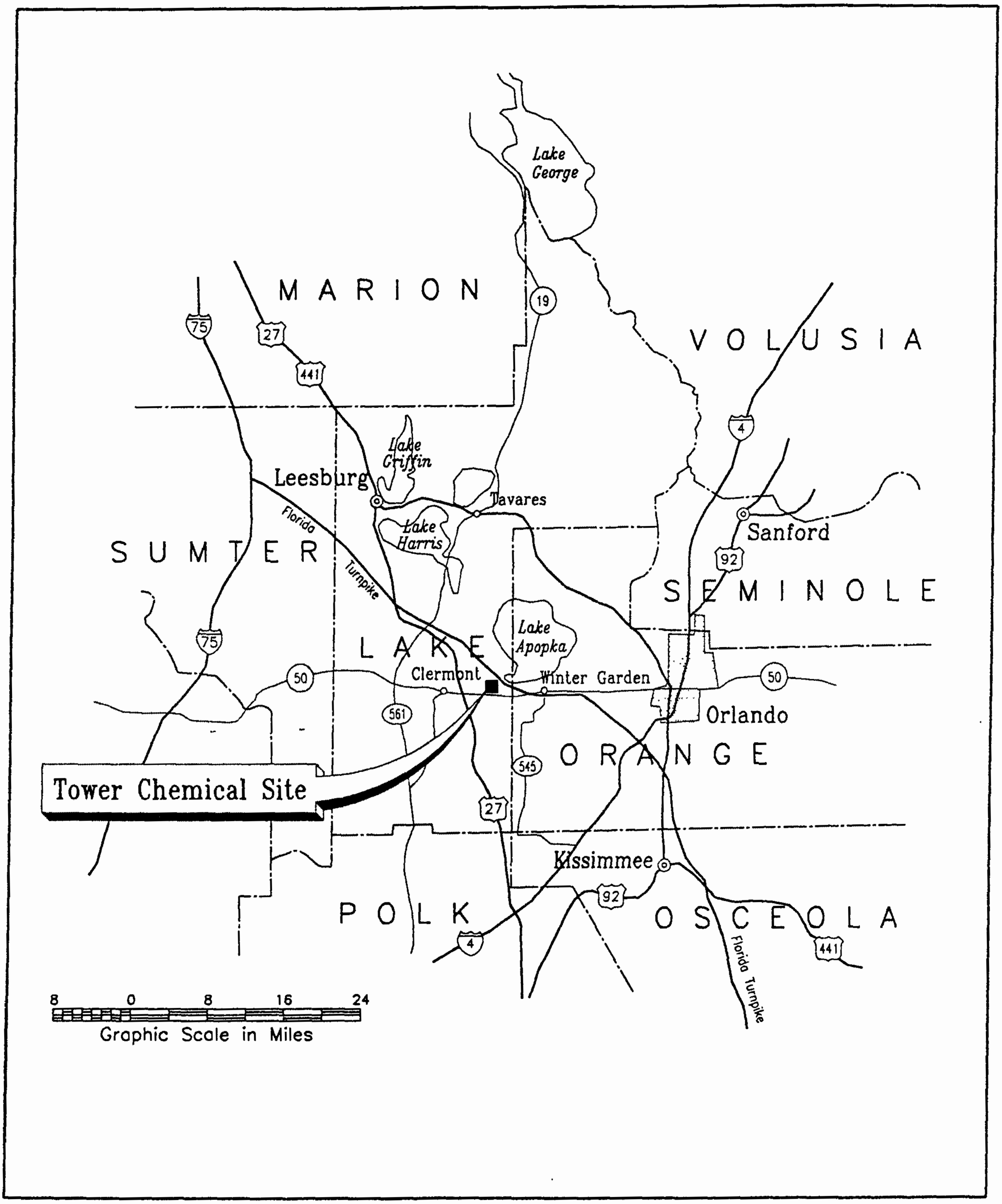

Figure 1

SITE LOCATION MAP

Immediate Removal Measure (IRM) was conducted by the EPA that consisted of contaminated soil excavation, buried drum removal and pond water treatment. The Remedial Investigation and Feasibility Study (RI/FS) were completed in 1987 by NUS Corporation, and the Record of Decision (ROD) was signed in July of that year. The ROD specified excavation and incineration of contaminated soil, with pump and treatment of contaminated shallow groundwater, in addition to other activities. Ebasco Services Incorporated (Ebasco) was tasked by the EPA in January 1988, to prepare a Remedial Design (RD) for contaminated groundwater. In May 1990, the design was expanded to include all site remediation tasks with some of the site preparation activities being implemented by the EPA Emergency Response Group, including security fence construction, contaminated soil excavation and backfilling, and soil testing. In late July 1990, at the request of the EPA, all site preparation tasks were incorporated into the design scope. Specifications and drawings were revised to include all soil clean-up activities in conjunction with the implementation of the groundwater extraction and treatment system. In August 1990, the design was submitted to the EPA, revised pursuant to review comments, and resubmitted to the EPA.

SITE DESCRIPTION

The main facility consists of a production building, a small utility building, an office, and two disposal areas: a burn/burial area for solid wastes and a percolation/evaporation pond for acidic wastewaters. Figure 2 shows the existing site conditions. The site is relatively flat with only about five feet of relief. Surface water drains into lower areas which eventually drain into an unnamed stream north of the site. The stream, in turn, flows into the Gourd Neck area of Lake Apopka. The lake and nearby swamps and wetlands provide an important natural habitat for local wildlife, including nesting bald eagles.

Groundwater in the vicinity of the Tower site occurs in the unconfined Surficial Aquifer and the confined Floridan Aquifer. The Surficial Aquifer extends over most of the site and is composed mainly of quartz sand with varying amounts of clay and silt. Groundwater in the Floridan Aquifer flows through solution channels and joint systems in the limestone. The Floridan Aquifer is the major potable drinking water source in central Florida and many local residents have potable water wells screened in the Floridan. Wells screened in the Surficial Aquifer are not used for domestic water supplies.

The Surficial Aquifer, in the area of the Tower Chemical Company site, flows generally to the northeast, towards the unnamed creek. The water table ranges from 0 to 5 feet below the land surface. Horizontal groundwater velocity is estimated to be less than two feet per year over most of the site, but localized areas can exhibit a horizontal velocity of 10 feet per year due to steep groundwater gradients.

The Floridan Aquifer, in the site area, is poorly confined by the overlying Hawthorne Formation which is laterally discontinuous across the main facility due to the presence of relict sinkholes. Groundwater in the Floridan Aquifer moves rapidly through solution channels in a northeasterly direction. The top of the Floridan Aquifer ranges between 54 and 188 feet below the land surface, with the potentiometric surface between 2 feet above to 10 feet below the land surface.

PREVIOUS SITE RESPONSE ACTIONS

Three Immediate Removal Measures (IRM's) were conducted at the site, following the closure of the Tower Chemical Company. The first IRM was conducted in 1981, at a nearby spray irrigation field, under the lead of FDER. The second and third IRMs were conducted in 1983 and 1988, by the EPA,

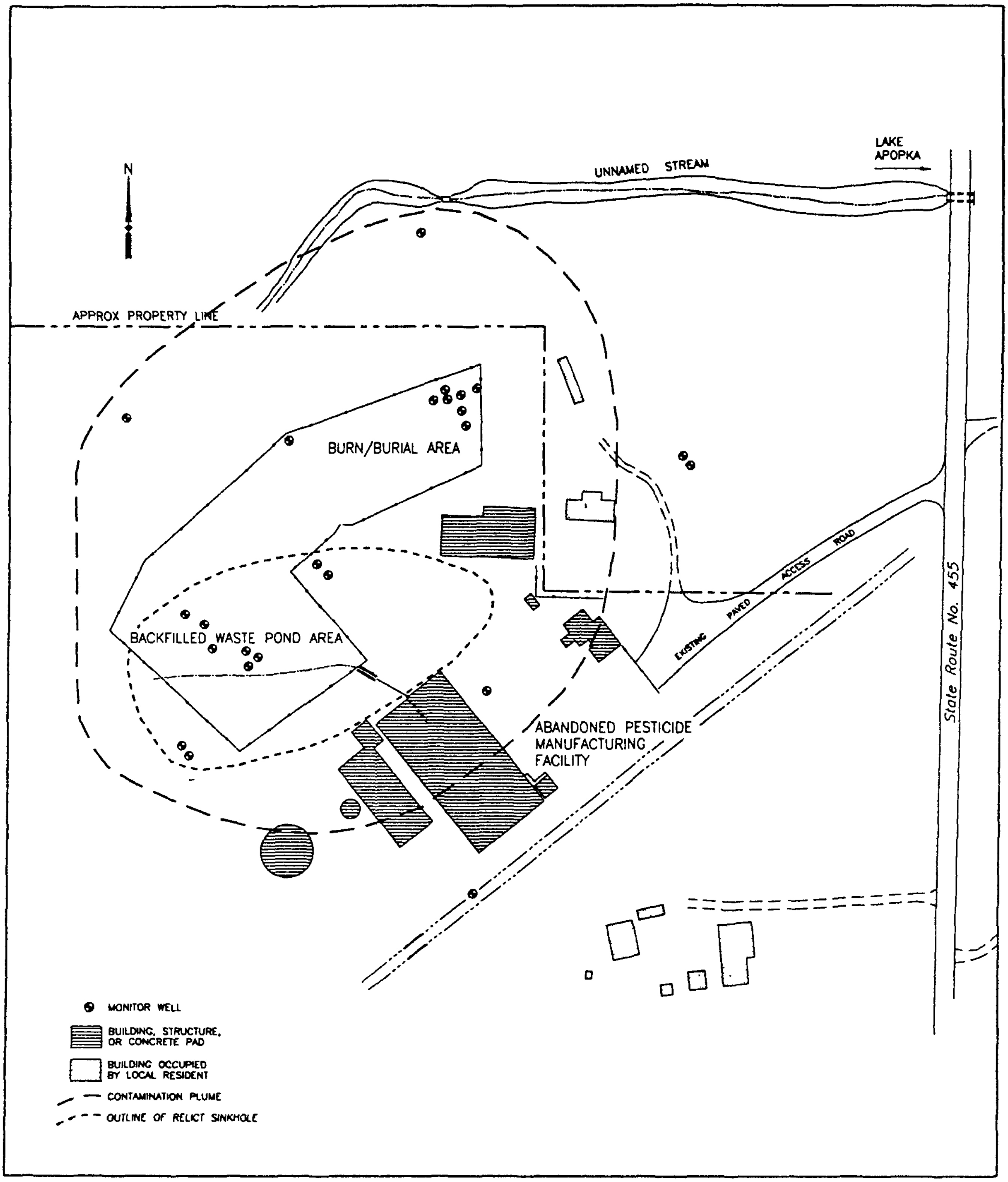

Figure 2

EXISTING SITE CONDITIONS

at the main facility site. Since it was determined from the results of the RI that the media present in the spray irrigationfields would not require further remediation, the most significant IRMs impacting the RD were those conducted at the main facility.

In 1985, the Centers for Disease Control, Agency for Toxic Substance and Disease Registry (CDC/ATSDR) determined that a potential threat to public health existed at the site due to the potential for exposure to wastes at the main facility. Field studies identified a 2,275 square foot area that comprised what is now referred to as the burn/burial area. This area was excavated to an average depth of eight feet below the surface at which point pesticide concentrations significantly decreased. At a depth of five feet, approximately 70 empty drums and two partially filled drums were unearthed. All of these excavated materials were shipped to the Chemical Waste Management facility in Emelle, Alabama for disposal.

Simultaneous with the excavation activities, water was pumped from the percolation/ evaporation pond just west of the burn/burial area. This water was treated onsite for DDT and dicofol using activated carbon absorption and pH adjustment, to levels which complied with existing laws. Once the water level in the percolation/evaporation pond was lowered sufficiently, excavation of the contaminated sediments began. The sediments were dewatered and bulked with the excavated soil from the burn/burial area before being shipped offsite.

Also affecting the design approach were site activities occurring during the design that increased contaminated soil quantities and changed site conditions. In 1988, the EPA demolished two storage tanks near the main facility containing hazardous wastes. Approximately 500 cubic yards of contaminated soil were excavated from beneath the tanks and moved within the fenced area of the site, along with the rubble from the tank foundation demolition.

DESIGN BACKGROUND

In January 1988, Ebasco was tasked by Region IV EPA, under the REM III Contract, to design a groundwater extraction and treatment system for the Tower Chemical site. This design was to be based on existing data contained in the RI Report. After evaluation of data suitability, the EPA halted the design effort in August 1988, to install additional wells and conduct pump tests. The design effort was restarted in January 1989, incorporating the additional data. At that time, the EPA also increased the design work scope to include design specifications and drawings for incineration of contaminated soil. Excavation, testing, backfilling and other miscellaneous site work were being designed and provided by another EPA Contractor and were not part of the Ebasco design. In August 1989, the design was expanded to include a confirming field sampling program to assess the leachability of pesticides and incinerability data. These data would be used to refine soil thermal treatment. In January 1990, a 60% RD was submitted by Ebasco to the EPA for review.

In April 1990, the Ebasco design scope was increased to include that site work proposed for another EPA Contractor. In May 1990, Ebasco was tasked to prepare a design that included all phases of remediation activity onsite, including contaminated soil excavation and backfilling.

In support of the RD, the EPA conducted groundwater pumping tests in late 1988, in the Surficial Aquifer, to determine the hydrogeologic properties of the site. One pump test was conducted within the backfilled waste pond, and one pump test was conducted within the burn/burial area. It was determined that the relict sinkhole of unknown dimensions beneath the waste pond discovered during the RI required further definition before an adequate groundwater recovery system could be designed.

In late 1988 and early 1989, the EPA collected soil samples and groundwater samples to determine the extent and levels of contamination in both media to help define critical parameters for the remedial design. Additional wells were installed to determine the edge of the groundwater plume, and additional surveys were conducted to delineate the extent of the relict sinkhole beneath the waste pond.

In January 1990, Ebasco collected groundwater elevation data and performed slug tests on the new monitor wells installed by the EPA to support groundwater remediation design. Soil samples were collected and analyzed for properties useful in preparing bids for thermal treatment. A leaching study was completed that simulated the flushing of contaminants from sinkhole sediments.

DESIGN DESCRIPTION

The completed design and contract package consists of performance specifications, detailed specifications, site data, drawings and schedule requirements to obtain and conduct RA services at the Tower Chemical site. A subcontract for excavation and thermal treatment of soil, and a separate subcontract for site work with groundwater extraction and treatment was prepared. These subcontracts are to be awarded and managed by a construction manager, who is under direction of the EPA Contracting Officer. A general overview of the two subcontract documents resulting from the RD is provided in the following:

THERMAL TREATMENT SYSTEM (TTS) SUBCONTRACT

The TTS Subcontract includes incinerator setup, trial burn, soil incineration, treated soil verification testing, maintenance of soil stockpile, contaminated soil excavation, treated soil backfill and TTS site preparation including construction and operation of a retention pond, and all necessary provisions in support thereof. Approximately 9000 cubic yards of contaminated soil in six different areas of the site require excavation, incineration, and disposal. An area of the site has been designated as the TTS work area and is to be used according to the needs of the Subcontractor (see Figure 3). The TTS Subcontractor will be responsible for all thermal treatment of waste, maintaining and minimizing the contaminated work area, providing security for the immediate TTS area, providing power and utilities as needed, pretreating process, excavation or decontamination water for on-site treatment by others, and setting up and maintaining decontamination facilities for TTS operations, equipment and personnel. As part of site operations, the TTS Subcontractor will manage water disposal in the retention pond. Water from excavations, decontamination and processing of soil may be directed to the pond provided pretreatment requirements are met and pond capacity/water treatment capacity are not exceeded. The TTS Subcontractor will provide all hardware and controls necessary to convey the water from the retention pond to the WTS .

It is expected to take 21 months to prepare for the trial burn plan, obtain EPA approval of the plan, mobilize, set up, shake down and conduct the trial burn prior to starting full production burning. Thermal treatment is expected to take approximately six additional months at 4.5 tons per hour and 25% down-time. It is possible that TTS operations will be completed early if greater incinerator capacity or less down-time is achieved.

The TTS Subcontractor will be required to collect and analyze soil samples to verify contaminated soil excavation completion. The construction manager will collect intermittent companion samples for verification analyses through the EPA-Contract Laboratory Program (CLP). Operations that may produce contaminated wastewater, such as excavation or sampling, will not commence until the water treatment system is functional and can accept the water. Work covered by the TTS Subcontract will be conducted in two phases. Phase One includes mobilization; excavation and treatment of the soil from excavations near the building; and treatment of the soil excavated during preparation of the TTS area (approximately 1,000 yd^3 of soil). Phase Two includes excavation and treatment of all remaining soil and demobilization.

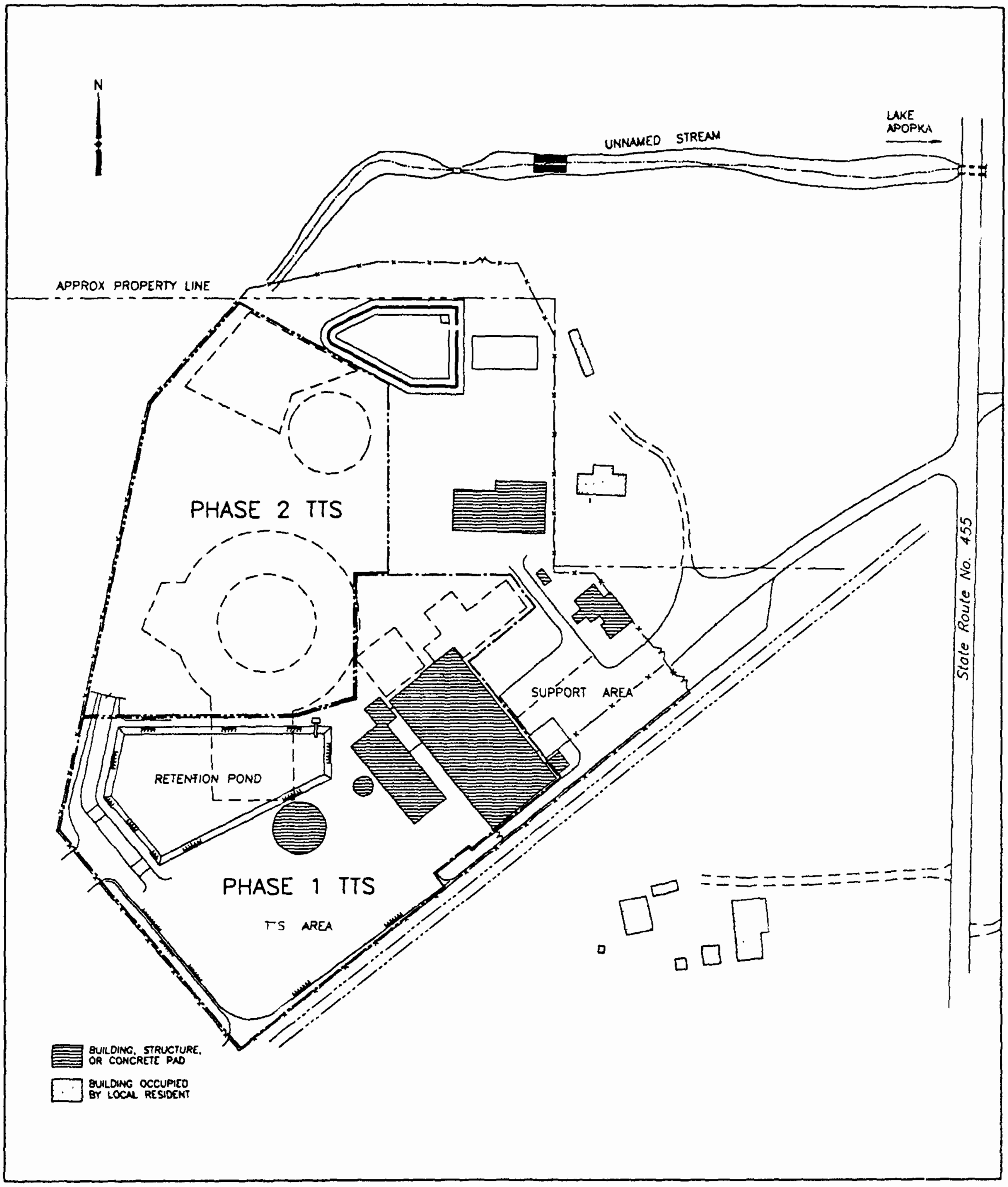

Figure 3

TTS SITE CONFIGURATION

WATER TREATMENT SYSTEM (WTS) SUBCONTRACT

A plume of contaminated groundwater extending across the site and covering approximately 10 acres will be extracted using 22 wells and treated to meet EPA-approved discharge criteria (see Table 1). A portion of the treated water will be discharged to a nearby stream while some of the treated water will be reinjected (see Figure 4). The WTS Subcontract includes construction of roads, and decontamination facilities for WTS equipment and personnel, grading of the site to promote proper drainage; installation of wells, piping hardware and controls for groundwater extraction and injection; construction of a building to house the system; and management and operation of a water treatment system. The WTS Subcontract includes responsibility for procuring and managing site perimeter security, as well as arranging for the installation of any utilities, offices, or other support required by the WTS Subcontractor to operate the system. The WTS Subcontractor will commence with the installation of the water treatment unit and building prior to the mobilization of the TTS Subcontractor. Upon completion of the WTS construction and shakedown of the system, the TTS Subcontractor can begin excavation of the contaminated soil.

The WTS Subcontractor will work concurrent with the TTS Subcontractor once the WTS is operational.

The groundwater extraction system will be installed in two phases. Phase One consists of installation of roads, wells, piping, controls and other hardware outside of the contaminated soil excavation area. Upon completion of soil treatment and backfilling, Phase Two of groundwater extraction system installation will be completed followed by one year operation by the WTS Subcontractor.

DISCUSSION

IN-SITU SOIL FLUSHING

A sampling program conducted by the EPA in November 1988 revealed pesticide-contaminated soil quantities up to seven times the quantities previously estimated. Instead of 5000 cubic yards of contaminated soil, the quantity was now approximately 34,000 cubic yards. The new soil data roughly defined the extent of soil contamination as shown in Figure 5. It is worth noting that the sampling points used to revise the estimated value were not surveyed nor located using scaled site maps or drawings. Although the majority of soil requiring remediation was based on some subjective estimates, it was clearly within the confines of the backfilled relict sinkhole. Depths of soil contamination appeared to be at least 18 feet below surface, and possibly deeper. In order to excavate these contaminated soil, it was expected that dewatering rates of several hundred to over a thousand gallons per minute would be needed. Treated water discharge criteria were required to meet Florida Class III surface water contaminant levels or Maximum Concentration Levels (MCLs), whichever were less. However, transporting a water treatment system to the site capable of meeting discharge requirements and handling large flow volumes was not desirable. Long term groundwater treatment capacity was not anticipated to exceed 125 gpm and the cost of incineration for the unexpected soil volume combined with rather large WTS requirements for dewatering effluent would increase initial remediation cost estimates by a factor of nearly 8.

With the Agency's concurrence, Ebasco decided to explore alternatives to complete excavation of the contaminated soil that would still achieve all clean-up goals and adhere to the intent of the ROD. The ideal alternative needed to meet three criteria: 1) avoid significant cost associated with major dewatering of the sinkhole; 2) utilize only the WTS capacity proposed for on-site groundwater remediation, and; 3) achieve cleanup of the soil within a reasonable period of time.

After observing that the key soil contaminant, dicofol, was also present in the groundwater plume, Ebasco proposed in-situ extraction or "flushing" the dicofol. A conceptual diagram of the in-situ

Table 1
Tower Chemical Site Clean-up Criteria

TREATED WATER DISCHARGE CRITERIA

Parameter	Maximum Observed Concentration (µg/L)	Surface Discharge Criteria (µg/L)
Arsenic	10	50
Barium	190	1000
Cadmium	5	0.7
Chromium	710	11
Copper	170	6.5
Iron	9300	300
Lead	51	1.3
Manganese	750	
Nickel	420	88
Sodium	270,000	160,000
Zinc	63,000	30
Cyanide	0.02	5
Benzene	8	1
Chlorobenzilate	9	100
Ethylbenzene	420	453
Toluene	14	175
Trichloroethene	6	5
Xylene	1,700	400
Phenol	37	256
Dicofol	1,400	0.08
DDT	BDL	0.1
DDE	BDL	0.1
DDD	BDL	0.1

TARGET GROUNDWATER CLEANUP LEVELS

Indicator Contaminant	Target Groundwater Cleanup Level (µg/L)
Arsenic	50
Nickel	350
Chromium	50
Alpha-BHC	0.05
Chloroform	5
DDT	0.10
Chlorobenzilate	10.0
Dicofol	0.08
Xylene	400

TARGET SOIL CLEANUP LEVELS

Indicator Contaminant	Target Soil Cleanup Level (mg/kg)
Copper	7,500
Lead	100
Arsenic	5
Dicofol	5
Chlorobenzilate	24
DDT	35
Xylene	50

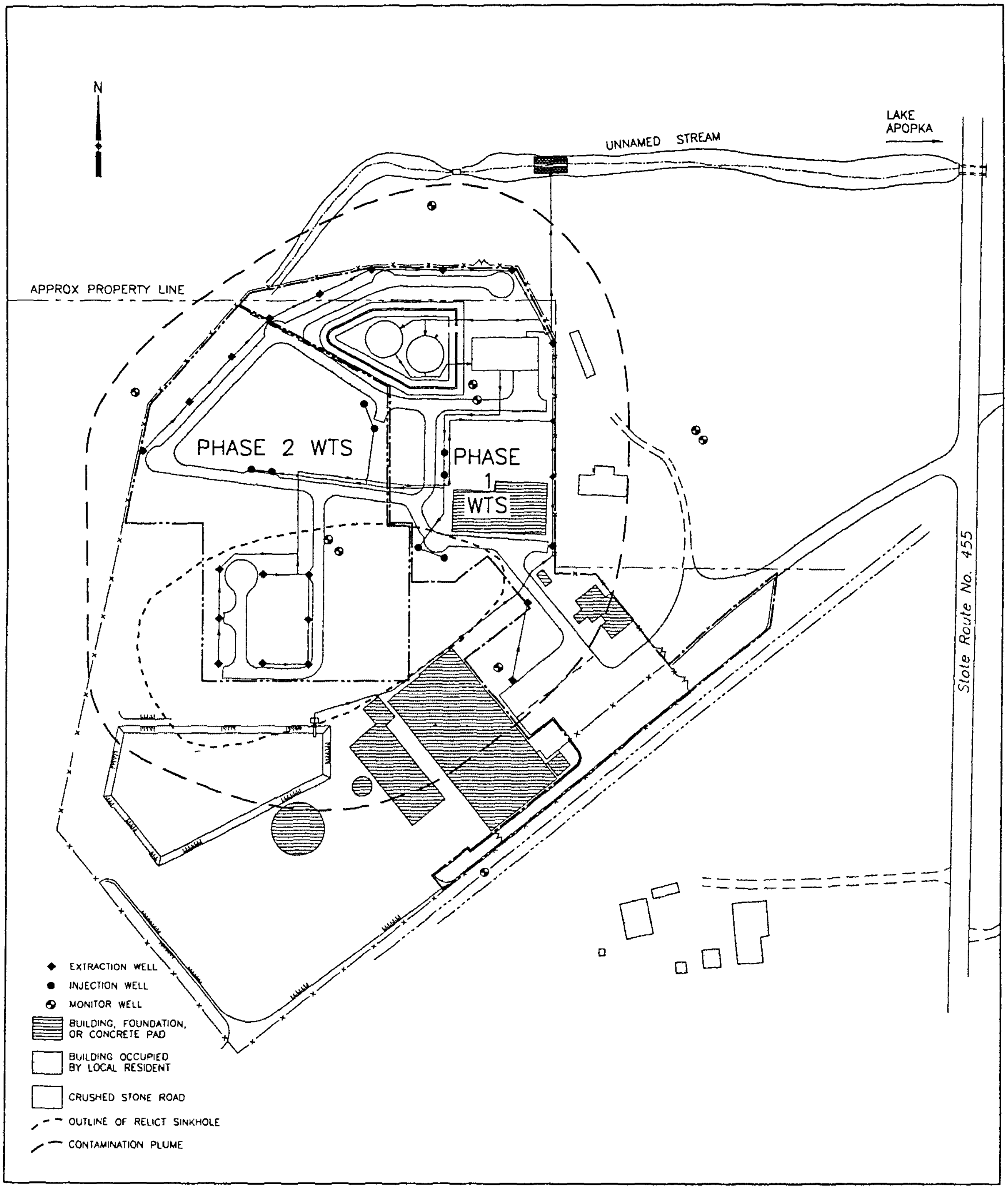

Figure 4

WTS SITE CONFIGURATION

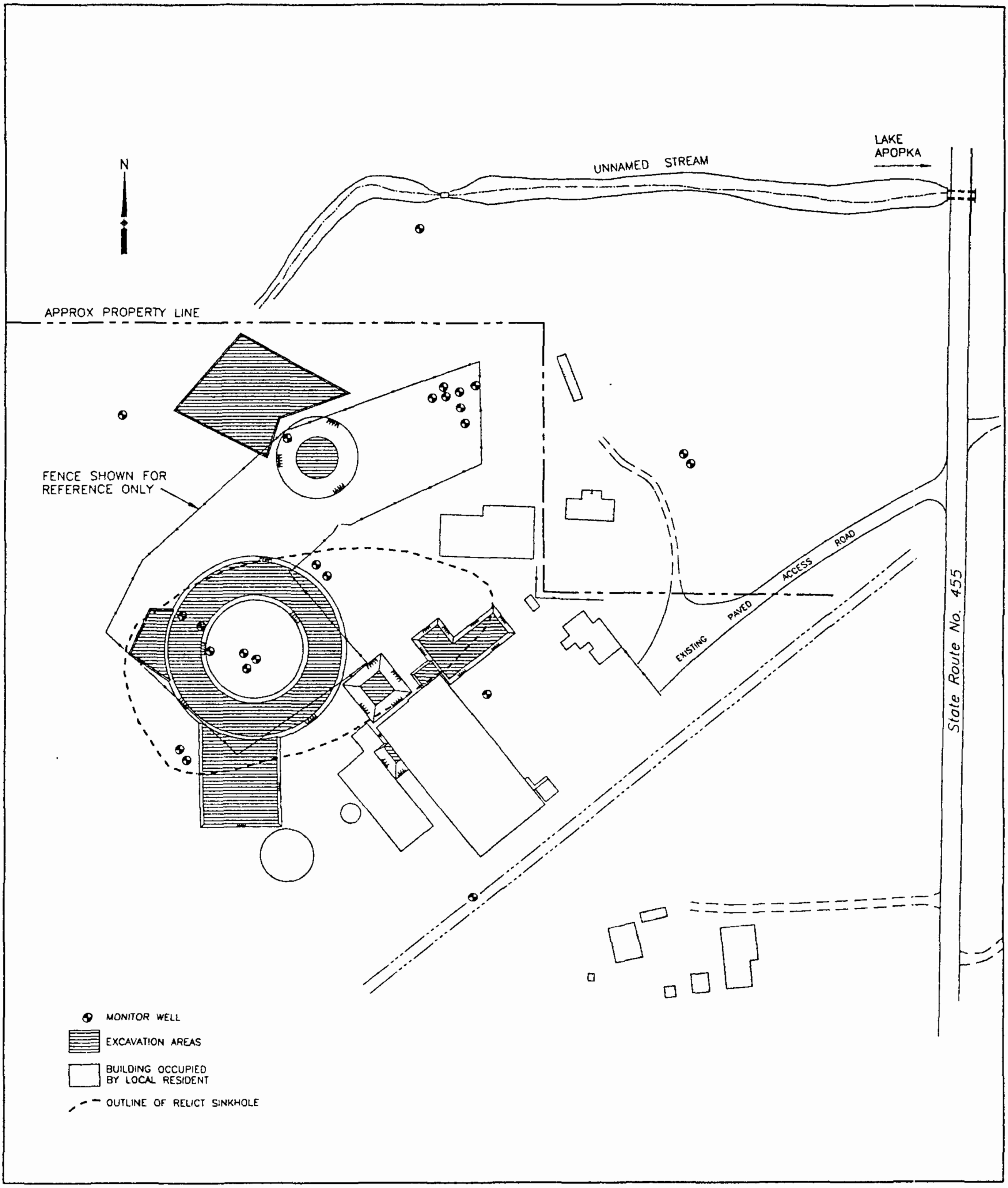

Figure 5

SOIL EXCAVATION

flushing approach is shown in Figure 6. This approach utilized the apparent hydraulic connection to the Floridan Aquifer caused by the relict sinkhole, and could be adjusted so as to not overwhelm the original design WTS capacity. Total excavation quantity would be reduced from 34,000 cubic yards to 9,000 cubic yards and the costs maintained at a level similar to the initial remediation cost estimates. An initial calculation of the required flushing time was performed based on measured soil dicofol concentrations, dicofol solubility in water and a simplified trans-port model. The calculations and concept were formalized and presented to the EPA as a viable alternative to excavation and thermal treatment.

Although the technical reviews of the in-situ flushing approach determined that this alternative was feasible, there was still the unknown variable regarding the actual extraction rate of contaminants from the soil. To resolve this issue, a bench-scale desorption rate study designed to measure dicofol leaching rates was subcontracted by Ebasco. The purpose of the study was to obtain "quick and dirty" data to eliminate some of the uncertainties related to the rate of leachability of dicofol. The leaching study focused on measuring the difference in dicofol concentrations at inlet and outlet of soil columns and at different flow rates expected both near and at the projected extent of the extraction well cone of influence. Samples of soil below the water table in the relict sinkhole where high dicofol concentrations were expected were collected and sent to the laboratory responsible for the leaching study. Three bulk samples were collected from three different locations in the contaminated area, but initial characterizations by the laboratory indicated that none of the samples contained dicofol concentrations that exceeded the clean-up criteria. Nevertheless, the study was conducted by spiking the soil samples with dicofol and measuring the rate at which that dicofol was removed from the soil. Study results indicated that original assumptions used during calculations were slightly optimistic, but the soil flushing would achieve the required clean-up levels within ten years and at a fraction of the cost necessary for excavation and incineration.

However, interpretation of results from the study assumed that the spiked medium would desorb dicofol at the same rate as the naturally acclimated soil onsite. Schedule and budget allocated for completion of this RD did not allow for an additional field sampling effort or subsequent leaching studies. The RD was completed with the qualification that the leachate calculations were based on an artificially contaminated medium. Ebasco's evaluation of the study and the results acknowledged the potentially non-representative nature of that test, but, if further studies were required by the EPA, they would have to be obtained during the planning phase of the RA.

CONTAMINATED SOIL LOCATION

It is likely that the unresolved questions about the dicofol leachability that remained at the conclusion of the design could have been avoided if contaminated soil samples had been found at the site. However, it was concluded that the actual location of the contaminated soil was probably not as depicted in Figure 5. The basis for this conclusion was that three random soil samples collected within the relict sinkhole area, all from different locations but within the prescribed contaminated area, all showed contaminant levels below the clean-up criteria. In addition to providing an inconclusive evaluation of the leaching study, the assessment of the soil characterization provided an uncomfortable level of confidence in the estimated volume of soil requiring thermal treatment and the most effective configuration for the in-situ soil flushing wells.

Uncertainty in the actual contaminated soil quantity propagated to other aspects of the design. Therefore, the EPA concluded with Ebasco that confirmational soil contamination data would be useful, but would be obtained during the initial planning of the RA under the ARCS IV Program.

To avoid the necessity of changing specifications and drawings for the WTS to accommodate any changes caused by a changed contaminated soil quantity, the WTS was designed to be modular. If the

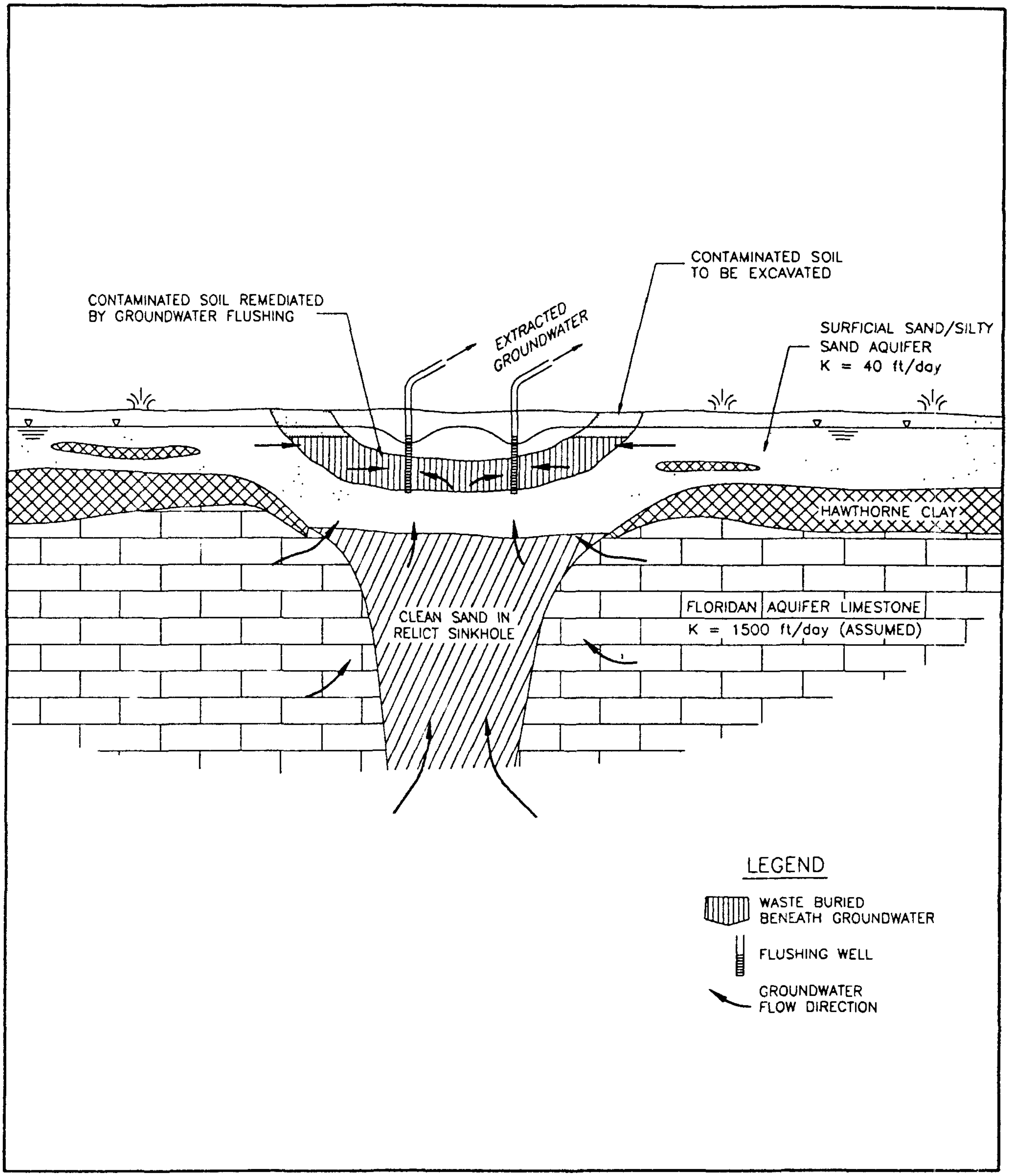

Figure 6

IN-SITU SOIL FLUSHING

contaminated soil quantity decreased dramatically, an additional optional WTS train would not be requested. On the other hand, additional capacity would be available for installation if the construction manager determined that the WTS capacity was likely to be exceeded during any phase of construction.

Ebasco was generally tasked under the ARCS IV Program to support the EPA's remedial construction manager. By collecting additional soil data and amending the design under the ARCS IV Program, the problems associated with the uncertain quantity of soil for thermal treatment were addressed. However, coordinating the work of two separate contractors with interdependent schedules was still anticipated to cause some difficulty for the construction manager.

TWO-CONTRACT APPROACH

The use of two subcontracts to perform the site remediation evolved initially because of early RD scope of work requirements. At EPA direction, specifications for obtaining soil thermal treatment services were prepared as a separate item with other (non-Ebasco) EPA contractors preparing the remaining design documents necessary for all soil remediation. As the RD proceeded, the EPA increased the scope of work under the existing Ebasco RD assignment to include all aspects of site remediation. At that time a decision was made jointly with Ebasco and the EPA to maintain the design as two separate contract documents. Unwanted side effects expected from a two-contract approach were generally related to the difficulties of coordinating two contractors with inter-related schedules. As shown in Figures 3 and 4, the remedial construction was divided into two phases for each subcontract, or a total of four phases. The WTS Subcontractor will be the first Subcontractor onsite and the last to demobilize. With careful management of the RA, however, it was expected that the potential benefits will outweigh any additional problems.

With two separate contract documents, there was expected to be substantial cost savings. For example, with one contract document and award including both TTS and WTS, it was considered likely that a TTS Subcontractor would have to subcontract the WTS (or vice versa) and there would be a fee on fee charge. The fee on fee for either the TTS or WTS was estimated to be far greater than any additional construction management costs associated with handling two subcontracts. Additionally, by reducing the contract value using a two-contract approach, it was anticipated that bonding and insurance would be easier to obtain by bidders. Also, there are some benefits expected during the procurement process. Although both contracts were scheduled to be awarded simultaneously, having two smaller, more manageable pieces to negotiate was considered an advantage. Work phasing did not require simultaneous contract award and therefore a delay in the TTS procurement would not necessarily delay the overall project completion.

CONCLUSIONS

During the development of the Tower Chemical RD, various issues arose that presented difficulties. Resolving these issues resulted in a RD substantially different than the one originally planned at the start of the design effort. From Ebasco's perspective, the design scope started as a groundwater pump and treat, progressed to include partial soil RD, and finally encompassed the entire site, including soil excavation and site development. When soil remediation was added and the ensuing dewatering requirements became essentially infeasible, it was necessary for the EPA to find satisfactory site remediation using a slightly more innovative approach. In-situ soil flushing provided the means for remediating the bulk of the soil while maintaining control of RA costs. The two-contract approach allowed the flexibility of staggered contract awards and avoided duplication of costs. Finally, ambiguous definition of soil contamination will be refined at the start of RA activities and will require minimal amendments to the design documents.

DISCLAIMER

The opinions and views expressed in this paper are those of the authors and do not necessarily represent the opinions or views of the United States Environmental Protection Agency. Any questions or comments regarding the content of this paper should be addressed to the authors.

The Importance of Test Fills for the Construction of HTW Caps and Liners

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1. Introduction. Construction problems related to site and material unknowns at hazardous waste sites, can cause serious schedule delays and often result in expensive project modifications. One way to better define various project unknowns is to specify and construct a test fill. A test fill consists of the construction of a structure which simulates a full-scale cap or liner system, including all associated components, using the materials, equipment, and processes which are specified for the project site. This paper will describe the usefulness of test fill construction as well as present the difference in rationale used to generate effective test fill specifications used to define design goals.

2. Background. The concept of using a test fill to verify the adequacy of project materials and placement methods was made popular during the era of large earthen embankment dams and extensive levee systems construction. The Corps of Engineers implemented test fill construction as a design tool to verify project specifications before beginning construction of a full-scale project.

The construction of cap and liner systems for landfills and other HTW-related sites require the placement of large amounts of compacted soil fill, geosynthetics, and topsoil material, most often times at sites regarded less than desirable for construction. In order to verify design assumptions, determine adequacy of construction materials and placement procedures, and to better define various site-specific unknowns, it is imperative that a test fill be constructed and evaluated before full-scale construction begins. The test fill serves to reduce the potential for costly delays due to construction problems and helps assure that an adequate cap/liner system will be built.

3. Cap/Liner System Test Fill Design. The designer must first identify the goals to be achieved by constructing the proposed test fill. The primary goal is to verify the overall constructability of the cap/liner system, that is, can the specified materials be placed according to the project specifications with the proposed construction equipment. The other goal is to insure that the final cap/liner system will function as designed. The most important function of the cap system is to retard moisture migration into underlying waste layers. The most important function of the bottom liner system is to prevent leachate from migrating into the ground water. The test fill program is used to verify if the specified compacted permeability of the low permeability

clay component of a cap/liner system can be achieved consistently when placed according to project specifications.

In order to insure that the design goals of the test fill are achieved, the designer <u>must</u> clearly specify proper QA/QC procedures for the test fill. The importance of an effective QA/QC plan for the test fill cannot be understated. A list of guidelines of some of the variables which should be monitored or controlled during the test fill condition are:[1]

(1) Full characterization of all materials from borrow areas proposed for use in both the test fill and the large scale project. In-situ moistures, Atterberg limits, and moisture, density relationships should be established as appropriate for each material type to be placed.

(2) All soil and/or additives placed in the test fill should be uniformly distributed to maintain homogenity of material for each lift placed. No large diameter (greater than 2-inch diameter) rocks, rubbish, debris, or organic material should be used.

(3) Specified water contents should be maintained during placement and the same moisture conditioning methods should be used for the full-scale project. It is preferable to maintain moisture contents above optimum value.

(4) All placement, moisture conditioning, and compaction equipment used on the test fill should be as specified for the full-scale project. (See Table 1 for typical equipment applicability for each phase of construction.)[2]

(5) The maximum specified clod size of material should be maintained and the effectiveness of the construction equipment to achieve this should be verified.

(6) The maximum loose lift thickness of material placed should be as specified as well as for the compacted layer thickness.

(7) Compaction and placement equipment traffic patterns should be as specified or otherwise monitored. The number of equipment passes used to compact each layer should be documented.

(8) The effectiveness of compaction equipment in re-

stricted areas should be verified and control measures taken to insure similar areas in the full-scale project will be properly compacted.

(9) The test fill should be constructed and maintained so as to reduce chances of either saturation of subgrade soil during rainfall events or desication due to drying of subgrade soil.

(10) Special precautions should be taken in order to insure that side slopes, layer penetrations (for soil testing), and damaged soil layers are sufficiently compacted and sealed.

(11) The specifications should include moisture and density test frequencies to verify uniform compaction effort is being achieved.

(12) The test fill should be constructed to the steepest slope anticipated for the full-scale project.

(13) As a minimum, the test fill for a cap/liner project should be constructed to the typical dimensions[1] shown in Figure 1 and the cross section shown in Figure 2.

(14) A test fill for a cap/liner project should be constructed to facilitate field permeability testing. When required, the construction of an under drainage system should be as shown in Figure 2.

(15) Laboratory testing should include permeability testing of low permeability clay layers.

Another key operation to consider during construction of the test fill is the placement of the geosynthetic materials. The test fill offers a great opportunity for the construction crew to develop the site-specific expertise in placement and seaming of material in the field with close QA/QC inspection within the project specification guidelines. This small-scale operation will serve to familiarize all parties on the construction/oversight team of what will be expected of them and how well placement methods will perform. A full suite of QA/QC testing should be performed according to project specifications on each layer of the geosynthetic material as it is placed. An effort should be made after test fill construction to verify the geosynthetic material survivability. In order to function as designed, the material must "survive or remain undamaged" through all phases of construction. It must be determined if any materials were damaged during construction activities, particularly during the placement of large amounts of fill material over the geosynthetic materials.

After completion of the cap/liner test fill, the specifications should include tests which will demonstrate that the compacted permeabilities of the clay layer is within the limits specified. A series of permeability tests run on undisturbed samples from the compacted clay layer can be used to verify the uniformity of the in-situ material and indicate how well the clay layers will perform. However, research has indicated that laboratory permeabilities may vary from the actual field permeabilities by as much as an order of magnitude.

Undisturbed samples of the compacted clay layer component can be inspected in order to determine how well the lift layers bonded. Lift layer bond has been determined to be a key factor for construction of effective low permeability soil layers.

The best method of verifying in-situ permeability of the cap/liner system test fill is to pond water over the surface and collect seepage with an underdrain system and supplement this information with data from surface infiltration [3]. Other popular options for determining in-situ permeability are the use of the single and double infiltrometers [3], sealed double-ring infiltrometers [3], and the borehole method developed by Boutwell and other methods specified in Daniel's paper, Earthen Liners for Land Disposal Facilities listed in the reference summary.

An innovative verification test procedure currently used involves the use of a simulated rainfall event. This test involves setting up a system which can deliver a measured amount of water at a set flow rate to the surface of the test fill. During the design rainfall event, the designer should measure any slippage of geosynthetic layers built on critical side slopes by monitoring exposed portions of geosynthetic layers aligned with control markers and paint lines. [4] Another aspect of this test is to monitor the discharge pipe of the underdrain layer in order to determine the effectiveness of drainage collection layers, as well as determine in-situ permeability after water has ponded on the liner surface.

Once it has been established that the in-situ permeability achieved in the test fill is satisfactory, then a set of index properties can be established for use on the full-scale cap/liner system. The index properties are defined as the factors which can be measured in the field by direct testing within the QA/QC program to verify full-scale material placement. The EPA recommends[5] measuring the following properties as a minimum:

(1) Hydraulic conductivity (undisturbed samples);

(2) In-place density and soil moisture content;

(3) Maximum clod size;

(4) Particle grain size distribution;

(5) Atterberg limits.

Other factors also include:

(1) Field moisture content during and after field placement;

(2) Loose lift and compacted layer thickness;

(3) Number of passes of specified construction equipment.

4. Waste Pile Test Fills. The use of soil and sludge solidification/stabilization techniques are becoming increasingly important in order to comply with federal, state, and local regulations on placement of contaminated soils in waste piles and landfills. The biggest challenge facing the designer of a large solidification/stabilization project is in determining an effective and economical waste soil mix design which will result in a material which complies with the various placement regulations. An important variation of the cap/liner test fill concept is to provide design information for placement of solidified/stabilized material within a waste pile. Although this is a variation of a pilot scale study, the designer can gain invaluable information concerning effective mix designs, placement methods and liner material survivability during test fill placement. Besides complying with the regulations for placing material in a waste pile such as free liquid content from the Paint Filter Test (EPA 9095), leachability, minimum soil strength, etc., the solidified/stabilized material should exhibit a compacted

soil strength great enough to insure final waste pile stability, equipment trafficability, control settlement of the placed material (and thus the final cap over the waste pile), and minimize or control leachate production due to pile overburden stresses.

To guarantee that the waste materials in the final waste pile are stabilized within placement regulations, exhibit needed design properties, and are placed so as not to damage any portion of the liner, a set of index properties can be derived from a test fill to determine a method specification for the final fill placement. The test fill consists first of the proper construction of the waste pile liner at the proposed site. The test fill should be located on the portion of the completed waste pile liner in which the stabilized waste can be placed to the dimensions outlined in Figure 1 and where waste material can be placed on at least one berm side slope, if applicable and practical. In order to insure the integrity of the underlying liner material, it is recommended that the initial lift of stabilized/solidified waste material be on the order of from 1.5 to 3 feet thick, with subsequent varying loose lift thicknesses. Once the initial lift is established and compacted to a point which will allow equipment trafficability, then the controlled fill procedure can begin.

The objectives of the test fill are to establish the index properties which can be used to develop a method specification for monitoring full-scale placement in the waste pile. The overall objectives of the test fill are as follows:

(1) Observe and evaluate trafficability and constructability of the waste materials;

(2) Obtain settlement and consolidation data to evaluate long-term stability;

(3) Determine in-place density and unconfined compression strength data to evaluate slope stability;

(4) Observe liner material during and after test fill construction to verify survivability of liner materials;

(5) Determine compliance of placed material with various placement regulations.

During construction of the test fill, the following parameters and operations should be measured and recorded in the field in order to help determine index properties that will be most critical for waste pile construction:

(1) Descriptions of material types and/or mix designs used during placement;

(2) Moisture content, compacted density, unconfined compressive strength, and other strength data relating to construction trafficability, such as cone index testing;

(3) Material placement, traffic patterns, and grading and spreading patterns;

(4) Lift thicknesses;

(5) Number of passes of compaction equipment;

Upon completion of the test fill the results of the various field tests should be analyzed in order to identify the critical index properties which should be monitored during full-scale construction. These properties will insure the stabilized waste is placed so as to achieve the overall full-scale waste pile construction objectives.

Typical plots comparing field test results are shown in Figures 3 through 7, with summary data in Tables 2 and 3. These plots were generated from the waste pile test fill for the Basin "F" Interim Action project at Rocky Mountain Arsenal and are typical of test results from a test fill. After analysis of that test fill data, it was recommended that Basin "F" contaminated sludge be mixed with on-site soil at a one-to-one mix ratio and that each lift be compacted with four passes of the compactor. The method specification for waste material placement included the following index properties: 1) All solidified material was to pass the Paint Filter Test; 2) The minimum unconfined compressive strength of the compacted material was eight psi and the maximum long-term strength was 25 psi; 3) The minimum cone index trafficability value was 150 psi; 4) The minimum percent of compaction was 80% of the standard proctor maximum. The test fill verified the importance of the index properties in fulfilling the objectives of the test fill which were:

(1) Reduce to a minimum the amount of leachate production from the waste material placed by placing all material within Paint Filter Test requirements;

(2) Insure slope stability for the finished waste pile and cover system by placing solidified waste at an unconfined strength of at least 8 psi;

(3) Not to solidify the waste material so as to be able to remove it for later soil incineration;

(4) To solidify waste material to insure equipment trafficability for constructability within the waste pile by specifying a cone index of at least 150 psi;

(5) Compact waste material in order to reduce cap settlement so that the final cap slopes would be at least 3% by specifying at least 80 percent compaction requirements.

(6) The stabilized material was to be easily excavatable after completion of the placement of the solidified material.

After completion of this test pile, the solidified material was removed and the liner material was inspected. No appreciable damage was done to the geosynthetic layers.

5. Cap System Test Fills for Difficult Sites. Since uncontrolled landfill sites were usually located in the least desirable locations, it follows that most sites offer unique construction problems for cap construction. Site-specific test fills can be used to determine overall constructability of caps over difficult sites. Constructability problems include:

(1) Placement of soil layers and geosynthetics over steeply sloping sites;

(2) Subgrade stabilization of soft subsoils to facilitate fill placement;

(3) Compaction over unconsolidated landfill materials which result in large differential settlements;

(4) Construction at sites at which there is limited space for staging material and equipment;

(5) Placement of fill in marshy areas with high ground water levels.

(6) Placement of geosynthetics over landfills which generate large amounts of gas.

Test fills offer the designer insight on how best to solve those constructability problems rather than trying to solve them during actual site construction when delays mean slipped schedules and expensive contract modifications. The small-scale test fill offers the designer an opportunity to try new materials and methodologies in order to solve some of these constructability problems.

6. Test Fill Specifications. It is recommended that a test fill be constructed for all large scale cap/liner construction projects. In order to write an effective test fill specification, the designer must have a clear idea of the objectives to be accomplished during and after construction of the test fill. The designer should include the following in the test fill specification:

(1) The size and location of the test fill including the thickness and material type of each layer;

(2) The slope of the layers as well as compaction and density requirements;

(3) Horizontal and vertical survey requirements;

(4) Clearing and grubbing of site subgrade;

(5) Regrading and clay cap/liner soil requirements to establish placement requirements such as compaction equipment, moisture and density requirements, maximum clod size and suitable fill material types for each layer;

(6) Placement requirements for each layer of geosynthetic material;

(7) Establishment of a vegetative layer for long term test fills;

(8) Development of a system to determine layer slippage of geosynthetic materials during material placement on critical slopes;

(9) Post construction testing such as infiltrometer or other in-situ permeability testing;

(10) Special post construction testing; i.e., settle-

ment of test fill;

(11) Removal of test fill layers to verify lift thicknesses, bond between layers and condition of the underlying geosynthetic layer.

The most important requirement of all to include in the test fill specification is the QA/QC program. The designer must specify construction quality control testing including test frequencies, methods and pass/fail criteria. Third party QA/QC is as important during the test fill as during the full-scale cap/liner construction.

7. Conclusion. The design and construction of a large-scale cap/liner system for hazardous waste site closure/remediation projects can be a very complicated task. One way to reduce and eliminate project problems due to site and construction material unknowns is to specify and construct a test fill.

The objectives of a test fill must be clearly understood so that a viable test fill method specification will result. The goal is to establish a set of index properties which can be used in the full-scale project which will result in a functional cap/liner system. Test fills can be used to define placement parameters for waste pile construction and to address constructability problems at problem sites. The single most important factor for test fill construction is to have an effective, well-organized QA/QC program. Along with this, is the need to record, the test fill placement specifications, site-specific test results, and performance records on a data base system so that engineers faced with designing future cap/liner systems can consult them.

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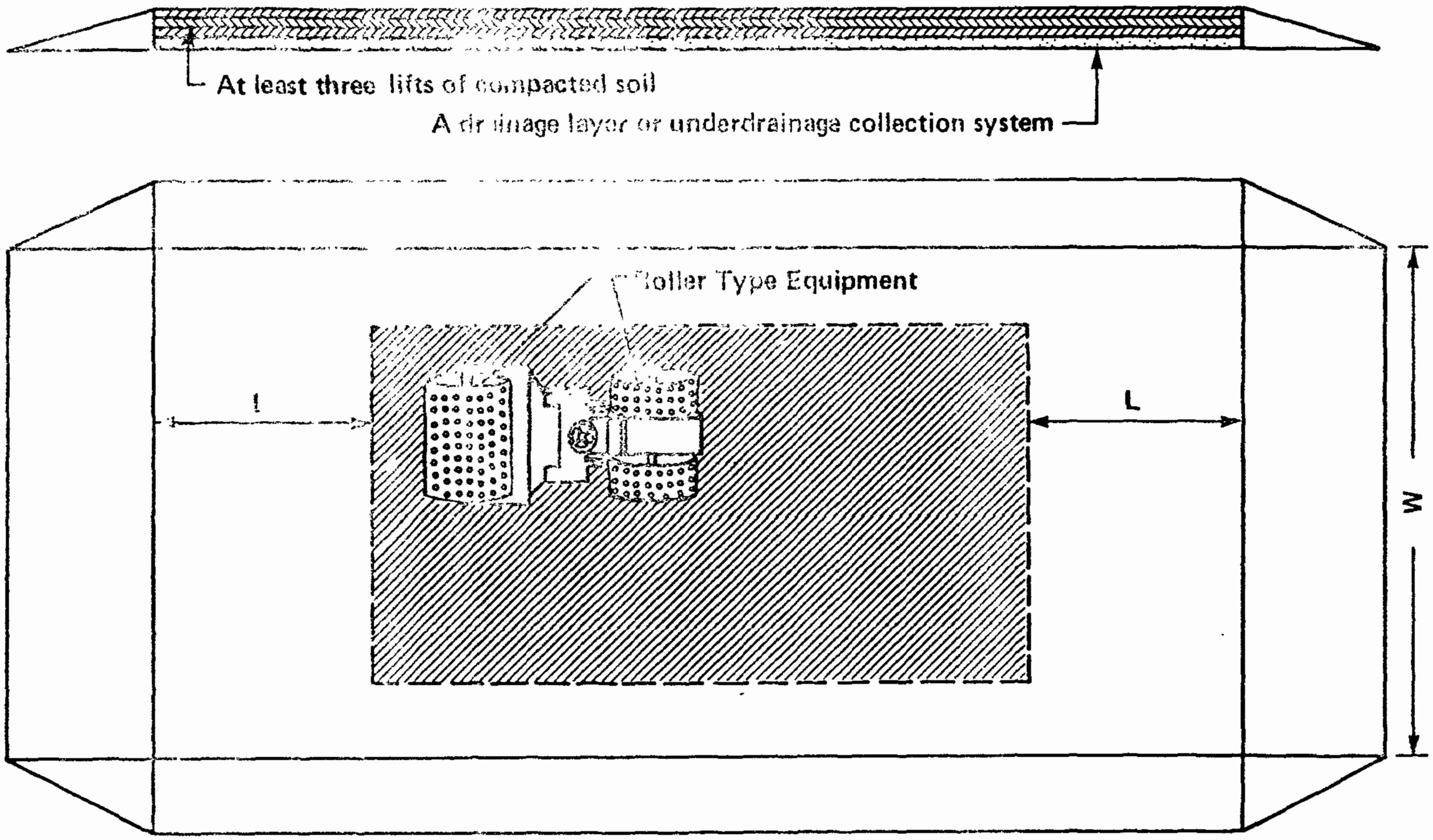

L = Distance required for construction equipment to reach normal running speed
W = Distance at least four times wider than the widest piece of construction equipment
▨ = Area to be used for testing

Figure 1 - Schematic of a test fill.

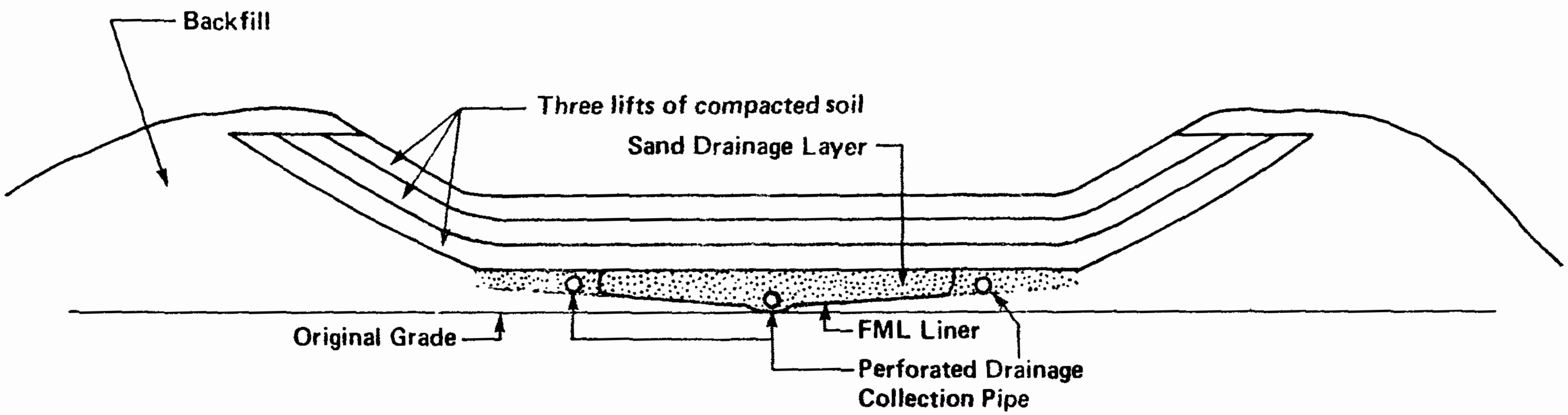

Figure 2 - Example of a test fill equipped to allow quantification of underdrainage.

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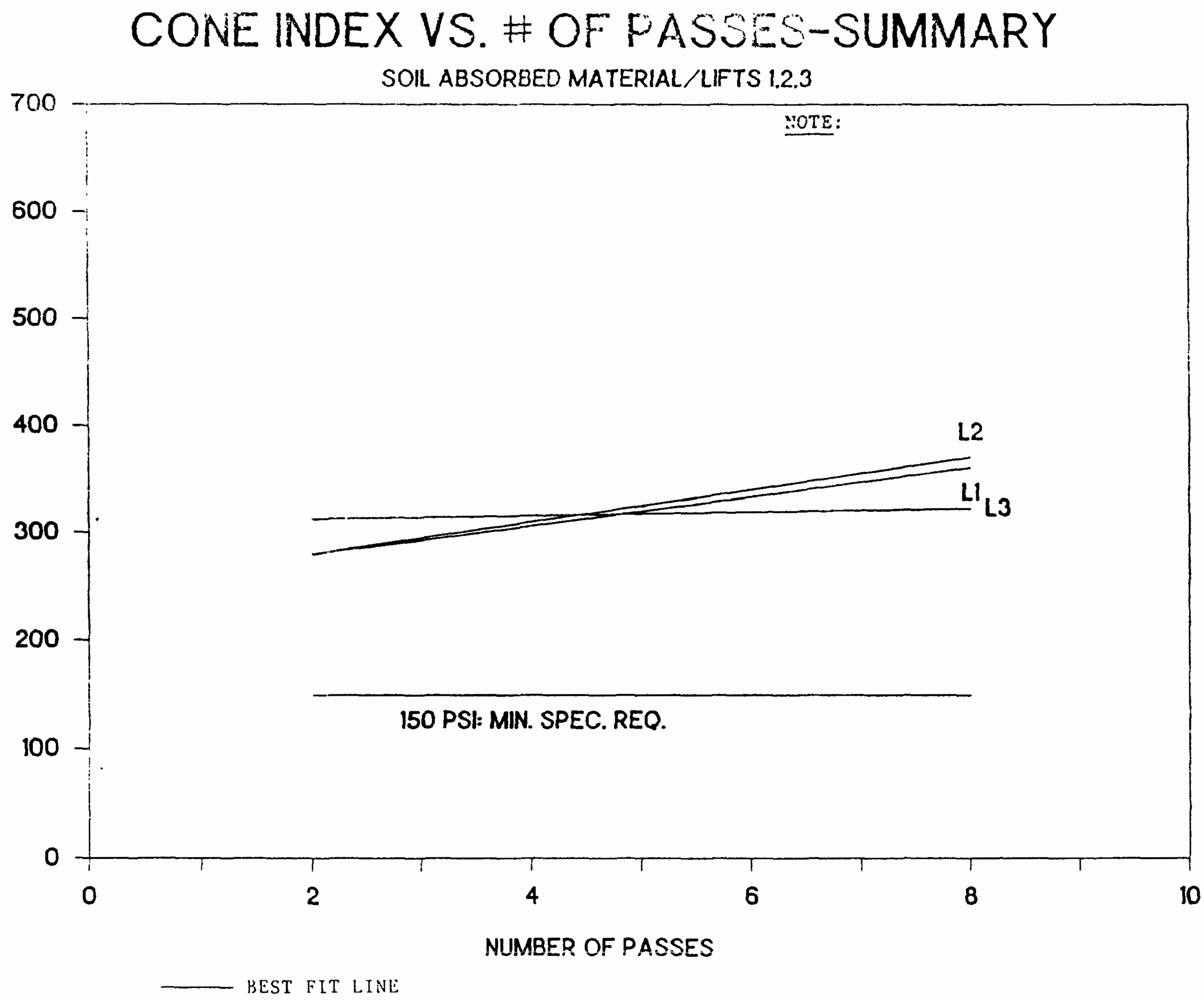

Figure 3

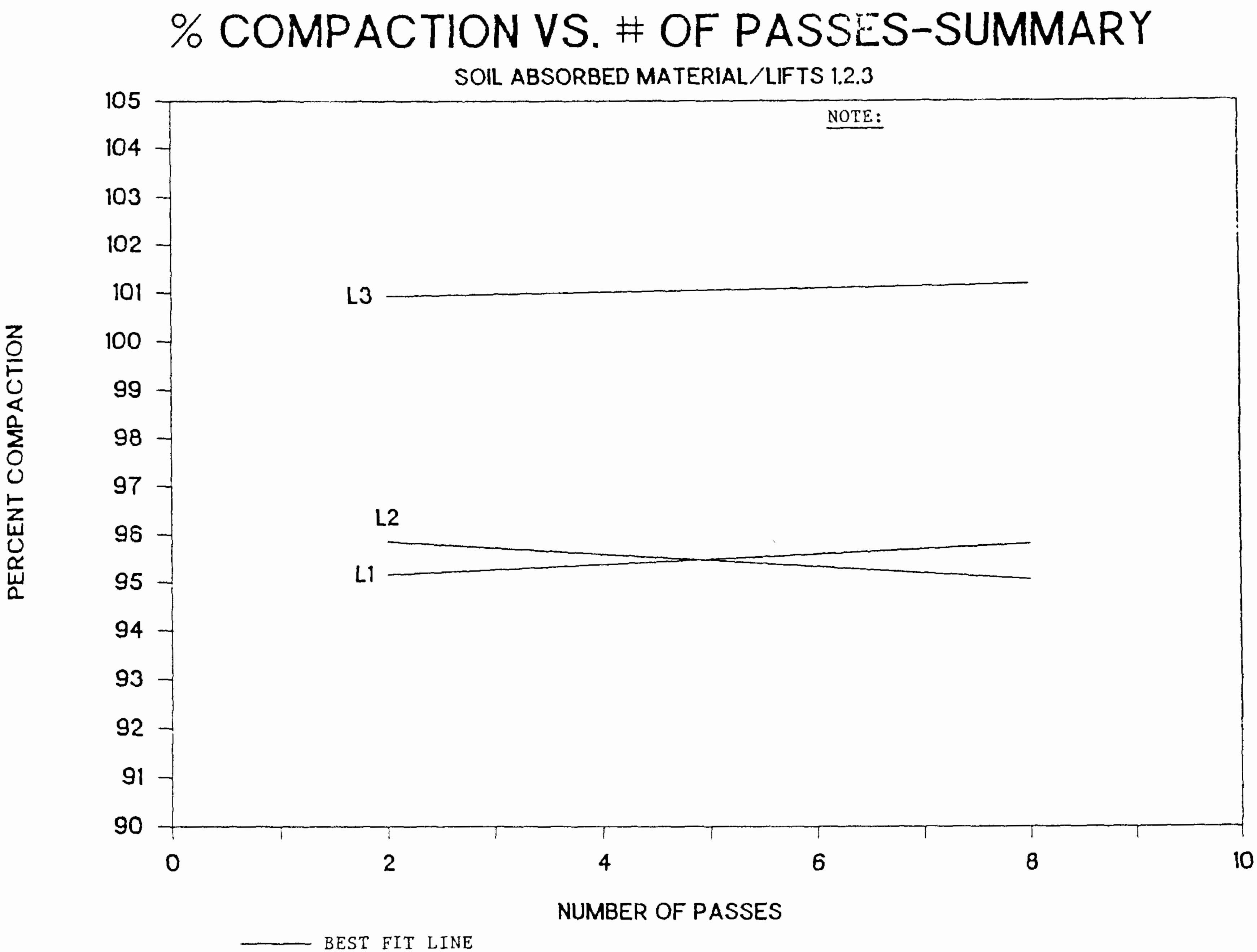

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Figure 4

1HR STRENGTH(q_u)VS.# OF PASSES-SUMMARY

SOIL ABSORBED MATERIAL/LIFTS 1,2,3

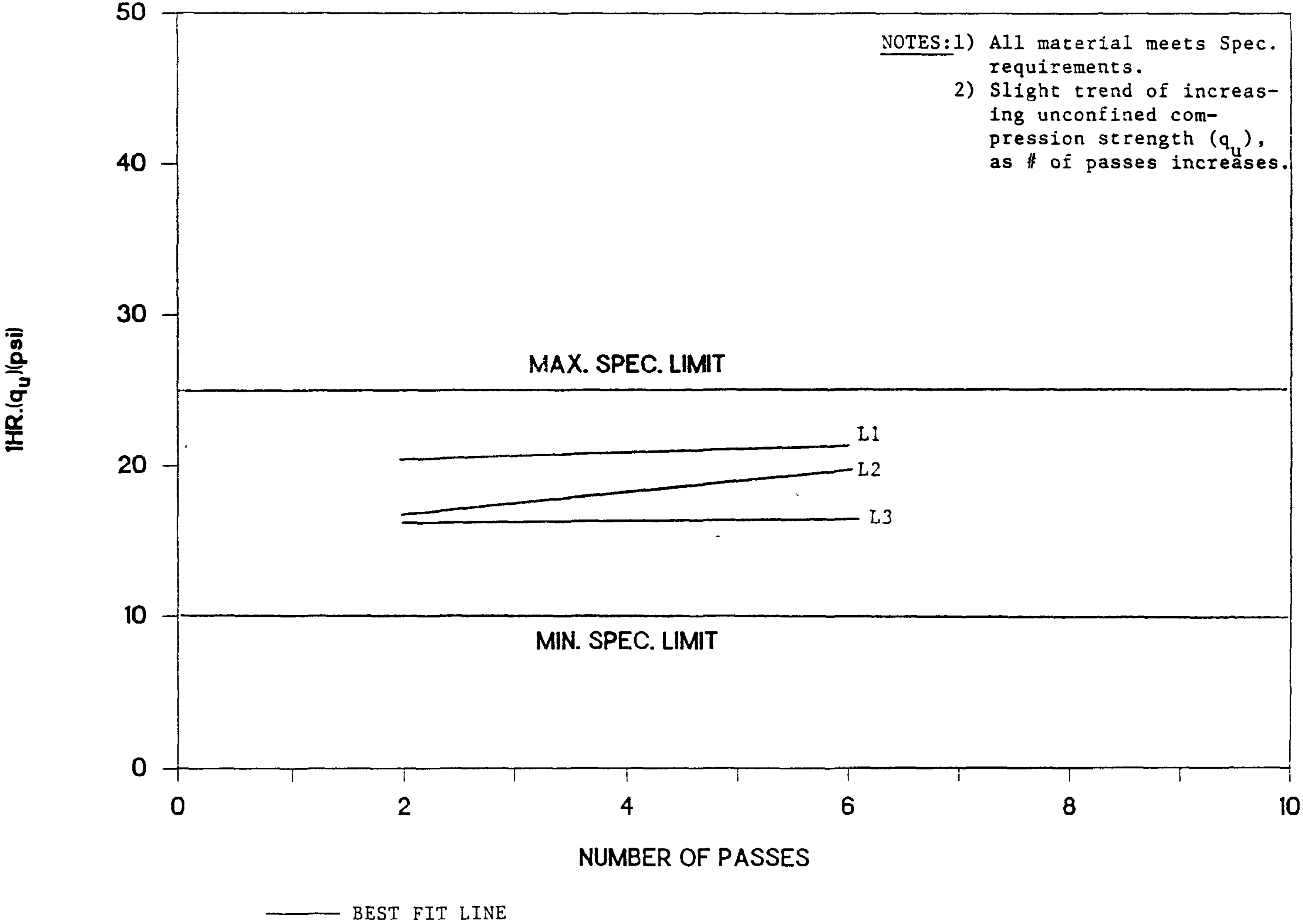

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Figure 5

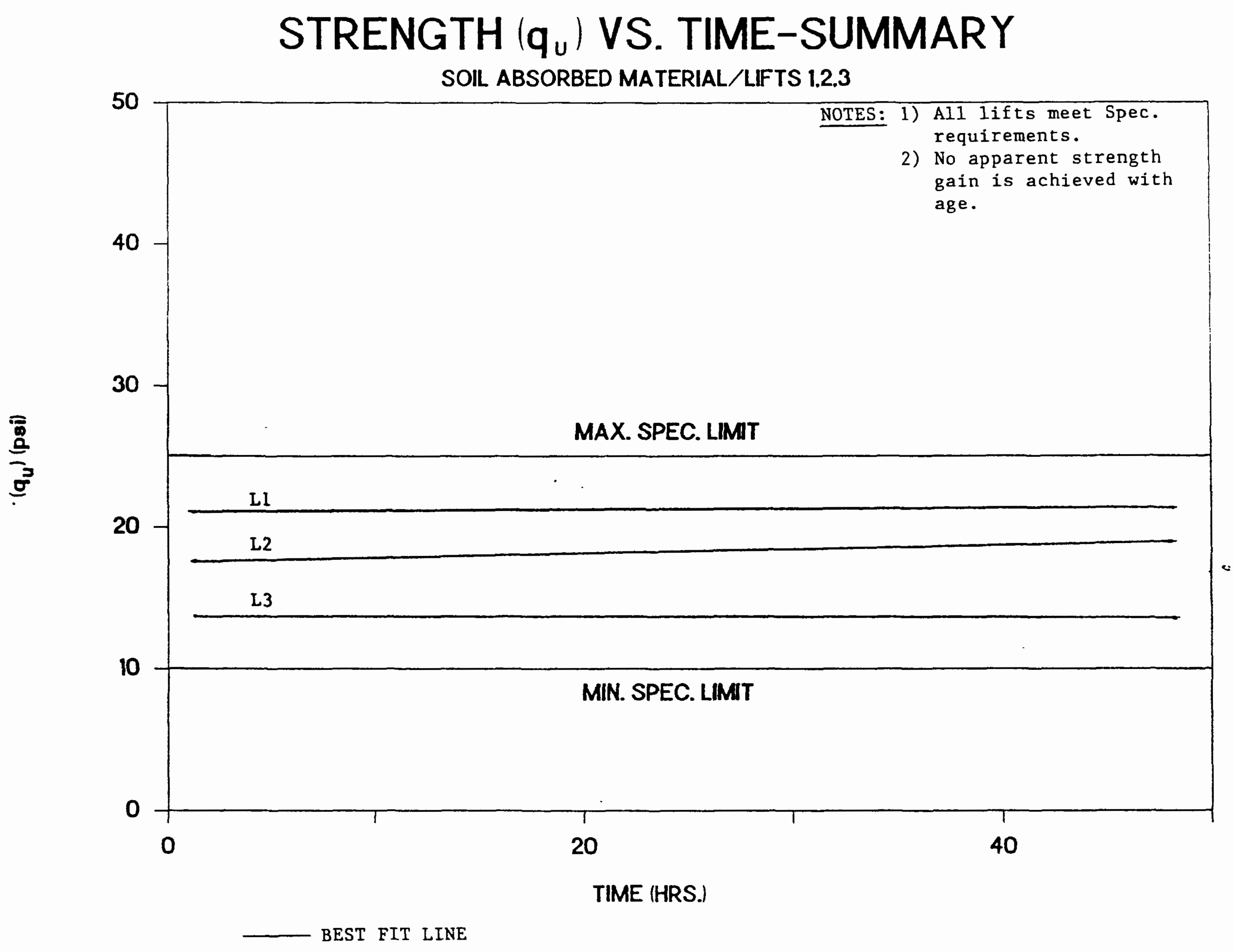
STRENGTH (q_u) VS. TIME-SUMMARY
SOIL ABSORBED MATERIAL/LIFTS 1,2,3
NOTES: 1) All lifts meet Spec. requirements.
2) No apparent strength gain is achieved with age.
MAX. SPEC. LIMIT
L1
L2
L3
MIN. SPEC. LIMIT
50
40
30
20
10
0
(q_u) (psi)
0
20
40
TIME (HRS.)
BEST FIT LINE

Figure 6

1HR STRENGTH(q_u)VS %COMPACTION-SUMMARY

SOIL ABSORBED MATERIAL/LIFTS 1,2,3

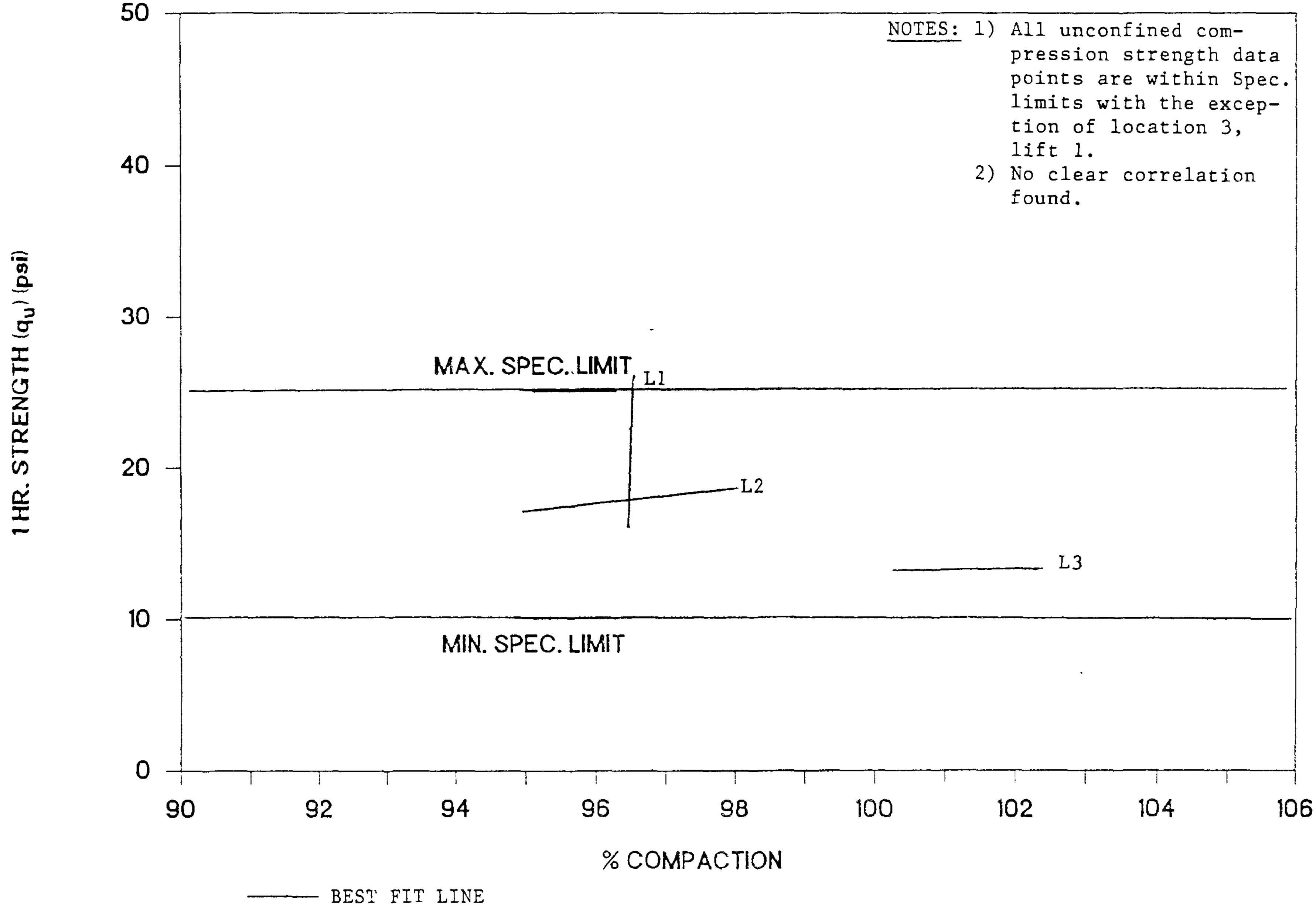

Figure 7

Table 1

APPLICABILITY OF EQUIPMENT TYPES TO VARIOUS OPERATIONAL FUNCTIONS

Operational Function	Equipment Type												
	Dozer		Scraper		Backhoe			Loader					
	Crawler	Rubber-Tired	Towed	Self-Propelled	Tractor	Excavator	Motor Grader	Crawler	Rubber-Tired	Compactor	Landfill Compactor	Power Shovel	Dragline
Site Preparation and Maintenance	G	F	F	F	F-P[c]	NA	G-F	G	F	NA	P	P	F-P
Excavate Cover Materials	E	F	E[a]	E[a]	E	E	NA	E	G	NA	P	E	E
Haul Cover Materials:													
1. 300 ft (91 m) or less	F	G	E[b]	G-F[b]	C	C	NA	F	G	NA	F-P	C	C
2. 300-1000 ft (91-305 m)	P	P	F	G	C	C	NA	C	C	NA	NA	C	C
3. More than 1000 ft (305 m)	P	P	P	E	C	C	NA	C	C	NA	NA	C	C
Spread Cover Materials	E	G	E-G	E-G	NA	NA	G	G	F	NA	F-P	NA	NA
Compact Cover Materials	G-F	G-F	NA	NA	NA	NA	NA	G-F	G-F	E	E	NA	NA
Shape Cover Materials	G-F	G-F	F-P	F-P	NA	NA	E	G	F	NA	P	NA	NA

E = Excellent; G = Good; F = Fair; P = Poor; C = Only in combination with other equipment; NA = Not Applicable

[a]Highly dependent upon site conditions and equipment size

[b]Economics of operation a prominent factor

[c]Depends on size of operation

Table 2

SOIL:ABSORBED TEST FILL DATA
Conclusions & Recommendations

Description	Report Section	Figure No.	Specification Requirements Pass	Fail	Observations and Conclusions
1. **Cone Index - Minimum 150 psi**					
1. Cone index vs # passes	4.1.2	2	x		All cone index tests at all # of passes meet specified limits
2. Cone index vs. % compaction	4.1.3	6	x		All cone index tests meet % compaction requirements (80% min)
2. **Percent Compaction-Min 80%**					
1. % compaction vs # of passes	4.2.2	10	x		Percent compaction appears to be independent of # of passes after two passes are made
3. **SETTLEMENT (Low Range)**					
1. Settlement vs # of passes	4.3.2	14	x		Data poor but general trend toward 4-6 passes. Overcompaction at 8 passes.
2. Settlement vs % of compaction	4.3.3	18	-		No correlation
4. **Unconfined Compression Strength (>10 psi <25 psi)**					
1. Strength vs # of passes	4.4.1.1	22	x		Compression strength appears to be independent of # of passes after two passes are made
2. Strength vs % compaction	4.4.1.2	26	-		No correlation
3. 1 hr vs % compaction (by location)	4.4.2	30			All locations meet specification limits at 1 hour
4. 24 hr vs % compaction	4.3.1.1	34	x		All locations meet specification limits at 24 hours
5. 48 hr vs % compaction	4.4.4.1	38	x		All locations meet specification limits at 48 hours
6. Strength vs Time	4.4.5.1	42	x		Compression strength appears to be independent of time (1 hr - 48 hr cone)
5. **Excavatability**	4.5		x		All materials are excavatable after 1 hr to 48 hrs of curing
6. **Sand Cone vs Nuclear Density**	4.6		x		Sand cone density and nuclear density are comparable on average

RECOMMENDATIONS: 4 number of passes be performed to provide specifications. Requirements while considering cost and Schedule Impacts.

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Table 3

SOIL:SLUDGE TEST FILL DATA

Conclusions & Recommendations

Description	Report Section	Figure No.	Specification Requirements Pass	Specification Requirements Fail	Observations and Conclusions
1. Cone Index - Minimum 150 psi					
1. Cone index vs. # of passes	5.1.2	46	x		All cone index tests at all mix proportions at all # of passes. meet specifications although 1 soil to 1 sludge produces marginal results.
2. Cone index vs % compaction	5.1.3	50	x		All cone index tests at all mix proportions at all % compaction meet specifications although 1 soil to 1 sludge produces marginal results.
2. Percent Compaction - Min 80%					
1. % compaction vs # of passes	5.2.2	54	x		All materials exceed minimum specification requirements. 1 soil to 1 mix exhibits loss of % compaction with increasing # of passes.
3. Settlement (Low Range)					
1. Settlement vs # of passes	5.3.2	58	x		Data poor but general trend toward 4 - 6 passes. 8 passes exhibits over compaction trend.
4. Unconfined Compression Strength (>10 psi <25 psi)					
1. Strength vs # of passes	5.4.1.1	66	x		Compression strength appears to be independent of # of passes after two passes are made.
2. Strength vs % compaction	5.4.1.2	70	-	-	No correlation
3. 1 hr vs % compaction	5.4.2.1	74	3:1	2:1 & 1:1	All materials fail to consistently achieve minimum strength of 10 psi (3:1 too strong).
4. 24 hr vs % compaction	5.4.3.1	78	3:1	2:1 & 1:1	Only 3 parts soil to 1 part sludge meets specification requirements.
5. 48 hr vs % compaction	5.4.4.1	82	2:1	3:1 & 1:1	1 part soil to 1 part sludge marginally meets specification requirements (3:1 too strong)
6. Strength vs time	5.4.5.1	86	3:1 & 2:1	1:1	1 part soil to 1 part sludge does NOT achieve minimum specification requirements.
5. Excavatability	5.5		x		All materials are excavatable after 1 hr to 48 hrs of curing
6. Sand Cone vs Nuclear Density	5.6		x		Sand cone density and nuclear density are comparable on average.

RECOMMENDATIONS:

1. 4 number of passes be performed on a soil:sludge mix of 2 parts to 1 part to provide specification requirements while considering cost and scheoule impacts.

2. If lower end of the unconfined compression strength is lowered to 8 psi, 4 number of passes will provide the new strength criteria at soil:sludge mix of 1 part to 1 part.

3. If material blending and homogenizing is performed on the entire soil mass in the north pool and prior to haul to the Waste Pile, 4 passes on a soil:sludge mix of 1 part soil to 1 part sludge will probably meet all specification requirements (not tested).

NUCLEAR WASTE DENSIFICATION BY DYNAMIC COMPACTION

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Introduction

Dynamic Compaction was used to achieve densification of buried nuclear waste at the Department of Energy's, Savannah River Plant. This procedure was the first step in the permanent closure capping of fifty-eight acres of buried low-level waste within the plant's Mixed Waste Management Facility. Before constructing a RCRA standard clay cap, the waste was compacted to reduce the potential for future subsistence which could possibly crack the permanent cap.

During the operation of this part of the burial ground from before 1976 until 1986, wastes had been deposited in a series of parallel trenches. The trenches were 20 feet wide by 20 feet deep with each trench separated by a 10 to 20 foot berm of natural undisturbed soil. The lower 16 feet of the trenches were filled with waste. In most cases, the waste had been simply dumped into the trenches. However, some trenches had been filled with waste which had first been placed in metal boxes. These metal boxes, known on site as B25 boxes, are similar to connex containers. Sometimes the boxes had been stacked in an orderly matrix within the trench, but some B25's had been randomly dumped into trenches. In all cases, loose dumped waste or boxed waste, the trenches had been covered with four feet of sandy silt.

The nuclear waste consisted of miscellaneous materials that had been exposed to nuclear radiation, including clothing, building materials, metal vessels, pipes, construction equipment, and fluids, such as oil, that were mixed with absorbent substances and placed in 55 gallon drums. The waste is classified as ranging from low level to intermediate level beta gamma.

It was observed that the initial soil cap which had been shaped to shed surface water was settling and water was beginning to pond in the low spots. This was considered undesirable since there was the likelihood of surface water seeping through and becoming contaminated from the nuclear deposits. The contaminated water could then possibly percolate downward to the groundwater table. To alleviate this problem, it was decided to densify the nuclear waste within the trenches to reduce future settlement and then to construct a new impervious cap.

In-Situ Improvement by Dynamic Compaction

Dynamic compaction is the process of dropping heavy tampers, typically in the 6 to 30 ton range, from heights varying from 30 to 100 ft. The tamper is raised and dropped by a single cable with a free spool which results in an energy lost of about 12% due to drum and sheave friction. On some projects, the tamper has been allowed to free-fall. In both situations, the high impact energy imparted to the soil causes deep densification. Dynamic compaction has been described in numerous technical papers (Charles et al, 1981; Leonards et al, 1980; Lukas, 1980, 1985; Mayne et al, 1984; Menard and Broise, 1975). The advantages and disadvantages of dynamic compaction are outlined by Lukas (1986) in a FHWA study. The process is ideal for compaction of nuclear or hazardous waste for several reasons.

1. Densification of the buried nuclear waste takes place from the existing ground surface without exposure to the waste. This is a critical requirement for the safety of construction personnel.

2. The weight of the tamper and the drop height can be adjusted to insure that compaction is obtained to the depth and degree necessary. In general, the heavier the tamper and the higher the drop height, the greater the depth and degree of compaction.

3. Wherever resistant materials are encountered below grade, additional energy can be applied to crush drums or displace large objects, thereby collapsing potential voids within the waste.

4. Dynamic compaction is generally the most economical site improvement process and for deep densification, it

is one of the safest. Other methods such as stone columns would have had to penetrate the nuclear waste and thereby expose construction personnel to radiation. Excavation followed by recompaction with conventional compaction equipment would, also, have led to unnecessary exposure.

Project Specification for Densification

The project specifications stated the following:

1. Prior to any waste trench being treated by dynamic compaction, a 2 ft. thick (+3",-0") soil blanket would be placed on top of the existing cover. This fill had no compaction requirement. (Most burial trenches had 4 ft. of initial earth cover so there would now be effectively 6 ft. of cover.)

2. Dynamic Compaction:

   a. Tamper - 20 tons with a flat bottom, eight (8) ft. diameter.

   b. Drop Height - 42 ft.

   c. Drop Pattern - The trench surface was subdivided into 10 ft. x 10 ft. grids designated primary and secondary grid drop locations. All primary craters within a work area would be compacted and backfilled prior to dynamic compaction of the secondary grid drop locations, Fig. 1.

   d. To facilitate tamper recovery, the tamper would remain attached to the crane cable during all drops.

   e. Each crater would be driven using 20 drops, or until a maximum crater depth of six (6) ft. was achieved. This maximum depth was specified for safety reasons, in order not to encounter the radioactive waste material. It was expected that on the average, 4.5 ft. deep craters would result from 20 drops.

3. Crater Backfilling:

   a. Place a uniform 4'-0" (±6") loose lift of fill material into the driven crater.

   b. Compact the loose fill by dropping the 20-ton tamper, five (5) times from 42 ft.

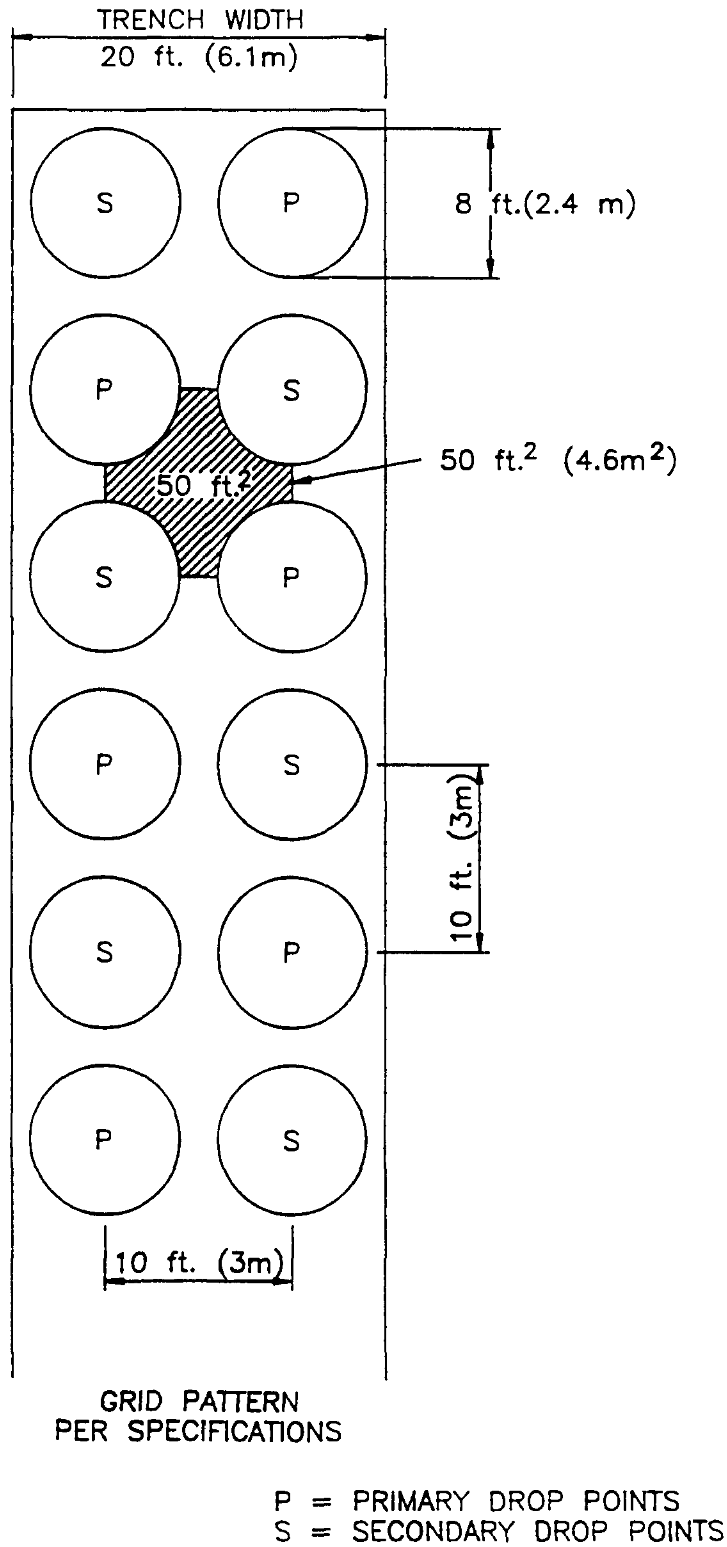

FIG. 1. Dynamic Compaction Tamper Drop Pattern, Mixed Waste Management Facility, DOE, Savannah River Plant

c. Continue backfilling and compacting as outlined in a & b until a 2'-0" maximum crater depth, measured from the surface of the soil blanket, is obtained.

d. Backfill would be compacted to 95% of maximum dry density (ASTM D698-79) at ± 2 percent of optimum moisture.

Dynamic Compaction Equipment

The machine utilized to perform this dynamic compaction work was specifically designed for the task, a Lampson LDC-350 "Thumper," Fig. 2. During compaction operations, the quick release and sudden stop, when the tamper strikes the ground, cause the boom and upper works of machines used for this work to experience severe rocking. The severity of this motion places unusual stresses on the undercarriage of full-revolving cranes. Consequently, the LDC-350 has no turntable and the upper works are fixed to the undercarriage, not pined. Each track of the machine has an independent motor. Therefore, instead of revolving, the machine is turned by counter direction travel of the tracks.

The LDC-350 has a larger than usual diameter hoist drum and a duel braking system. The braking system is a combination of an air-operated caliper disc and a non-self energizing 60 inch diameter band brake. The main brake applies sufficient resistance so that the tamper can be stopped and held at a desired height. It is rated to hold a 50-ton load. The second brake is more like a drag on a fishing reel. When dropping the tamper, the operator applies the drag brake just before the mass strikes the ground. This prevents drop line backlash. If, as on most other machines, the operator has to use the main brake for this purpose, there can be severe damage to the machine when the brake is applied prematurely. With the combination system, the operator cannot inadvertently shock-load the machine by attempting to stop the dropping tamper.

The LDC-350 boom is raised into its operating position with an erection line and then tied off with two (2) rear boom pendants. Additionally, there are two front kickback pendants. Once these pendants are connected, the boom angle is fixed and there is no stress on the boom hoist line drum. This is a separate hoisting system, independent of the system used for dropping the tamper.

Elevating scrapers, Fig. 3, were used to haul backfill material to each crater location. A 335 HP track bulldozer, Fig. 4, would then push the fill into the crater. One blade load of a machine this size provided all the required backfill.

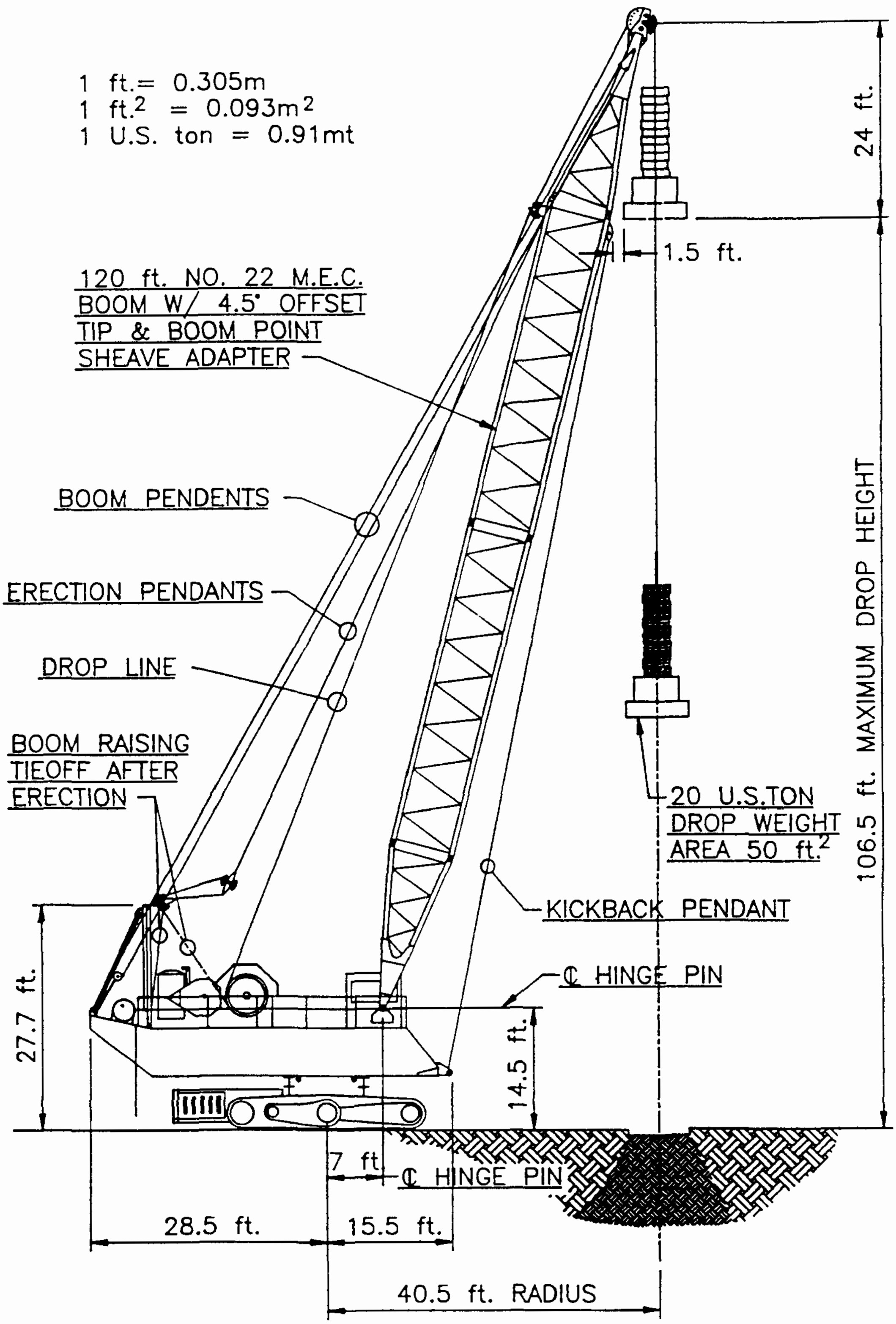

FIG. 2. Lampson LDC-350 "Thumper," Dynamic Compactor, Mixed Waste Management Facility, DOE, Savannah River Plant

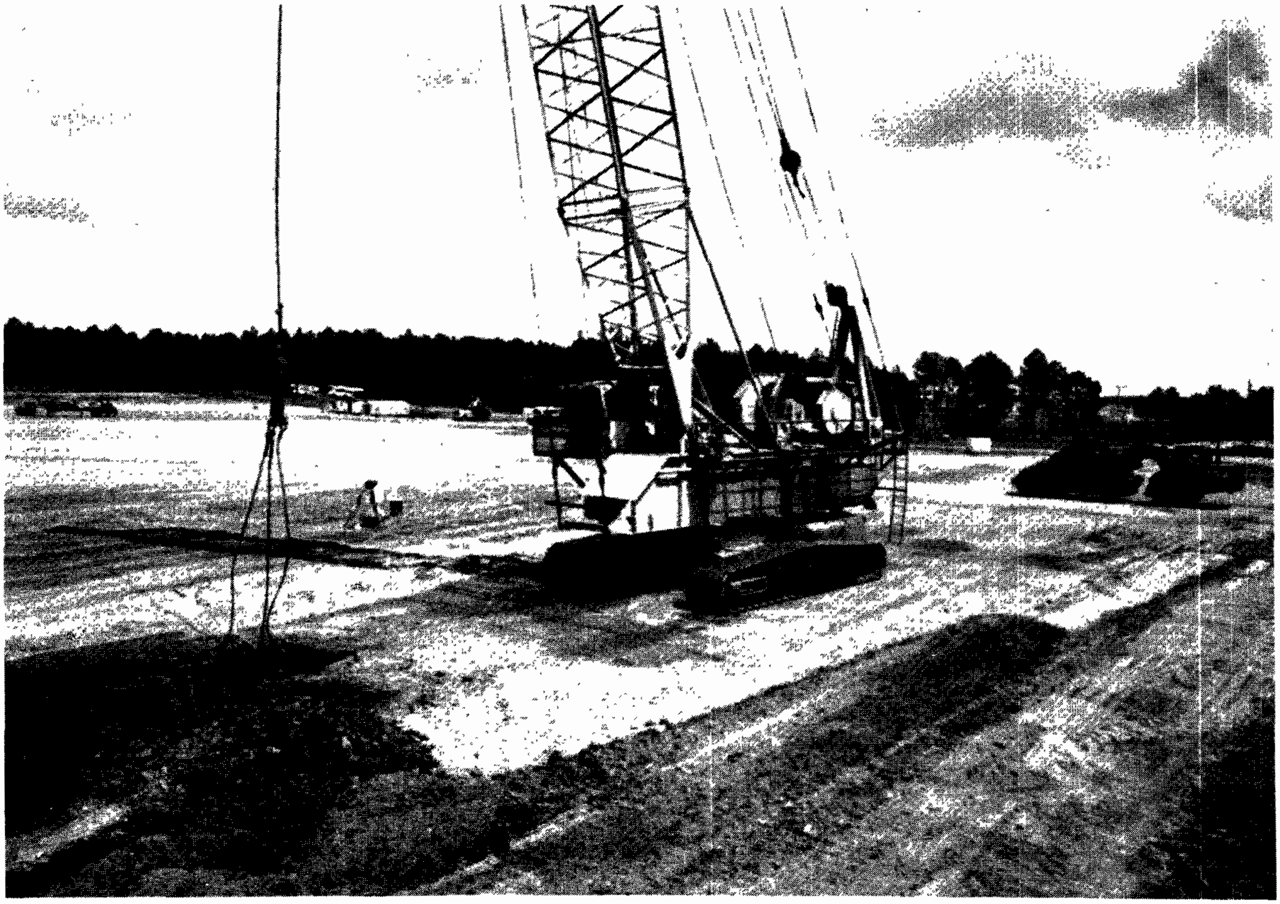

FIG. 3. LDC-350, "Thumper" and Elevating Scraper Hauling Crater Backfill, Mixed Waste Management Facility, DOE, Savannah River Plant

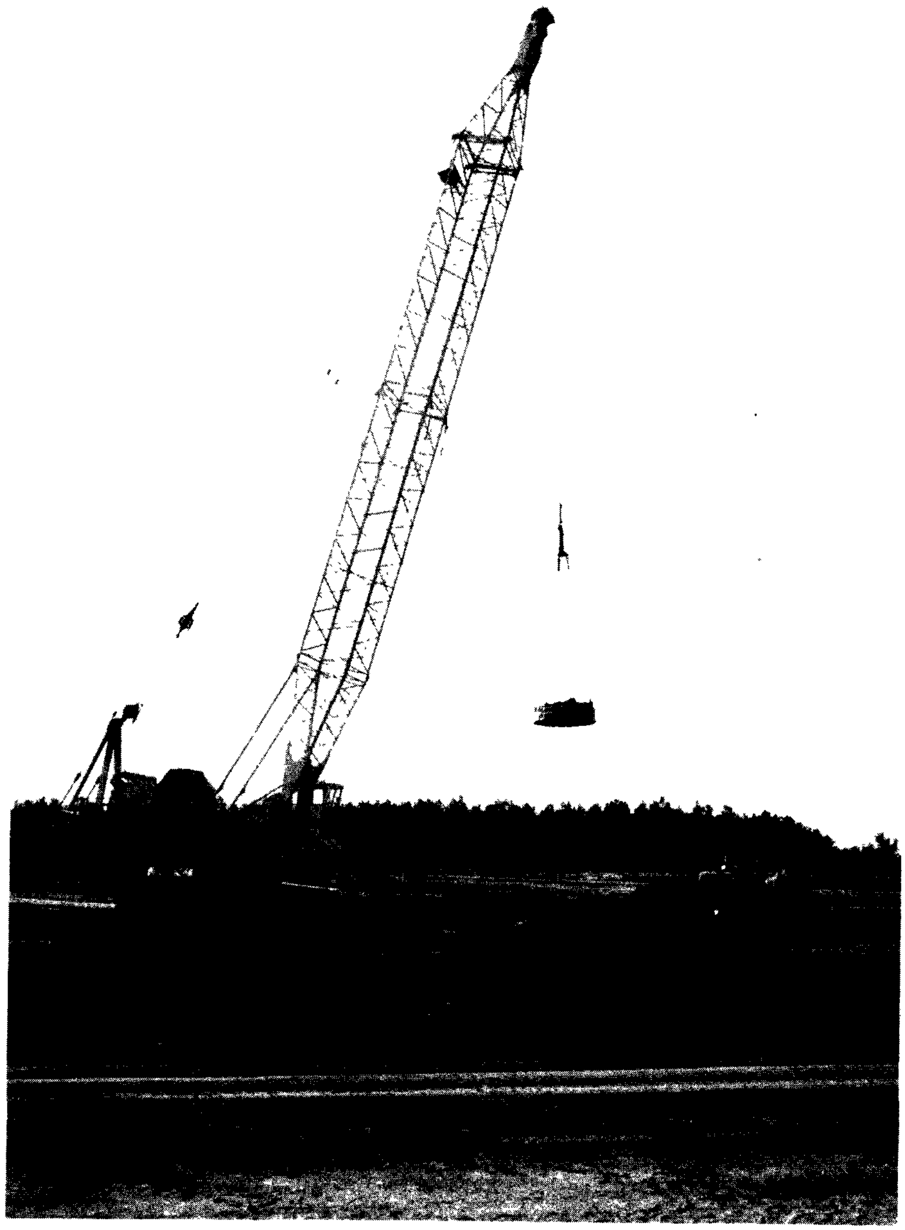

FIG. 4. Bulldozer Pushing Crater Backfill, Mixed Waste Management Facility, DOE, Savannah River Plant

This meant the dozer was idle a large portion of the time; however, the effect on total cycle time per crater justified the use of such a large machine. Employing such a large machine enhanced safety since it could fill the crater without having to maneuver directly under the hoisted tamper.

An analysis of hoist line wire rope performance was made during the first 60,674 dynamic compaction tamper drops. This represented about 25 percent of all project drops. A summary of that data is presented in Table 1. From the analysis, it was decided that new 1 1/2 inch 6x25 IWRC (Independent Wire Rope Core) wire rope would be used on the hoist line. This decision was based on safety. Whereas the new 1 1/2 inch 6x25 had a better average number of drops than the 1 1/2 inch 6x37 surplus rope, the cost difference was 255 percent greater while the performance was only improved by 11 percent. Another point of interest from the Table 1 data is the performance of the 1 1/2 inch 6x41 rope. This rope contains too many fine wires and is not good for dynamic compaction type work.

In most cases, the line was replaced before complete failure, because periodic inspection noted distress. The most common distress observed was broken and crushed wires at the point where the extended cable would break over the boom's point sheave. There were, however, three sudden separation failures during this analysis phase at the beginning of the project.

During the next 86,419 drops, there were 13 replacements of new 1 1/2 inch 6x25 rope. The best rope life was 7,530 drops, the least was 5,514 drops and the average was 6,648. There were no further sudden separation failures during the remainder of the project. This can be attributed to the prescribed inspection and replacement procedures which resulted from the analysis. At 5,000 drop cycles, close visual inspection of the rope was performed on a weekly basis. The inspection included climbing the boom in order to view the 42 feet of rope that was continuously running over the point sheave. Additionally, once a rope had experienced 7,000 drops, it was replaced during the next machine maintenance period even if inspection did not find evidence of excess stress.

Dynamic Compaction Test Program

Three test sections were proposed, each was the full width of the trench and a minimum of 200 ft. long. Two sections were situated in the low level alpha trenches and one section in an intermediate level trench. The first drop at each location was from a height of 42 feet to confirm that there was not a loose layer below an upper crust. For the second drop the height was varied as shown on the Table 2. If the difference in crater depth between the first and second drop was less than 1 foot,

Table 1. Dynamic Compaction Hoist Line Wire Rope Study for 20-Ton Tamper, Dropped by a Single Line from 42 Feet; Boom Height - 130 Feet

AVERAGE NUMBER OF DROPS (1)	SIZE inch (2)	CLASS IWRC (3)	PURCHASED NEW/SALVAGE (4)	NUMBER OF REPLACEMENTS (5)
1450	1 1/2	6x41	New	1
1753	1 3/8	6x19	Surplus	1
2780	1 3/8	6x37	Surplus	2
4499	1 1/2	6x25	Surplus	1
4865	1 1/2	6x19	Surplus	2
6058	1 1/2	6x37	Surplus	4
6725	1 1/2	6x25	New	2

Table 2. Contractor Dynamic Compaction Test Program Drop Height Sequence, Mixed Waste Management Facility, DOE, Savannah River Plant

NUMBER OF DROP POINTS* (1)	Height of Drops, Ft. 1ST DROP (2)	2ND DROP (3)	REMAINING DROPS UNTIL CRATER DEPTH OF 6 FT (4)
4	42	42	50
4	42	42	60
4	42	42	70
4	42	42	80
4	42	--	60
4	42	--	70
4	42	--	80

All tests were with a 20-ton tamper.

*A minimum limit, repeat the most promising drop height.

then additional drops were undertaken from the height specified in the test program until such time as the crater depth reached 6 feet. The reason for using the higher drop heights was to achieve the compression as quickly as possible with the least number of drops. Because the 20-ton tamper had already been constructed, no variation in tamper weight was attempted.

If, after any individual impact the crater depth was more than 1 foot deeper than the previous depth, the drop height was maintained at 42 feet until the incremental crater depth was less than 1 foot per drop.

Safety was maintained during the program by:

1. Using the reduced drop height during the initial tamping to confirm there was no weak spot directly below an upper stiff layer.

2. Using the incremental crater depth measurement of 1 foot maximum per drop as an indicator for reducing the drop height.

3. Limiting the crater depth to 6 feet.

4. Measuring for nuclear emissions at all times with air monitors and wipe tests on the tamper.

Monitoring was undertaken during the test sections and consisted of the following:

1. The depth of crater following each drop was measured.

2. The volume of the crater was determined by using a depth measurement, a top of ground diameter measurement and the known diameter of the tamper for the bottom of the crater measurement. The volume of the crater was determined for each drop.

3. Long spikes were driven into the ground adjacent to the craters from which ground elevations were obtained to determine if heave of the adjacent land mass was occurring. Heave was compared with the volume measurements obtained under Step 2 which was an indicator of how effective each drop was in compacting the mass.

4. The time taken to complete each test section was monitored to determine the most efficient dynamic compaction procedure.

5. During the dynamic compaction of the test sections,

measurements of peak particle velocity were taken at the ground surface with a seismograph. Seismograph readings were obtained at distances of 25, 50, 75, 100 and 125 feet from the drop point in both down-trench and cross-trench directions.

Test Sections D-4, D-5 and E-10

Trench D-4, which was 390 feet long, contained low level alpha waste. Trench E-10 was 239 feet long and contained intermediate level waste. In both areas the miscellaneous nuclear contaminated debris had been either dumped loosely into the trenches or was in cardboard boxes placed within the trenches. Test Section D-5, a 200 foot long portion of Trench D-5, was filled with randomly dumped metal B25 boxes containing low level alpha nuclear waste.

At all three test sections, the drop pattern was undertaken as shown in Figure 1. For the initial drop points on both the primary and secondary pass, the first two drops of the weight were both from 42 feet after which the following drops were all from a higher height. It was immediately apparent that the advantage was very slight for the 50 foot height. Therefore, on the second set of tests, the first drop within each test section was undertaken from a height of 42 feet, and then the additional drops were undertaken from heights varying from 60 to 80 feet. The number of drops required to reach a crater depth of approximately 5.5 feet at test sections D-4 and D-5 is summarized in Figures 5 and 6.

For Test Section D-4, the most efficient method of applying the energy was to use the highest drop height, in this case 80 feet. After the initial drop from 42 feet, it took only 5.8 additional drops from a height of 80 feet to reach the required crater depth at the primary grid points, and approximately 7.4 drops at the second grid points. The number 5.8 and 7.4 represent an average for various locations, thereby resulting in something other than a whole number of drops. The amount of energy applied for the various drop heights is summarized in Tables 3 and 4. It can be seen that approximately the same amount of energy was applied for each grid point, even though the drop height and number of drops varied. At the D4 primary grid point locations, the average energy required to achieve the densification was approximately 9,174 foot/tons. While at the D4 secondary grid points, the average energy required was 13,387 foot/tons. More energy is required for the secondary grid points, because some densification takes place in these areas during the impacting at the primary grid point locations.

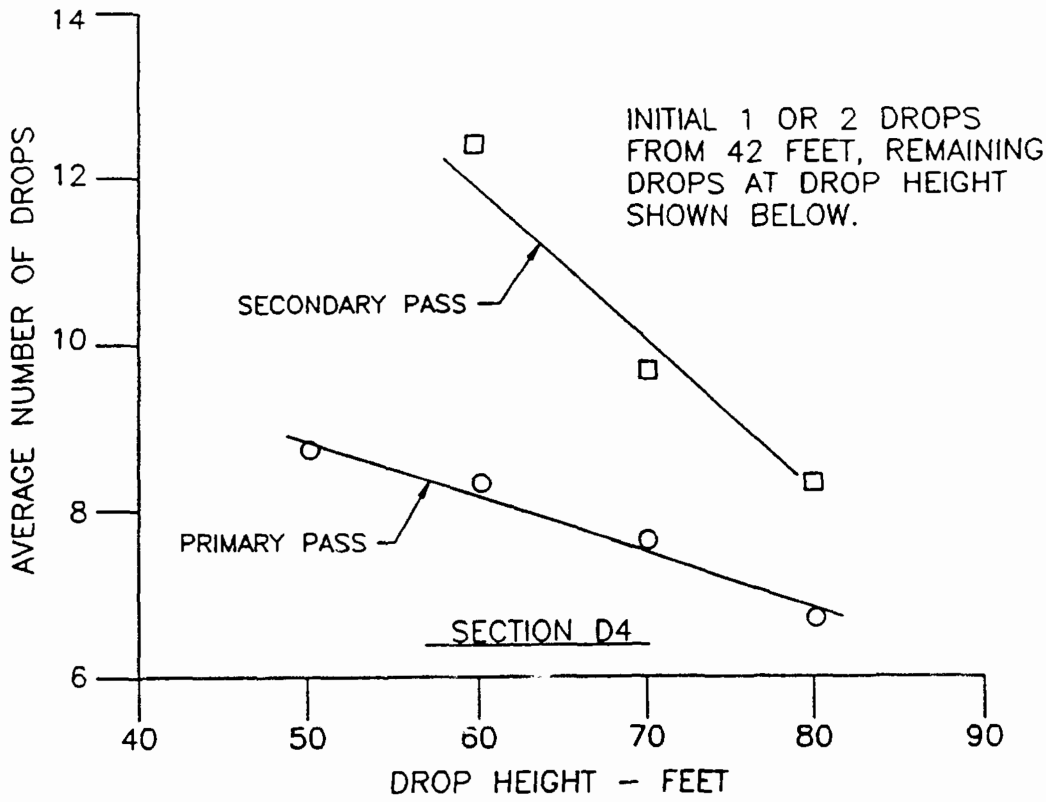

FIG. 5. Number of Drops from Varying Drop Heights to Induce a Crater Depth of 5 1/2 Feet, with 20-Ton Tamper, Test Section D-4, Mixed Waste Management Facility, DOE, Savannah River Plant

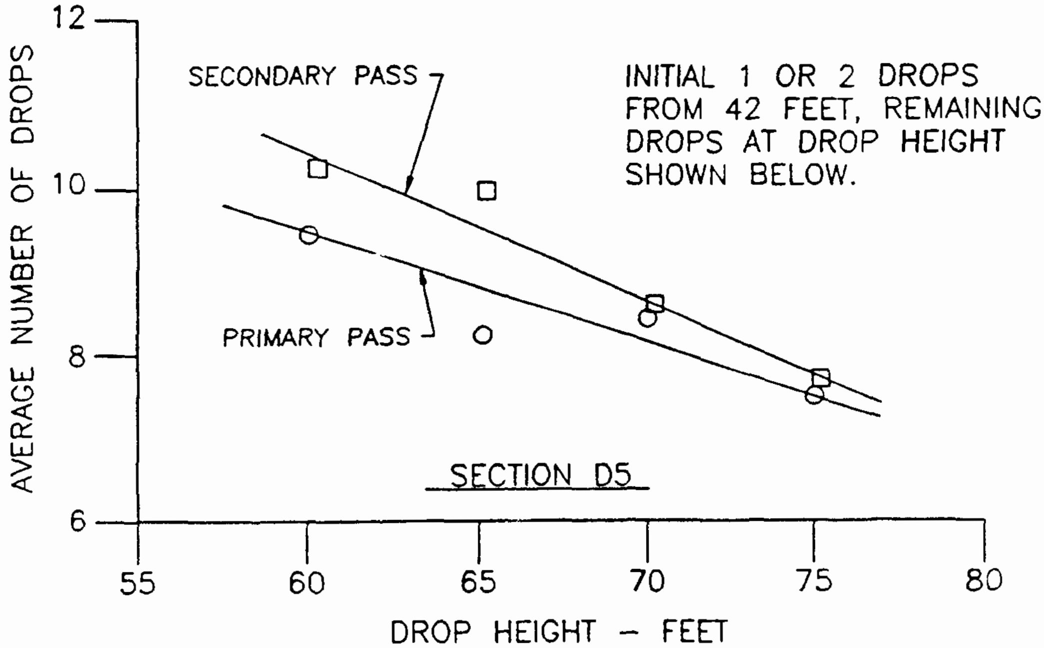

FIG. 6. Number of Drops from Varying Drop Heights to Induce a Crater Depth of 5 1/2 Feet, with 20-Ton Tamper, Test Section D5, Mixed Waste Management Facility, DOE, Savannah River Plant

Table 3. Energy Required to Induce Crater Depth of 5.5 Feet at Primary Drop Points, Mixed Waste Management Facility, DOE, Savannah River Plant

Test Section (1)	Drop Height - Feet 50 (2)	60 (3)	65 (4)	70 (5)	75 (6)	80 (7)	Average Energy All Drop Heights (8)
D4	8,680	9,276		9,380		9,360	9,174
D5		11,040	11,430	11,060	10,185		10,929
E10		9,792					9,792

Energy - Weight of Tamper x Drop Height x Number of Drops
Energy Units in Table Expressed in Foot-Tons

Table 4. Energy Required to Induce Crater Depth of 5.5 Feet at Secondary Drop Points, Mixed Waste Management Facility, DOE, Savannah River Plant

Test Section (1)	Drop Height - Feet 50 (2)	60 (3)	65 (4)	70 (5)	75 (6)	80 (7)	Average Energy All Drop Heights (8)
D4		14,040		13,440		12,680	13,387
D5		11,740	12,310	11,860	11,010		11,730
E10				12,684			12,684

Energy = Weight of Tamper x Drop Height x Number of Drops
Energy Units in Table Expressed in Foot-Tons

Test Program Heave Measurements

Heave measurements were taken during driving of 41 Trench D-4 craters. Twenty-two of these were primary craters and 19 were secondary craters. At the primary craters, heave occurred at 16 and a mixture of heave and settlement at three (3). At the closest measuring point, which was seven (7) feet from the center of the crater, heave was on the order of six (6) inches. This is not considered significant. Volumetric calculations of ground displacement indicated that heave ranged from 15 to 25 percent of the crater volume. On that basis, it was concluded that most of the dynamic compaction energy was being transmitted into the ground, causing compression.

During driving of Trench D-5 primary craters, heave was generally less than six (6) inches when measured seven (7) feet from the center of crater. At the secondary craters, the ground adjacent to all craters exhibited heave. This is to be expected because of the area wide densification effected during compaction of the primary crates. At four locations, the heave adjacent to the secondary crater was in the range of six to ten inches; this was not considered major.

Ground heave was more noticeable at the Trench E-10 craters. At the primary craters, heave was not significant. However, at twelve (12) of the 23 secondary craters, heave was in the range of six (6) to twelve (12) inches adjacent to the crater. This was still not considered an excessive amount of heave and it was concluded that most of the energy was still effective in causing densification.

Test Program Seismograph Readings

Seismograph readings were taken both parallel to the trench and perpendicular. This was done because perpendicular to the trench the ground vibrations were transmitted through both fill and through natural soil, whereas vibrations parallel were transmitted entirely through waste fill. In order to minimize damage to adjacent facilities, it was recommended that the peak particle velocity be kept to about 1 inch per second or less.

When using a 20-ton tamper from a height of 75 feet, the Trench D-4 data for the parallel case translated into a required distance of 79 feet from the point of impact. The data points for peak particle velocity measurements taken perpendicular to the trench exhibited wider scatter. This is attributd to the ground vibrations traveling through both loose waste and dense natural soil. For the 20-ton tamper and a height of 75 feet, the safe perpendicular distance was 72 feet.

The magnitude of the ground vibration produced during dynamic compaction of Trench D-4 was representative of the Trench D-5 and E-10 data. Therefore, in order to limit the peak particle velocity to 1 inch per second or less, it was recommended that for dynamic compaction utilizing a 20-ton tamper and a 75 foot drop height, a clear distance of 79 feet in line with critical objects or 72 feet for objects at right angles to the trench be maintained. If compaction had to be performed at distances less than the above values from critical facilities, the drop height should be reduced and more blows applied to achieve desired crater depth.

Field Operations

A Spectra-Physics El-1 electronic level laser system was used to check the final depth of every crater. Average incremental crater depth for primary craters was 0.51 feet and 0.40 feet for secondary craters. This difference was to be expected because the construction sequence created a stiffer matrix around the secondary craters. Some voids were encountered with resulting incremental depths as high as 1.73 feet per blow. The result of achieving an average incremental depth of 0.45 feet per blow was that on the average, only 13 drops were required to drive the craters. The resulting average crater depth for the project was 5.63 feet.

The average ground compression was 12.85 percent, as computed by the following expression:

$$AG = \frac{D_C \times A_T}{G.S. \times D_F}$$

where: AG = average percentage ground compression

D_C = depth of crater: 5.63 ft

A_T = area of tamper: 50.2 ft^2*

D_F = depth of fill: 22 ft**

G.S. = grid spacing: 10 ft x 10 ft

*For 8 ft diameter tamper
**Two ft blanket plus 20 ft trench

The craters could easily have been driven deeper but as a safety measure, driving was stopped when the depth reached or passed the 5.5 foot mark. This policy was instituted when it was realized that the incremental depths being experienced were close to one-half foot.

The effect of the B25 boxes which must have had large void spaces both within and between boxes was apparent. In the D area, the average number of drops for all craters, primary and secondary, in the B25 trenches was 11.7. The average number of drops for trenches having random mixed waste was 14.1. The point should be made that this is not an equal comparison; the 11.7 drops in the B25 trenches produced an average crater depth of 5.69 ft. The 14.1 drops in the mixed trenches produced only a 5.41 ft. deep crater. Table 5 further illustrates the differences between miscellaneous mixed waste trenches and trenches with B25 boxes.

The difference between expected average crater depth, 4.5 ft., and required blows to achieve as stated in the project specifications, and what was actually realized during the project, was the result of the differences in the equipment used during the original design test program and the machines selected for use by the contractor. The result was a final product very close to the high end of the expected 11 to 13 percent waste matrix compression versus 12.85 percent actual.

A depth of greater than 5.5 ft. was achieved with less than 20 blows for 85.6 percent of the crates. The average depth for those 1,875 craters which did receive the specified maximum 20 blows was 4.9 ft. The average number of backfill 42 foot drops, was 6.78.

Initially, there were problems with backfill compaction. There was one trench in the D area which required a total of 517 drops to drive the craters and 521 drops to compact the backfill. The specifications called for a backfill density of 95% of standard proctor. Standard Proctor Energy is 12,375 ft.-lbs./cubic foot. Additionally, the specifications limited the backfill lift to a maximum of 4.5 feet and called for five drops of the 20-ton tamper to compact. A 20-ton weight free falling from 42 feet imparts 1,680,000 ft.-lbs./drop. Mechanical losses for the LDC-350 using a single line are 11.1 percent. Therefore, for five drops, the resulting energy is 7,467,600 ft.-lbs. A 4.5 foot lift 8 feet in diameter is 226.2 cubic feet or 33,014 ft.-lbs./cubic foot. This is 2.67 standard proctor energy. Heave or rebound was experienced in the top part of the compacted backfill. Additionally, it was found that with so much energy, the backfill operation was actually a secondary driving operation.

To correct this situation, a change was instituted in the backfill operations. The number of blows required was adjusted to the depth of backfill lift and the lift thickness increased. When the thicker backfill lift was tried, difficulties were experienced with keeping the weight level. The final procedure adopted was to fill the crater completely including about one

Table 5. Dynamic Compaction Results, "D" Area, Mixed Waste Management Facility, DOE, Savannah River Plant

TYPE OF TRENCH (1)	Primary Craters: AVERAGE CRATER DEPTH ft. (2)	Primary Craters: AVERAGE NUMBER OF DROPS (3)	Secondary Craters: AVERAGE CRATER DEPTH ft. (4)	Secondary Craters: AVERAGE NUMBER OF DROPS (5)
Loose Mixed Waste Trenches	5.50	12.79	5.31	15.34
B25 Trenches	5.79	9.75	5.60	13.62
All Trenches	5.59	11.85	5.40	14.81

foot of overfill; drop the weight one time from 15 feet to take the fluff out of the loose fill; then push in additional soil so as to again completely fill the crater; and finally, at this point, to apply five drops from 42 feet. This resulted in an energy application of about 2.2 times standard proctor. Density tests were taken at different levels in the compacted backfill to verify that the 95 percent compaction specification was being achieved for the full depth, Table 6. Once the procedure was proven, it became the standard for the project.

Backfilling normally required two fillings. The first was as described above. The second filling, after the initial full depth and 5 blows, usually had a depth of less than three feet. For this second filling, only 2 blows from 42 feet were applied to achieve compaction.

It should be noted that the first backfill step which imparted roughly 2.2 times standard proctor energy, is about the limit that can be applied effectively. When too great an amount of energy is applied, the material is found to rebound or experience tension in the uppermost portion. Even at 2.2 times standard proctor energy, half the tests performed in developing the revised procedure, Table 6, had greater densities at the five (5) foot depth than at the three (3) foot depth, test 1, 3, 9-13.

When a second backfilling was required because the compression during the first filling left a crater having a depth greater than two (2) feet, the energy level applied was about 2.4 times standard proctor. In this shallow crater situation, there was insufficient lateral restraint provided by the two ft. of uncompacted soil blanket and only one foot of original trench fill. The backfill material would be driven laterally in many cases. In some cases, heave of as much as two feet resulted at the edge of the crater during backfill compaction. The heave would taper out over a distance of about six feet. This was a heave situation during backfilling and should not be confused with the nominal heave observed during initial driving of the craters.

The majority of the craters were completed by:

--Thirteen initial driving blows from 42 feet.

--A first backfill with one 15 foot fluff compaction drop and five 42 foot compaction drops.

--A second backfill with two 42 foot compaction drops.

There were 13,002 drop point locations in the project area. These required a total of 161,096 initial driving drops and

Table 6. Crated Backfill Density as Percent of ASTM D698-79 Maximum Dry Density, Backfill Compacted According to Revised Procedure, Mixed Waste Management Facility, DOE, Savannah River Plant

TEST NUMBER (1)	TRENCH (2)	HOLE (3)	COMPARATIVE DENSITY % (4)	DEPTH OF TEST ft from surface (5)
1	D4	P15	100.7 102.3	3.0 5.0
2	D5	S5	99.0 91.8*	3.5 5.0
3	D5	S6	97.4 98.0	3.0 5.0
4	D5	S7	101.9 98.9	3.0 5.0
5	D5	S8	98.4 97.7	3.0 5.0
6	D5	S9	99.0 98.5	3.0 5.0
7	D5	S10	103.6 101.0	3.0 5.0
8	D5	S11	103.4 102.2	3.0 5.0
9	D5	S12	98.4 103.1	3.0 5.0
10	D5	S15	100.7 102.3	3.0 5.0
11	D5	S16	100.3 104.0	3.0 5.0
12	D5	S18	95.0 99.3	3.0 5.0
13	D5	S19	98.8 103.2	3.0 5.0
14	D5	S20	102.6 97.6	3.0 5.0

*Moisture was too high, greater than 2% above optimum.

85,879 backfill drops. The first machine mobilized, worked for five days before the second machine was ready to begin. These two machines worked from March thru July 1989. In August, a third machine was mobilized and three machines were utilized from 11 August 1989 until 21 February 1990. The total dynamic compaction duration was 357 calendar days. That period included 205 workdays, 39 days lost due to weather, and 113 non-workdays (Saturday, Sunday & Holidays).

Of the total work time available, 86.4 percent was productive. The remaining 13.6 percent was lost to machine availability. Considering production time only, 3.35 craters were driven and backfilled per hour or conversely, it required 17.9 minutes to complete all work at a crater location. Twelve and one-half minutes were required to complete the 20 driving and backfill drops. The remainder of the time was for pushing backfill and positioning the machine. Weather was not a major hinderance. The machines could not work in the rain or lighting and sometimes the backfill material became too damp, but weather accounted for only 11 percent of all non-work time. The dynamic compaction phase of the project was completed three months ahead of schedule.

Dynamic Cone Penetrometer Measurements

To check on the degree and depth of improvement throughout the full depth of the nuclear waste facility, dynamic cone penetrometer readings were undertaken. These tests were performed after the 2 ft. soil blanket had been removed. Therefore, both the initial and final tests were from the same elevation, top of the original cap.

The dynamic cone penetrometer consists of a 2 inch diameter conical cone with a 60 degree cone angle which is connected to a drill rod that is driven by a 140 pound hammer falling 30 inches. This cone is driven into the nuclear waste and the number of blows per foot that are required to advance to the penetrometer are recorded. Readings were taken in the nuclear waste before and after dynamic compaction. In all cases, there was a significant increase in the penetration resistance following dynamic compaction. Fig. 7 is the test results for a specific location, B25 Trench D-13 at secondary crater S-21, while Fig. 8 is at primary crater P-53 of miscellaneous mixed waste Trench A-4. An illustration of the range in cone penetrometer values before and after dynamic compaction covering two different areas of the burial grouns is presented in Fig. 9.

Typically, the cone penetrometer values before dynamic compaction were found to range from about 5 to 20 blows per foot with occasional higher values. It was assumed the high values were the result of encountering large objects within the waste.

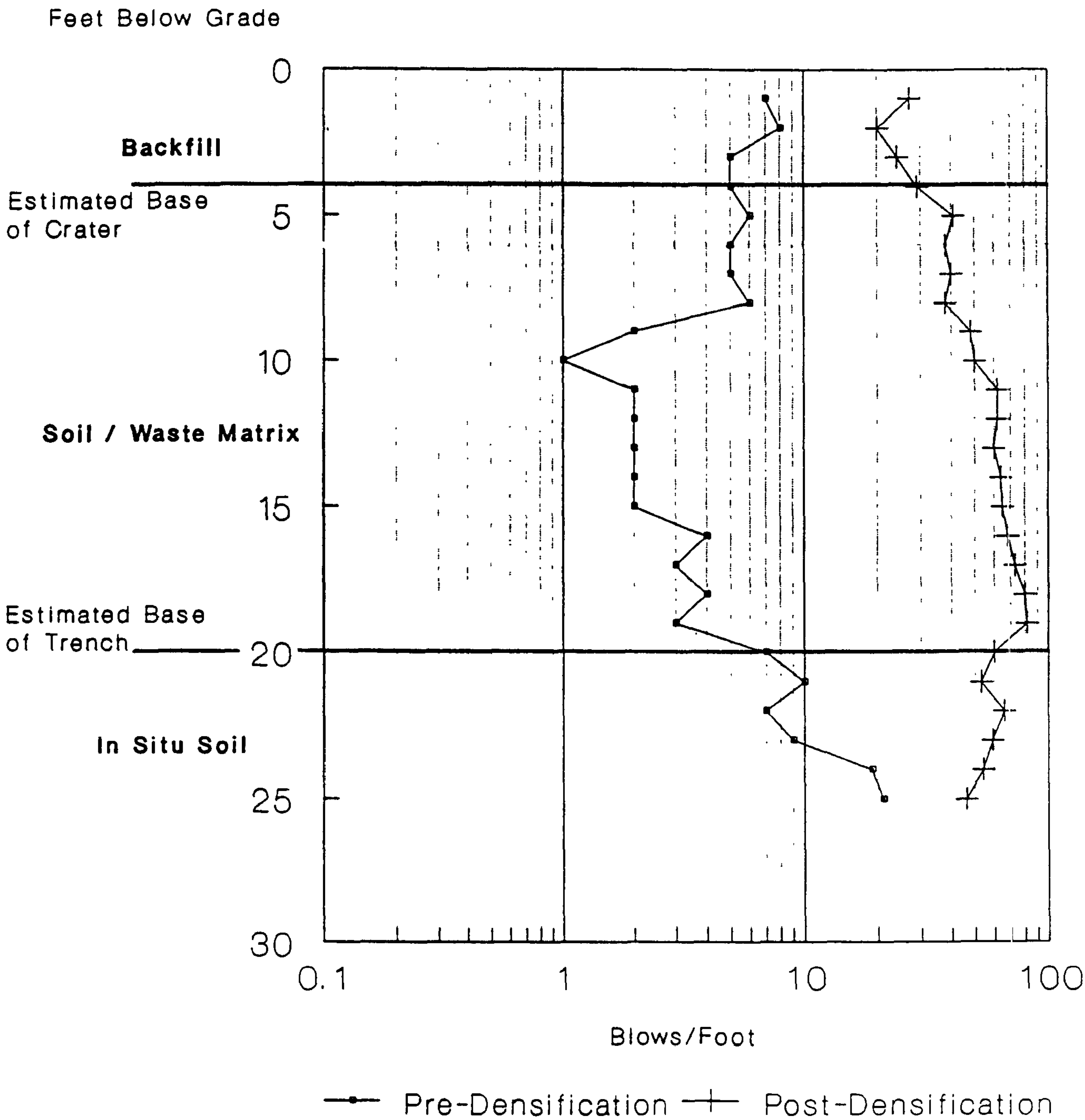

FIG. 7. Cone Penetrometer Data for Trench D-13, Containing Metal "B25" Boxes, Secondary Crater Location S-21, Mixed Waste Management Facility, DOE, Savannah River Plant (from Chas. T. Main, Inc. Letter Report May 31, 1989)

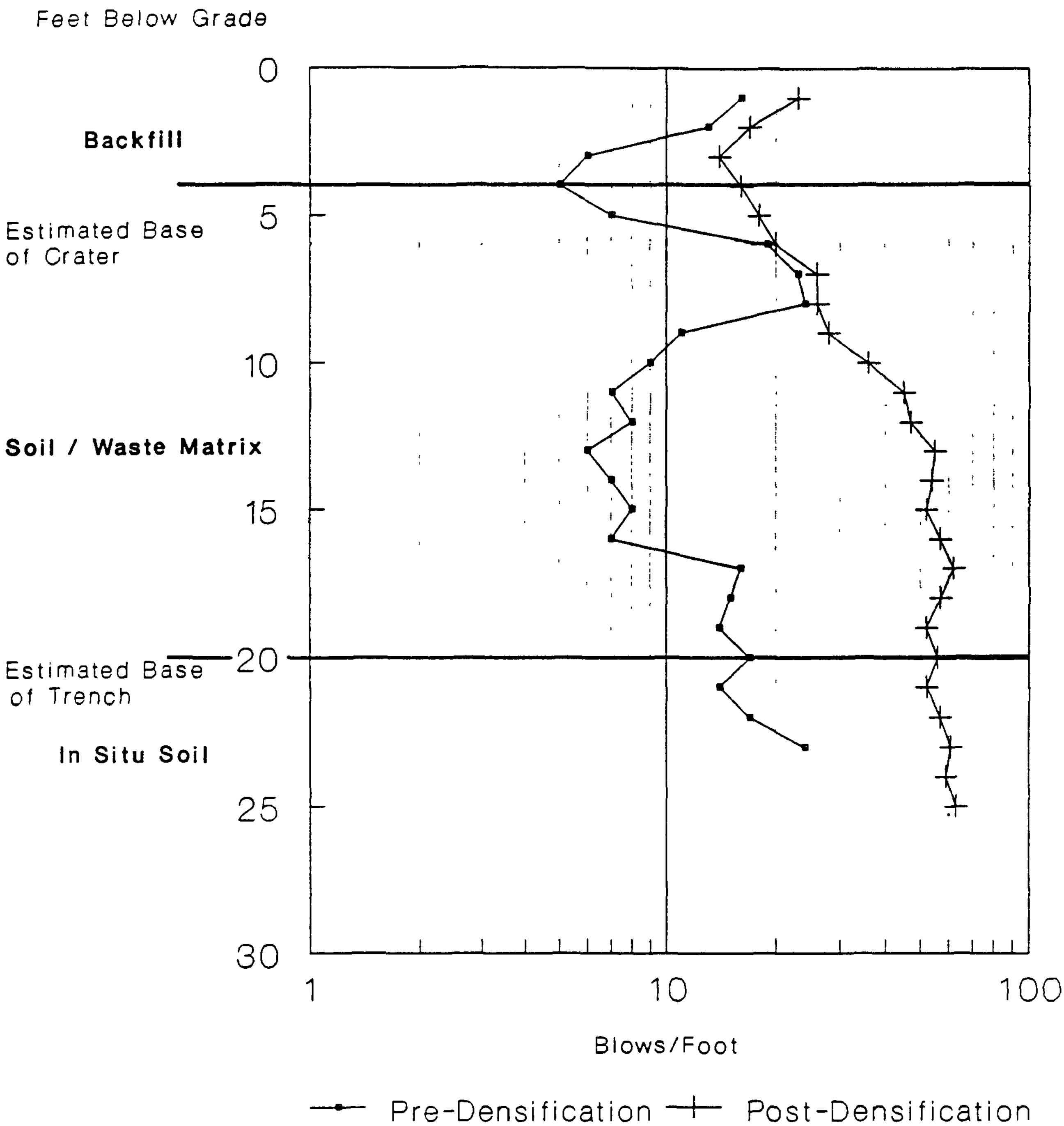

FIG. 8. Cone Penetrometer Data for Trench A-4, Containing Miscellaneous Mixed Waste, Primary Crater Location P-53, Mixed Waste Management Facility, DOE, Savannah River Plant (from Chas. T. Main, Inc. Letter Report December 20, 1989)

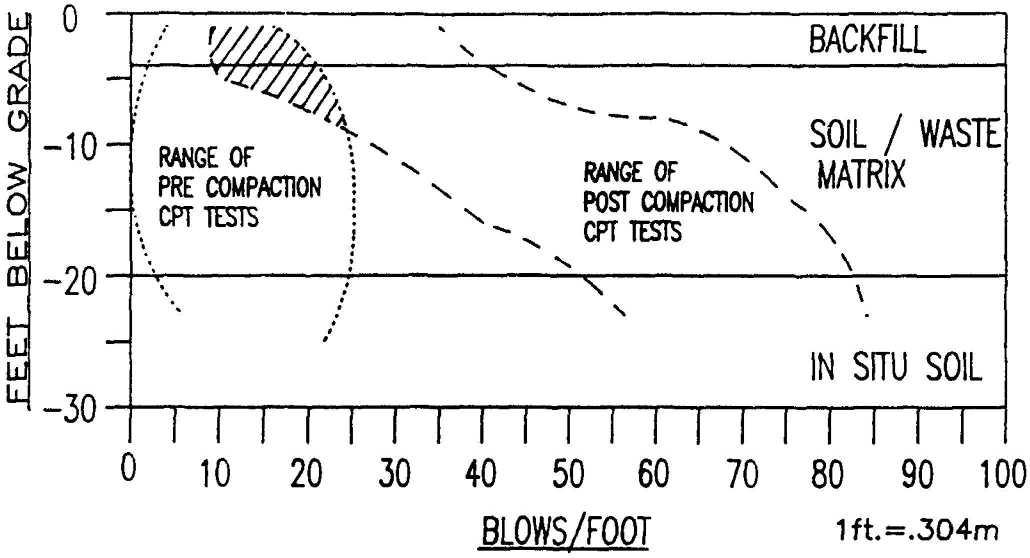

FIG. 9. Comparison of Cone Penetrometer Test Results, "A" and "D" Areas, Mixed Waste Management Facility, DOE, Savannah River Plant

After dynamic compaction, the typical cone penetrometer values showed a relatively uniform penetration record throughout the entire depth of fill, a desirable result.

Conclusions

Based upon the data from the actual dynamic compaction of this 58 acre site, it is concluded that:

1. Densification of the nuclear waste was accomplished by the dynamic compaction procedures.

2. The craters formed by the impact of the drop weight averaged 5.63 feet which resulted in an average ground compression of the nuclear waste of approximately 12.85 percent.

3. Cone penetrometer tests taken before and after dynamic compaction indicated a significant increase in the penetration resistance, thereby confirming the high degree of densification within the nuclear waste deposit.

4. Safety was maintained at all times by limiting the crater depth to 6.0 feet. Measurements were taken with air monitors around each compactor, monitoring of craters before backfill, and wipe tests of the weights during the entire dynamic compaction construction period. These confirmed that radioactive debris was not discharged.

Acknowledgements

The authors wish to thank Mr. Jay D. Rasmussen, Civil Engineering student, Iowa State University and Miss. Ann M. Schexnayder, Nello L. Teer Company, for their efforts in assembling and sorting the raw field data from which this paper was developed. Mr. Patrick E. Geluso, P.E., and Mr. William N. Lampson of Neil F. Lampson, Inc. gave valuable counsel and shared their knowledge concerning machine mechanics. A special word of appreciation goes to Mr. Walter D. Munn, P.E., Senior Editor, Highway & Heavy Construction, for his advice and guidance concerning equipment and methods both before and during the project.

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Appendix II. Metric Conversion Factors

1 foot = 0.305 meters

1 foot^2 = 0.093 meters^2

1 U.S. ton = 0.91 metric ton

U.S. EPA Region II Treatability Trailer for Onsite Testing of Soils and Sludges

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INTRODUCTION

Over the history of the Superfund program, treatability studies have generally been postponed until the remedial design phase, following selection of the remedy. However, remedial planning guidance and directives from the U.S. Environmental Protection Agency (EPA), and recent administrative reviews of the Superfund program, have emphasized the importance of conducting these studies during the remedial planning process. The emphasis on supporting remedy selection with treatment data will increase the need for timely and cost-effective performance of treatability studies.

In anticipation of this need, EPA Region II has developed a treatability trailer for onsite testing of treatment technologies for soils and sludges. The treatability trailer has been designed to provide a generic working platform capable of supporting a number of different bench-scale test programs with a minimum of modifications. Provisions have been included to support testing of treatment technologies for soil, sludges and water, and to support screening-level chemical analyses of these matrices. Although the optimum application of the trailer is within a field operations center with separate facilities to support field office, sampling activities and analytical services, the trailer is capable of operation at remote locations with minimal support. The first use of the trailer is scheduled for August 1991 as part of a Superfund RI/FS.

Among the potential benefits to be realized from the use of the treatability trailer are an increased availability of equipment and facilities for onsite testing, increased experience with these technologies at the contractor level, reduced need to ship waste offsite or to obtain permits for testing, and avoidance of hidden costs associated with offsite studies. Realization of these benefits will make it easier to implement studies of innovative and conventional treatment technologies, and will help to promote performance of treatability studies in the remedial planning phase.

CANDIDATE TREATMENT TECHNOLOGIES

The number of technologies available for treatment of soil and water has increased over the history of the Superfund program. Application of these technologies generally requires that testing be performed to evaluate the feasibility of using a treatment technology to attain remedial criteria or to develop design data for implementation of a selected remedy.

As an initial design activity, existing data on treatability studies that were planned or performed under the Superfund program were reviewed to identify the technologies most suitable for onsite testing.

The review focused on the application of bench-scale treatability tests as the most appropriate studies to support the remedial planning process. As expressed in the Guide for Conducting Treatability Studies Under CERCLA (EPA 1989a), "bench-scale testing can verify that the technology can meet the expected cleanup goals and can provide information in support of remedy selection." These tests usually employ standard laboratory equipment or other simple test apparatuses, and are performed over short periods of time using relatively small amounts of material. Data quality objectives for bench-scale screening are generally quantitative in nature and require fairly rigorous quality assurance and quality control measures (QA/QC). Less sophisticated methods with limited QA/QC are also used to direct the studies or evaluate the applicability of treatments.

The bench-scale tests were also reviewed for how easily they could be performed in the field. Tests that required specialized equipment or posed unique hazards, such as some solvent extraction processes or incineration, or tests of proprietary technologies were not considered to be suitable for inclusion in the field trailer. Identification of appropriate test equipment was oriented toward supporting the tests which were most frequently required during remedial planning or for which testing services were not readily available in the marketplace. Requirements for sample preparation and phase separation were also considered.

Based on this review, a number of technologies were identified as being potentially feasible for testing in the treatability trailer. Selected technologies for soil and sludge treatment were:

- o Low-temperature thermal desorption
- o Soil washing
- o Solidification/stabilization
- o Alkaline dechlorination (KPEG)
- o Solvent extraction

The technologies selected for water treatment were:

- o Air stripping
- o Carbon adsorption
- o Ion exchange
- o Metals removal

Lists of recommended physical tests, chemical analyses and bench-scale test equipment were produced for each technology that was reviewed. These served as the basis for the recommended design criteria and equipment inventory for the treatability trailer (FPC 1990). Tables 1 through 3 present the lists generated for bench-scale testing of stabilization/solidification as examples of the information that was developed.

Other technologies that were not included in the review may also be suitable for testing in a mobile field laboratory. The requirements for field-testing any technology should be evaluated on a project-specific basis.

TRAILER DESIGN AND OPERATION

The principal objective of the treatability trailer design was to provide a facility that would support a broad range of treatability study programs with a minimum of modifications. This made it necessary to design the trailer as a generic working platform.

Design criteria were developed to define the key features of a functional laboratory environment. These were grouped into eight areas, which are discussed herein:

- o Trailer construction
- o Transportation requirements
- o Space utilization
- o Laboratory furniture and appliances
- o Utility requirements
- o Heating, ventilation and air conditioning
- o Laboratory safety requirements
- o Analytical support requirements

The following sections present the design criteria for the trailer and discuss the specific features that are provided to support performance of the treatability studies. The elevation and plan view sketches presented in figures 1 through 8 illustrate the manner in which the various features of the trailer have been integrated to create a functional laboratory environment.

Although the trailer is capable of operating with a minimum of support, its optimum application will be as part of a field operations center where its functions would be supported by a separate facility for field office and sampling activities and a close support analytical laboratory. Some of these additional support activities could be accommodated within a larger treatability trailer with little additional design effort, but at a significantly greater cost. Others, particularly close support analytical activities, can be performed most effectively in a separate onsite facility.

Trailer Construction

The principle criteria for construction of the trailer addressed its durability, maintainability and conformance to applicable codes, standards and practices.

Exterior elevations of the treatability trailer are shown in figure 1. The trailer body is of the standard semi-trailer, or "box trailer", configuration. Another common trailer style is the tow-trailer, which sits low to the ground, allowing for easier entry and exit. However, the semi-trailer allows the towing hitch to be placed above the rear wheel axles of the towing vehicle, providing greater stability and leverage than can be obtained when the hitch is placed behind the rear wheel axles. The trailer hitch would be of the fifth-wheel configuration to provide the necessary stability and versatility for transporting a trailer of this size.

Construction of the trailer body conforms to standard industry practices. This should provide sufficient durability for the trailer to perform its expected services through the ten-year life of the ARCS II contract, with a minimum of maintenance or repair. The trailer also complies with the requirements and standards of the U.S. Department of Transportation (DOT) and the Interstate Commerce Commission and Society of Automotive Engineers (ICC/SAE) for over-the-road vehicles:

- o Reinforcement for loading in excess of 6500 pounds
- o Rating labeled on the exterior of the trailer
- o Wheel assembly sized to accommodate loading
- o Furnished with break away braking system
- o Furnished with emergency disconnect brakes
- o Double axle for trailers over 25 feet in length
- o Finished exterior with running lights at the rear and sides

The trailer frame has been constructed with extra reinforcement to accommodate the stresses of travel over unfinished roads and off-road conditions. The structural members and walls are also reinforced to support overhead cabinets and wall-mounted apparatus.

The running gear consist of a heavy-duty double axle assembly with air-glide suspension and shock absorbers. The braking system is air-operated on both axles to provide 110 percent braking of the trailer and its controls can be interconnected with the tow vehicle. An emergency braking system is provided to cause total braking of the trailer in case of on-the-road breakaway.

The exterior is finished with riveted aluminum sheeting and coated with polyacrylic paint. The interior sidewalls and ceiling are continuous sheeting of nontextured panel with the number of seams minimized to facilitate decontamination. All corners, seams and penetrations are sealed to be leak free for the life of the trailer.

The trailer is provided with two doors along the curb side of the trailer. The rear door is of the standard 3-foot width. The front door is extra-wide to allow loading and unloading of large equipment. Aluminum stairs and platforms are provided as part of the trailer's equipment. An all-weather canopy, supported by an aluminum frame, has been provided for outdoor work such as sample preparation. These items fold for storage in compartments below the trailer.

Transportation Requirements

The treatability trailer has been designed to withstand stresses associated with transportation over paved and non-paved roadways. The trailer will be sturdy enough for occasional off-road activities, however, frequent travel over rough terrains would shorten its useful life.

A commercial trailer transporter will be contracted to tow the trailer between sites. The semi-trailer configuration with fifth-wheel towing hitch is commonly used for long-distance hauling, and transport services are widely available. A medium-duty tractor or larger vehicle will be used for towing.

As discussed above, the trailer design is in conformance with the pertinent federal transportation regulations. Local limitations relative to permissible height or weight may be exceeded along some routes. No special permits will be required for over-the-road travel, as the trailer width does not exceed 8 feet.

Space Utilization

The design of the treatability trailer must provide a safe, controlled and open environment for the workers. The permanent furniture and fixtures have been arranged to provide adequate open area for operations and allow unimpeded movement of personnel and equipment. Sufficient open area is provided to allow large or floor-standing equipment to be mounted in the trailer or removed as needed. The arrangement also allows the work areas to be segregated into "clean" and "dirty" zones to facilitate control of contamination.

Adequate bench space and storage space is provided to allow safe, uncluttered performance of the tests and analyses, and maintain the necessary equipment and supplies within the trailer. The arrangement of the benches and cabinets uses the available space as efficiently as is practical.

Cabinet and bench space arrangements for the laboratory interior are illustrated in figures 2 and 3, Plan View and Interior Elevations. This arrangement provides about 34 linear feet of bench space over about 256 cubic feet of cabinet, cupboard and drawer space. About one-third of this space is occupied by utilities and fixed equipment. Overhead storage provides about 72 cubic feet of storage space in large cabinets with sliding panel fronts. There is about 100 square feet of open floor space, 30 of which is available for free-standing laboratory equipment.

Laboratory Furniture and Appliances

The principle criteria for selection of fixtures and furniture for the treatability trailer were their durability and maintenance requirements, and their suitability for use in a generic laboratory environment. Standard items have been selected to the maximum extent practical so that replacements can be readily obtained. The materials and construction techniques used are expected to last the duration of the ARCS program (10 years). Assemblies and finishes are designed to facilitate cleaning and minimize decontamination efforts.

A plan view and elevation of the laboratory interior have been presented in figures 2 and 3.

Laboratory furniture. Materials of construction that were considered for the base units and overhead cabinets include wood, plastic laminate and enameled steel. Steel was chosen because of its superior durability. Wood and plastic laminate base units are estimated to cost less than steel by 8 and 20 percent, respectively, but such units would be more likely to require repair or replacement over the life of the trailer.

Stainless steel and epoxy were considered as materials for the worktop surfaces. Epoxy surface with a plywood base was identified as a suitable material because of its strength and chemical resistance. Epoxy worktops are less expensive than stainless steel and replacement parts are readily available in standard sizes.

The worktops are provided with a lipped front and an integral backsplash to control spills and facilitate cleaniong. The base cabinets are installed about 8 inches away from the wall to allow access to service lines through service shelving or the back panels of the base units. The epoxy worktops are designed to be tilted into place so that the backsplash fits under the service shelving. Furniture modules can be removed to provide additional floor space when needed.

Laboratory appliances. The fume hood selected for the treatability trailer is large enough to accommodate test equipment, such as furnaces or distillation apparatus, that may be used during the treatability studies. It is equipped with an integral exhaust blower, capable of drawing 1120 cubic-feet-per-minute of air.

Other appliances that have been provided include a deionized water system and a standard laboratory refrigerator. The water purifier unit has four modular purifiers with a built-in pump and a resistivity/temperature monitor. Purification modules include a prefilter, an activated carbon cartridge, ion exchange cartridges and an adsorbent resin cartridge for removal of trace organic contaminants.

Other features. In many applications, the treatability trailer would be located at a field operations center, for which communications and security will have been arranged. For independent operation, the trailer has been provided with telephone jacks and the necessary wiring to allow connection of telephone service. A standard telephone is included as part of the trailer inventory. A mobile phone or two-way radio would be needed in those situations where telephone service was unavailable.

A security system has been installed for the exterior doors and windows, to provide a 90 decibel audible exterior alarm upon unauthorized entry. This system would be turned on or off with a key from the exterior of the trailer. The trailer wheels have been equipped with anti-theft bars and a protective cover has been installed over the rear window.

Utility Requirements

The treatability trailer provides fully-developed utility systems to support the execution of bench-scale studies in the field.

The general design criteria for these systems were developed to enable the trailer to operate with a minimum of outside support. These systems are capable of supporting an array of different appliances and equipment without rewiring or replumbing. Utility connections are designed for quick connection to minimize mobilization and demobilization times. The installation of the utility should meet the requirements of the local codes and regulations in the areas that the trailer will be used.

Provisions have also been made to accomodate electrical and water supply in remote areas, and for proper segregation and handling of wastes generated during the studies.

Electrical systems. The electrical systems for the trailer provide a high voltage power supply for appliances and test equipment and a battery-powered low voltage system for the security system and exterior lighting.

The electrical plan for the high voltage system is shown in figure 4. Power supply and electrical distribution are provided through a 200 amp service panel mounted inside the trailer. Electrical power at 220 VAC and 120 VAC electrical power outlets and services to appliances are provided throughout the trailer. Outlets for 220 VAC power are also provided at the exterior of the trailer for operations performed out-of-doors. Exterior outlets and outlets in the equipment area are provided with tight-fitting caps for protection from water and dirt. Voltage surge dampening is provided on selected 120 VAC circuits to protect analytical and data management equipment.

The low voltage system provides power to operate the security system and security lights. Cable and connectors are provided for connection to the tow vehicle's power system. The standby power system includes a 12-volt deep-cycle battery and automatic battery charger.

The maximum high voltage requirement for the trailer is estimated to be 32 kilowatts (KW), including power surges at startup. This power can readily be supplied through a high voltage line and transformer.

The potential need for a generator should be assessed on a project-by-project basis. For many projects, electrical power will be available at the site, or the electrical demands may be low enough to allow use of a smaller generator. At remote locations, it may be necessary to provide a fuel-powered generator to power the trailer and equipment. The costs of leasing a generator for occasional use under these conditions should be much less expensive than purchasing a large system.

Lighting. Interior lighting is provided by three ceiling-mounted fluorescent tube fixtures with wrap-around lenses. An additional single-tube fluorescent light fixture is incuded as part of the fume hood equipment. Emergency lights with self-contained power supplies have also been installed inside the trailer.

Exterior lighting is provided by low-pressure sodium-vapor security lights, mounted on the sides of the trailer. A low-power courtesy light would be provided over each door.

The trailer is equipped with highway running lights, tail lights and brake lights as required under DOT and ICC/SAE rules and guidelines.

Area lighting is not included as part of the trailer equipment. If such lighting was needed, equipment could be leased for the specific project, and powered through the trailer's electrical distribution system.

Pressurized water system. The pressurized water system plan is shown in figure 6. This system includes an onboard storage tank, pressure pump, water heater, distribution system, hot and cold service fixtures and provisions for connection to an external domestic water system. Freeze protection has been provided near hatches and through the underbelly of the trailer.

Pressure control is provided by small pressure tanks of the type used with household well systems. This system has been designed to operate over the pressure range of 20 to 40 psig and prevent excessive pump cycling during episodes of high water usage.

Two pressure tanks, stored in a cabinet inside the trailer, provide pressure to the distribution system. Two additional tanks provide pressure to the safety shower. A check valve installed before the shower tanks prevents loss of pressure from the safety shower to the distribution system.

The pump has been sized to deliver a minimum of 10 gpm to the safety shower at 30 psig. This will allow the system to operate near the high end of the pressure range under heavy water demand. Pressurized water can also be pumped directly into the distribution system from outside, bypassing the trailer's pump and pressure tanks.

Compressed air system. The treatability trailer has been provided with an onboard air compressor and distribution system. Four deck-mounted air nozzles have been provided: one near each sink, and two at the fume hood. Media for preparing the air to meet experimental needs (e.g., filters or desiccant tubes) will be provided by the specific studies.

Waste drain system. Schematic drawings of the waste drain system are presented in figure 7. Drains have been provided from the sinks, hood and safety shower, and from two locations in the trailer floor. The drain outlets are about 4 feet above ground level, which will allow drainage by gravity flow to external containers. In situations where gravity flow is not sufficient, the waste may drain to a sump, and then be pumped to the disposal point. The drains at each end of trailer have been installed as separate systems, allowing segregation of the wastewater streams.

Collected wastewater will be removed for offsite disposal, whenever required during the study.

Heating, Ventilation and Air Conditioning (HVAC)

The HVAC system for the trailer will regulate the temperature and humidity within the trailer against the full range of external atmospheric conditions that may be encountered during field operations at sites in Region II. It will maintain adequate indoor ventilation rates, as required by the Occupational Health and Safety Administration (OSHA), and be capable of a rapid turnover of the room air when necessary.

A wall-mounted air conditioning and ventilation unit has been installed at the front of the trailer. Heating is provided by a heat pump, with an electric heating element as a backup system. The system has been sized to maintain an interior temperature of $75^{o}F$ and about 60 percent relative humidity against air exterior temperatures of minus 10 to plus $110^{o}F$ and humidities up to 100 percent. Air temperature is thermostatically controlled.

The ventilation system can maintain up to four air changes per hour through air diffusers distributed throughout the trailer interior. More rapid air changes can be provided by operating the fume hood with its below-counter air intakes closed.

The components of the HVAC system are indicated on figure 8.

Laboratory Safety Requirements

The safety features incorporated in the laboratory design meet generally accepted safe laboratory practices and the applicable requirements of OSHA (for example: 29 CFR Part 1910 Subpart H). Specific features include exhaust vents to provide adequate indoor ventilation, two entrances and exits, and provisions to segregate corrosives and flammables in separate cabinets. The layout of furniture and fixtures also facilitate segregating the work areas into "clean" and "dirty" zones.

A fume hood has been provided for operations that pose a fume or splattering hazard. The hood fan is capable of maintaining a flow of up to 100 linear feet per minute. A charcoal filter pack has been installed in the exhaust line to capture particulates and organic contaminants.

Specific safety equipment that has been provided includes a full-deluge safety shower, a portable face-and-eyewash station, fire extinguishers and fire blankets, smoke detectors, and emergency lights. Signs will be placed in the interior of the trailer as warning or precautionary devices. A laboratory first-aid kit is also provided, and test equipment is provided for monitoring performance of the ventilation system. Other safety equipment and information, such as material safety data sheets (MSDS), personnel protective equipment or air monitoring equipment, will be supplied by the individual projects.

The acid and solvent storage cabinets incorporate the required safety features. Solvent storage cabinets are specially designed to prevent spread of flames within the cabinets, and to shield their contents from exterior fires. The cabinet floor is recessed below the door sill to contain spills. Acid storage cabinets are made with acid-resistant material and have vents in the doors. Both types of storage cabinets have been modified to vent directly into the fume hood. Safety containers and labels for temporary storage of spent solvents and chemical solutions, will also provided by the specific projects.

ANALYTICAL SUPPORT REQUIREMENTS

There are several advantages to supporting an onsite treatability study with onsite analytical capabilities. These include shorter turnaround times, increased flexibility in the experimental program, and better characterization of unstable chemical species generated by the treatment process. However, it would be necessary to segregate the more sophisticated analytical equipment in a separate trailer to minimize cross-contamination and prevent power fluctuations and vibrations that would be associated with operation of the treatability test equipment. The costs of maintaining onsite analytical capabilities are much greater than the costs of performing the analyses off site, and maintenance of data quality is more difficult.

The relative benefits and disadvantages of performing chemical analyses in a trailer on site or at a fixed facility off site must be evaluated during the design of each treatability study. The quality of treatability testing data should be appropriate to the potential impacts of the decisions that will be based on those data. The EPA has published guidance that defines the framework and processes for developing appropriate data quality objectives (DQOs) (EPA 1987).

The treatability trailer provides working areas and basic laboratory equipment to perform screening tests to direct the progress of the study or determine whether a treatment process is potentially applicable (DQO Levels I or II). Selected samples can be analyzed at a fixed facility to verify the screening data, or to attain the more stringent data quality objectives required to evaluate treatment performance or develop design data (DQO Levels III or IV).

The pre-design review of bench-scale studies identified screening-level chemical analyses that could provide reliable data at the lower DQO levels in the treatability trailer environment. These tests and the equipment required to perform them are listed in tables 4 and 5, respectively.

A summary list of the test and analytical equipment recommended for eventual inclusion in the trailer inventory is presented in table 6. This list was compiled from the technology-specific lists developed from the pre-design review.

CONCLUSION

The treatability trailer will be deployed for its first assignment in August 1991, when it will serve as a field laboratory for treatment of contaminated soils for a Superfund RI/FS. Test plans for these studies are presently under development.

In this application, the trailer will be operated as part of a field operations center where commercial power and city water will be provided. Its operations will be supported by a separate field office and a close support analytical laboratory. While this situation will not test the trailer's full capabilities, it will provide a demonstration of the applicability of an onsite facility for treatability testing.

The particular benefits expected from the use of the treatability trailer for the upcoming study are an improved flexibility in executing the test program, a reduced need to ship waste offsite or to obtain permits for testing, and an increase in experience and understanding of the the technologies that will carry through the later phases of the site remediation and that can be applied to remedial planning activities at other sites.

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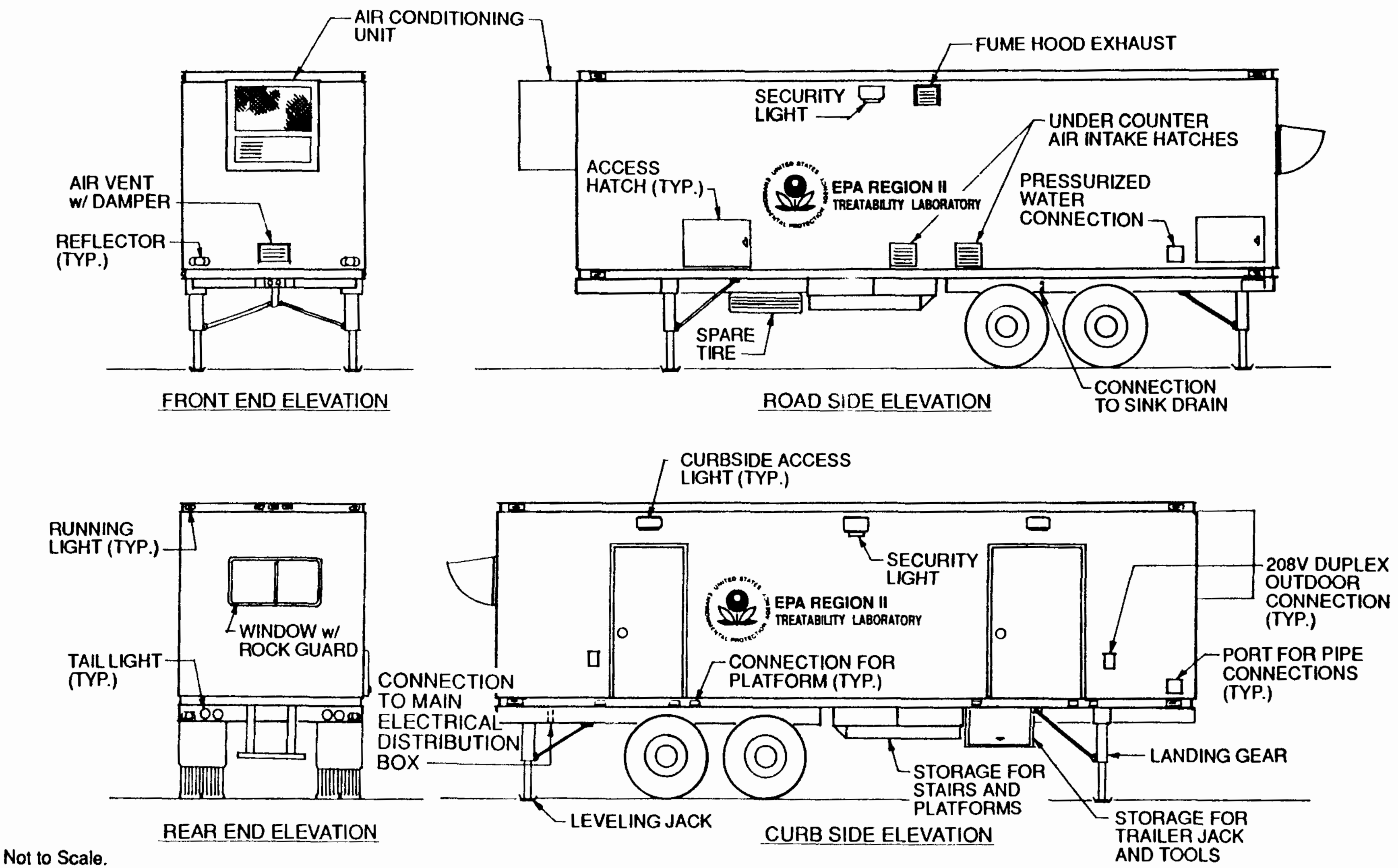


Figure 1

EXTERIOR ELEVATIONS

U.S. EPA REGION II TREATABILITY TRAILER

① CABINET [29" x 48" x 29"- HIGH]

② FILLER [29" x 48"]

③ CABINET, CUPBOARD, DRAWER COMBINATION
[29" x 48" x 36" - HIGH]

④ COUNTERTOP w/ 30" DOUBLE SINK, CABINET BOTTOM
[29" x 48" x 36" - HIGH]

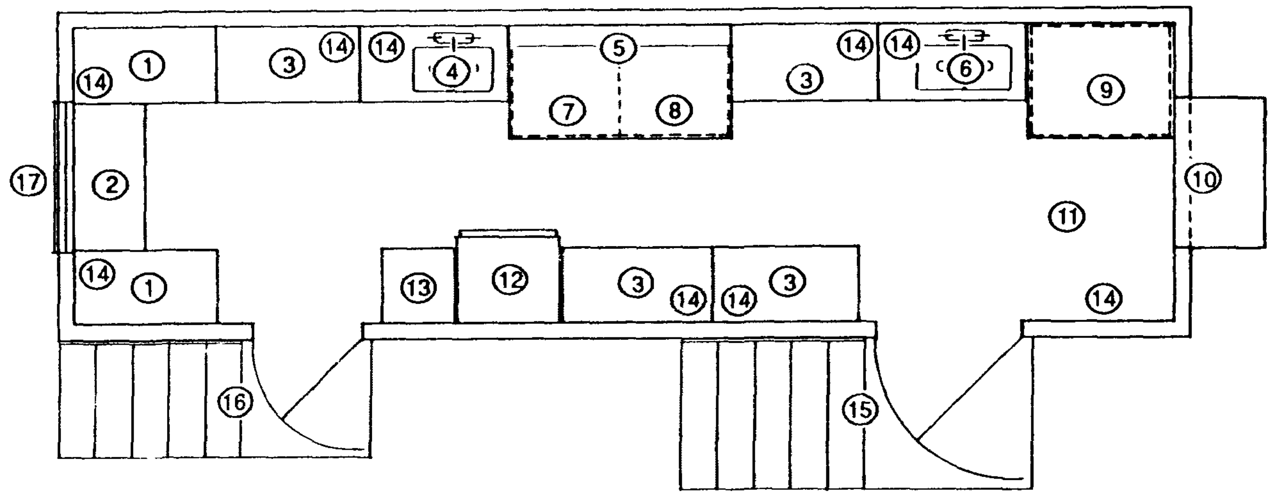
⑤ FUME HOOD [32" x 72"]

⑥ COUNTERTOP w/ 30" DOUBLE SINK, CABINET BOTTOM
[29" x 48" x 29" - HIGH]

⑦ ACID CABINET [29" x 36" x 30" - HIGH]

⑧ SOLVENT CABINET [29" x 36" x 30" - HIGH]

NOTES: 1. STATED DIMENSIONS ARE NOMINAL VALUES.
2. UNITS ① THROUGH ⑧ INCLUDE EPOXY COUNTERTOPS.



⑨ LOCATION OF DELUGE SAFETY SHOWER AND DRAIN

⑩ AIR CONDITIONER/HEAT PUMP SYSTEM

⑪ LOCATION OF FREE-STANDING EQUIPMENT

⑫ REFRIGERATOR / FREEZER
[24" x 30" x 48" - HIGH]

⑬ COAT CLOSET [29" x 24" x 48" - HIGH]

⑭ OVERHEAD CABINET AND CUPBOARD
w/ SLIDING DOORS [18" x 48" x 24" - HIGH]

⑮ PLATFORM [48" x 60" w/ STAIRS]

⑯ PLATFORM [36" x 48" w/ STAIRS]

⑰ WINDOW w/ROCK GUARD [24" x 48"]

Scale: 1" = 5'

Figure 2

PLAN VIEW

U.S. EPA REGION II TREATABILITY TRAILER

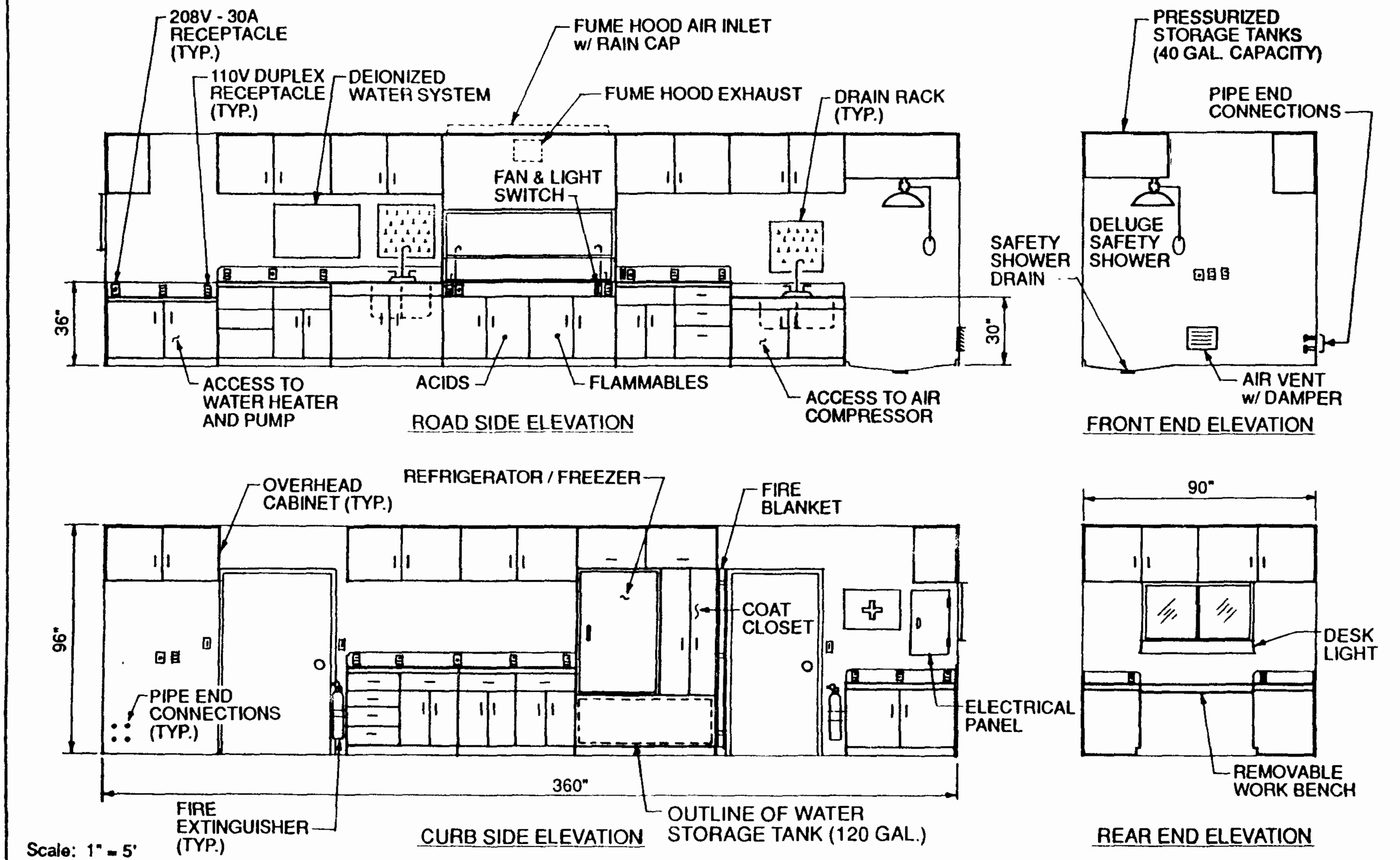
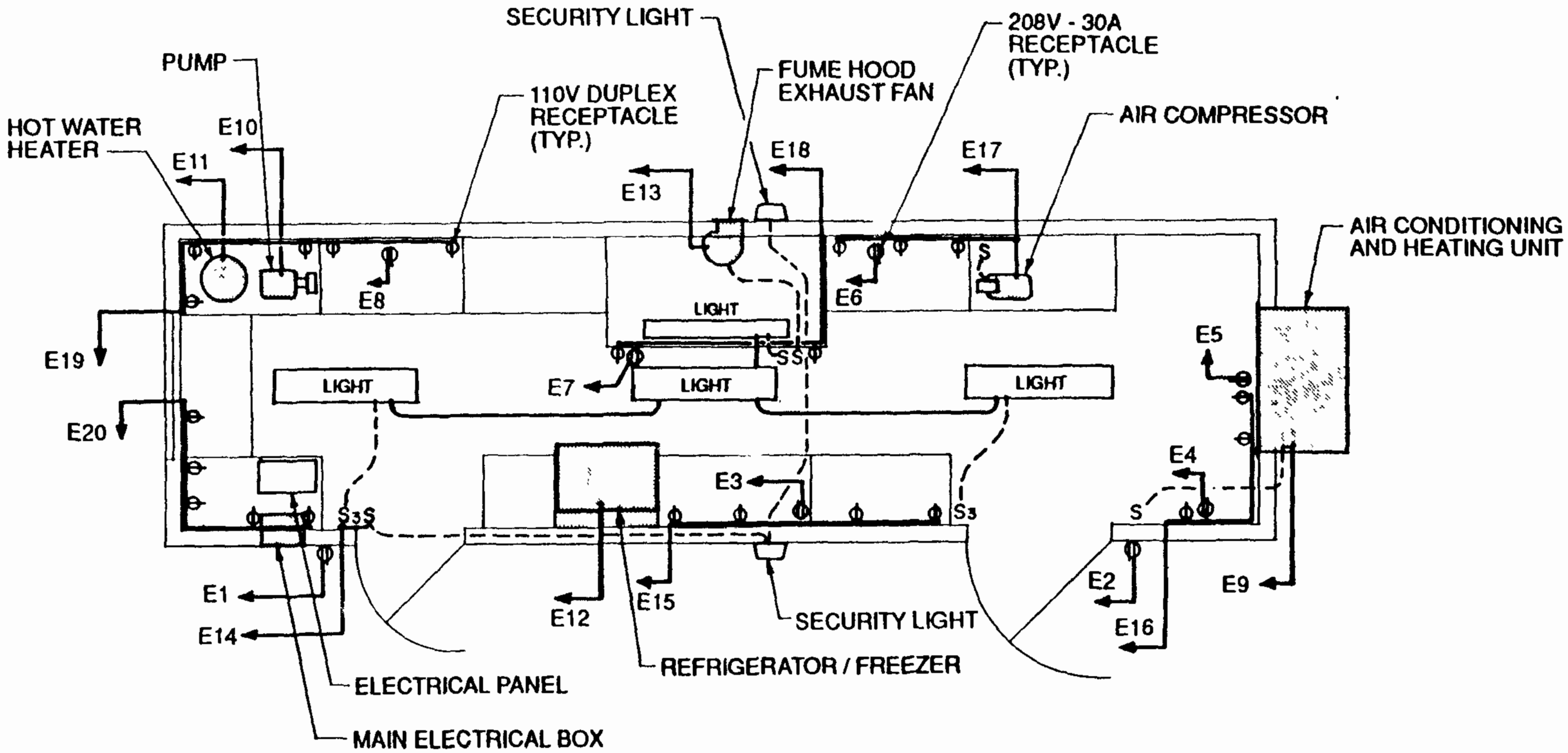


Figure 3

INTERIOR ELEVATIONS

U.S. EPA REGION II TREATABILITY TRAILER



NOTES:

1. ELECTRICAL PANEL - PROVIDE PANEL SUITABLE FOR CIRCUITS PROVIDED (SEE ELECTRICAL LEGEND).
2. MAIN BREAKER - PROVIDE MAIN BREAKER SUITABLE FOR CIRCUITS PROVIDED.
3. PROVIDE JUNCTION BOX AND DISCONNECT FOR ON BOARD CONNECTION OF ELECTRICAL PANEL TO OFF BOARD METER BASE.
4. ↰ INDICATES HOME RUN TO CIRCUIT BREAKER IN ELECTRICAL PANEL.

Scale: 1" = 5'

Figure 4

ELECTRICAL PLAN

U.S. EPA REGION II TREATABILITY TRAILER

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ELECTRICAL LEGEND

CIRCUIT	DESCRIPTION		
E1	220V	30A	RECEPTACLE, DEDICATED
E2	220V	30A	RECEPTACLE, DEDICATED
E3	220V	30A	RECEPTACLE, DEDICATED
E4	220V	30A	RECEPTACLE, DEDICATED
E5	220V	30A	RECEPTACLE, DEDICATED
E6	220V	30A	RECEPTACLE, DEDICATED
E7	220V	30A	RECEPTACLE, DEDICATED
E8	220V	30A	RECEPTACLE, DEDICATED
E9	220V	20A	AIR CONDITIONING AND HEATING UNIT
E10	120V	10A	WATER SYSTEM PUMP
E11	120V	20A	HOT WATER HEATER
E12	120V	10A	REFRIGERATOR / FREEZER
E13	120V	10A	FUME HOOD EXHAUST FAN
E14	120V	10A	INTERIOR AND EXTERIOR LIGHTS
E15	120V	20A	PLUG MOLD
E16	120V	20A	PLUG MOLD
E17	120V	20A	PLUG MOLD, AIR COMPRESSOR
E18	120V	20A	RECEPTACLES AT FUME HOOD PANEL
E19	120V	20A	PLUG MOLD
E20	120V	20A	PLUG MOLD
E21	120V	20A	SPARE
E22	120V	20A	SPARE
E23	120V	20A	SPARE
E24	120V	20A	SPARE
E25	120V	20A	SPARE

Figure 5

ELECTRICAL LEGEND

U.S. EPA REGION II TREATABILITY TRAILER

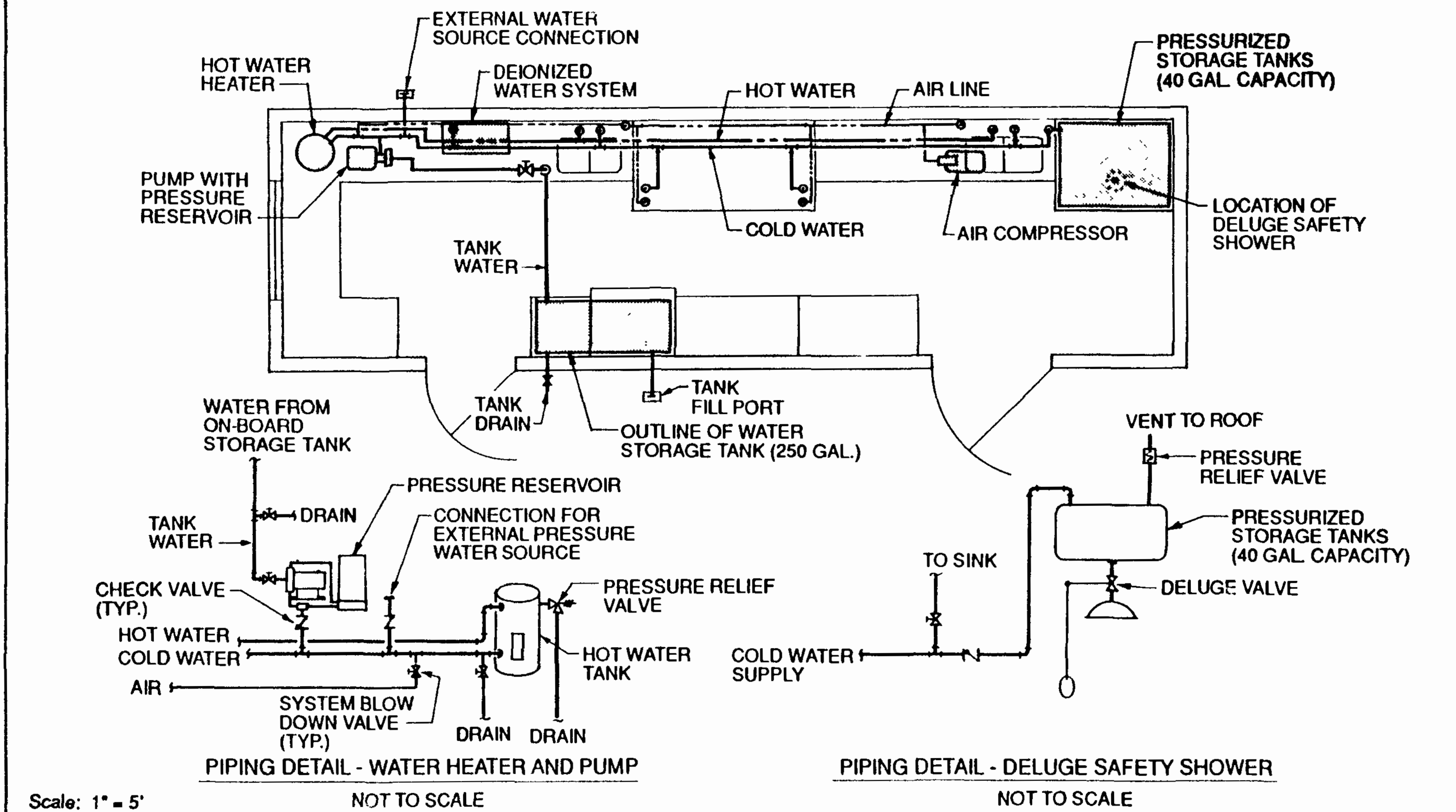
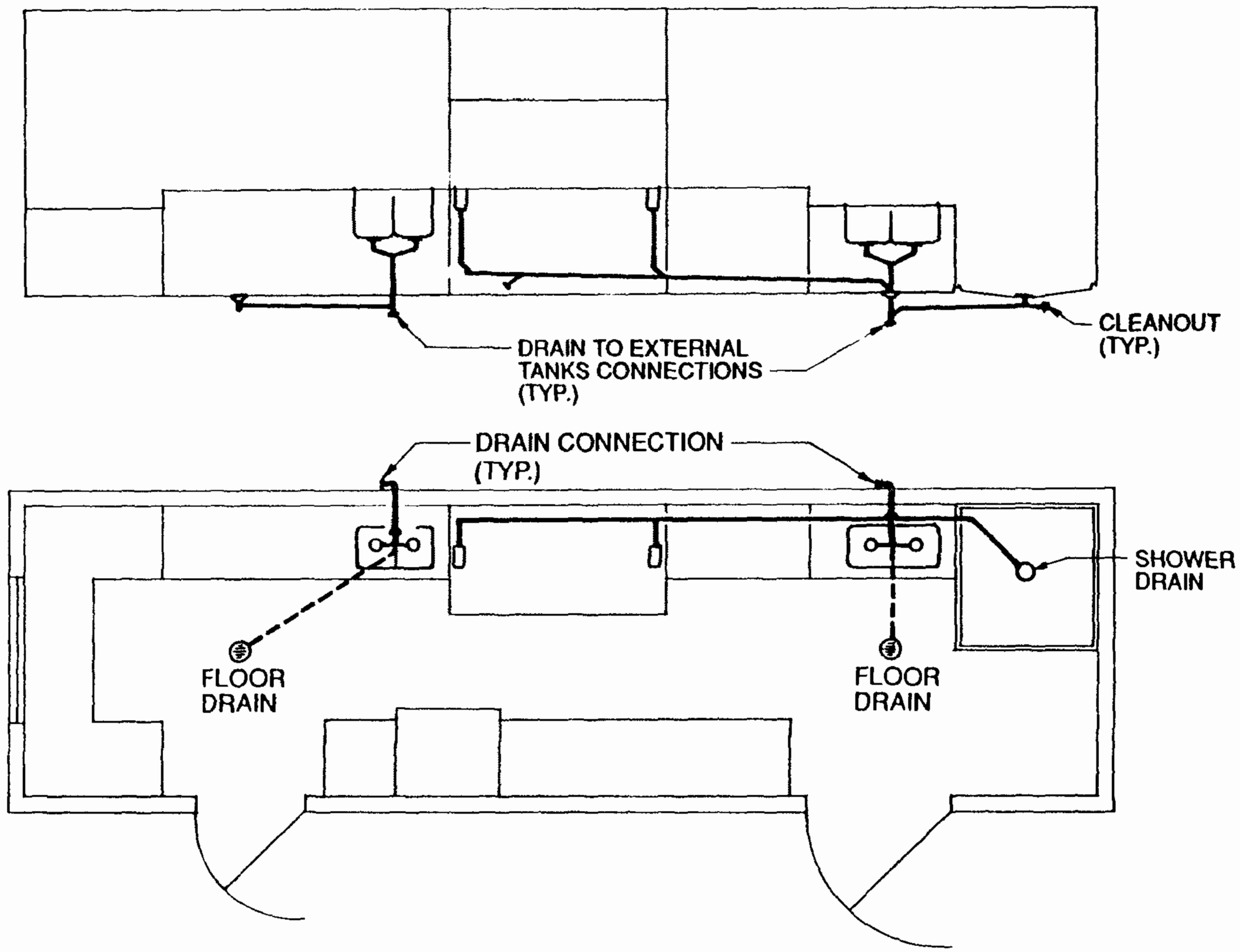


Figure 6

PLUMBING PLAN

U.S. EPA REGION II TREATABILITY TRAILER

1429



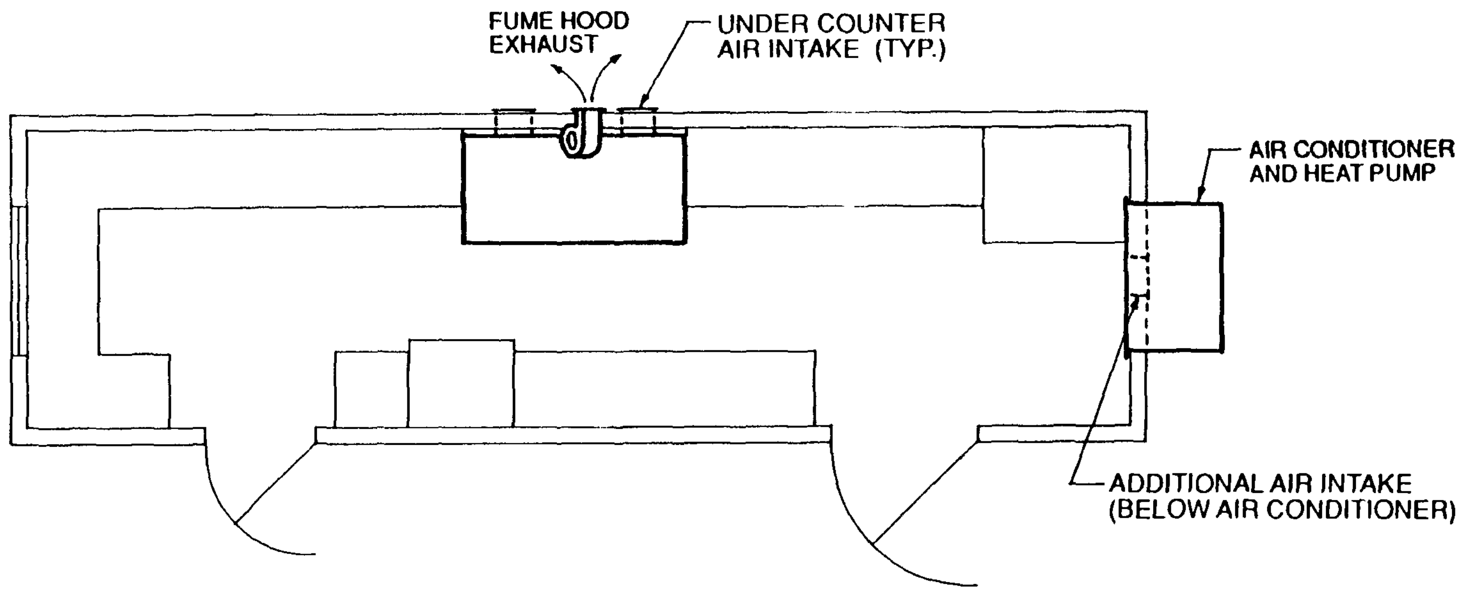
Scale: 1" = 5'

Figure 7

DRAINAGE PLAN AND SECTION

U.S. EPA REGION II TREATABILITY TRAILER

1430



NOTES:

1. AIR CONDITIONER AND HEAT PUMP - DUCTING TO BE INSTALLED TO DISTRIBUTE AIR THROUGHOUT INTERIOR OF TRAILER.
2. UNDER COUNTER AIR INTAKE - AIR INTAKE THROUGH LOUVERS AT BASE OF EXTERIOR SIDEWALLS, VENTED THROUGH BASE CABINETS INTO FUME HOOD.

Scale: 1" = 5'

Figure 8

VENTILATION PLAN

U.S. EPA REGION II TREATABILITY TRAILER

TABLE 1

PHYSICAL TEST METHODS - STABILIZATION/SOLIDIFICATION

Parameter	Test method	Applicability
Particle Size Analysis	ASTM D422-63	Particle size distribution influences the effectiveness of treatment
Moisture content	ASTM D2216-80	To determine water content
Permeability (falling head and and constant head)	USEPA method 9100 (SW-846)	To measure the rate which water will pass through a soil-like material.
Unconfined compressive strength of cohesive soils	ASTM D2166-85	To evaluate how cohesive soil-like materials behave under mechanical stress
Unconfined compressive strength of concrete specimens	ASTM D1633-84	To evaluate how cement-like materials behave under mechanical stress
Flexural strength	ASTM D1635-87	To evaluate the treated material's ability to withstand loads over a large area
Cone index	ASTM D3441-79	To evaluate the treated material's stability and bearing capacity

Reference: Stabilization/Solidification of CERCLA and RCRA Wastes, EPA.625/6-89/022

TABLE 2

CHEMICAL TEST METHODS - STABILIZATION/SOLIDIFICATION

Parameter	Test method	Applicability
pH	EPA method SW-9045	Leachability of hazardous constituents (e.g., metals) may be governed by the pH of the solid
Major Oxides	ASTM C114	Mineralogy of the stabilized/solidified waste may aid in interpretation of leach test results
Total Organic Carbon	Combustion method	Used to approximate the nonpurgeable organic carbon in wastes and treated solids
Oil and Grease	EPA method 413.2	Presence of oil and grease in the untreated wastes will influence the effectiveness of the treatment
Elemental Analysis	EPA method SW-846	Used to determine the fraction of metals leached to the total metals content of the untreated and stabilized/solidified wastes
Target Compound List Parameters	EPA methods 624, 625 or current CLP methodology	To quantify contaminants of concern.
Alkalinity	Titrometry	Alkalinity changes in leachates may be used to evaluate changes in stabilized/solidified waste form

Reference: Stabilization/Solidification of CERCLA and RCRA Wastes, EPA/625/6-89/022

TABLE 3

EQUIPMENT LIST FOR STABILIZATION/SOLIDIFICATION

Item	Quantity
1) Single-use cardboard cylinder molds	48
2) Single-use cylinder lids	250
3) Stripping tool	1
4) Beam molds	30
5) Cube molds	30
6) Laboratory mixer, 12-qt. capacity	1
7) Jar mill - 2 tier	1
8) Compaction vibrator	1
9) Cylinder carrier	1
10) Sample cart	1
11) Autogenous concrete curing container	1
12) Wet sieve tester	1
13) Round test sieves, U.S., standard sizes 2-inch, 1-inch, 3/8-inch-inch, No.4, No.10, No.20	6
14) Scalping apparatus, with sample trays	1
15) Scalping screens, U.S. standard sizes 2-inch, 1-inch, 3/8-inch-inch, No.4, No.10	5
16) Mechanical soil compactor (with molds)	1
17) Unconfined compression tester (with molds)	1

TABLE 4

RECOMMENDED ANALYSES FOR CONTAMINANT SCREENING

Analysis	Method
Volatile Organics	Headspace analysis by gas chromatograph or extraction followed by gas chromatograph analysis
Semi-Volatile Organics	Extraction followed by gas chromatograph analysis
Selected Metals	Colorimetric
pH	pH electrode
Turbidity	Light Scattering
Total Dissolved Solids (TDS)	Gravimetric
Total Suspended Solids (TSS)	Gravimetric
Alkalinity	Titration
Biological Oxygen Demand (BOD)	5-day incubation
Chemical Oxygen Demand (COD)	Digestion
Methlyene Blue Active Substances (MBAS)	Colorimetric
Hardness	Titration
Specific Ion Analyses	Specific ion electrodes

TABLE 5

EQUIPMENT FOR SCREENING-LEVEL ANALYSES

Portable Gas Chromatograph

COD Reactor

Spectrophotometer

Turbidity Meter

Zero Headspace Extractor

Moisture Determination Balance

Soil pH Kit

Benchtop pH/mV Meter with:
- Chloride Electrode
- Cyanide Electrode
- Oxygen Electrode
- Redox Electrode

BOD Incubator

TABLE 6

RECOMMENDED EQUIPMENT INVENTORY

General Laboratory Equipment

Item	Quantity
Gravity Convection Oven	1
Microscope with 35 mm Camera	1
Analytical Balance	1
Pressure Filter Apparatus	1
Heavy Duty Balance	1
Dual Memory Electronic Timer	1
Peristaltic Pump Kits	2
Submersible Pump with Level-Activated Switch	2
Heavy Duty Mixer	1
Flow Meters	4
Handheld Thermocouple with Type K Probe	1
Additional Type K probes	2
Temperature Recorder	1
Refrigerated Circulation Bath	1
Rotating Shaker Unit with Shaker Carrier	1
Vacuum Filter Pump	2
Tool Kit	1
Conductivity Meter with Probes	1
Stop Watch/Timer	2
Dessicator	2
Hot Plate	2
Magnetic Stir Plate	2

TABLE 6

RECOMMENDED EQUIPMENT INVENTORY
(continued)

General Laboratory Equipment

Item	Quantity
Compressed Gas Cylinder Holder	3
Pressure Regulators	
Nitrogen	1
Air	1
Jar Mill	1
55-Gallon Polyethylene Containers	2
Laboratory Racks	3
Micro Dispensers	2

Miscellaneous Laboratory Supplies

Beakers	Erlenmeyer flasks
Large glass containers	Watch glasses
Test tubes	
Graduated cylinders	Pipets
Volumetric flasks	Thermometers
Steel bowls	Steel pitcher
Buchner funnels	Filter flasks
Filter paper	Microfiltration filter holders
Membrane filter paper	
Measuring spoons	Spatulas
Tweezers	Tongs
Tubing	Bungi cord
Stirring rods	pH paper
Pipet micro tips	Metal weighing dishes
Magnetic stirrers	Squirt bottles
Scrub brushes	

TABLE 6

RECOMMENDED EQUIPMENT INVENTORY
(continued)

Analytical Equipment

Item	Quantity
Portable Gas Chromatograph with Adapter	1
COD Reactor	1
Spectrophotometer	1
Turbidity Meter	1
Zero Headspace Extractor	1
Moisture Determination Balance	1
Soil pH Kit	1
Benchtop pH Meter with:	1
Chloride Electrode	1
Cyanide Electrode	1
Oxygen Electrode	1
Redox Electrode	1
BOD Incubator	1

TABLE 6

RECOMMENDED EQUIPMENT INVENTORY
(continued)

Equipment for Soil Testing and Sample Preparation

Item	Quantity
Wet Sieve Tester	1
Sieve Mesh Protector	
Rubber Gaskets & Filter Paper	
Round U.S. Standard Size Test Sieves	
Sizes: 3-inch, 2-inch, 1 1/2-inch, 1-inch, 3/4-inch, 3/8-inch, No. 4	
8-inch diameter	7
12-inch diameter	7
Sizes: No. 10, No. 20, No. 40 No. 60	
8-inch diameter	4
12-inch diameter	4
No. 140	
8-inch diameter	1
12-inch diameter	1
No. 200	
8-inch diameter	1
12-inch diameter	1
Hydrometers	2
Portable Concrete Mixer	1
Scalping Apparatus, with Sample Trays	1
Scalping Screens, U.S. Standard Sizes 2-inch, 1-inch, 3/8-inch, No.4, No.10	5
Unconfined Compression Apparatus	1
Mechanical Soil Compactor	1
Compactor Molds:	
4-inch ID Split	1
6-inch ID Split	1

TABLE 6

RECOMMENDED EQUIPMENT INVENTORY
(continued)

Filtration Apparatus

Item	Quantity
Centrifuge	1
Filter Leaf Apparatus	1
Plate and Frame Filter press	1
Air-Driven Diaphragm Pump	1
Additional Filters and Screens	

Test Equipment For Soils Treatment Technologies

Item	Quantity
Muffle Furnace	1
Tube Furnace	1
Combustion Tubes	6
Distillation Glassware Kits	6
Single Use Cardboard Cylinder Molds with Lids	48
Stripping Tools	1
Beam Molds	30
Cube Molds	30
Laboratory Mixer	1
Compaction Vibrator	1
Cylinder Carrier	1
Autogenous Concrete Curing Container	1

TABLE 6

RECOMMENDED EQUIPMENT INVENTORY
(continued)

Test Equipment For Water Treatment Technologies

Item	Quantity
Bubble column - 6-inch diameter, 9-ft height; fine bubble diffuser, flange in center of column, bottom and middle sample port, drain (custom-made)	1
Column test assembly - 4-inch diameter, 6-ft height, connected in series, connector piping, valves, sample ports, pressure gauges, flow meter	1
Variable-speed centrifugal pumps	2
Jar test apparatus - six paddle stirrer	1
DAF bench-scale test kit - includes pressurized tank, flotation receiver, air release valve, and other fittings as needed	1

Summary of Issues Affecting Remedial/Removal Incineration Projects

(Author(s) and Address(es) at end of paper)

INTRODUCTION

Incineration is a very popular method of remediating superfund sites. This is because it is a proven technology that is capable of decontaminating a wide variety of waste. The residues from incineration can often be disposed of without further treatment whereas residues from many other treatment technologies require incineration prior to final disposal.

As with other remedies, implementing incineration is not always straightforward. Identifying Applicable or Relevant and Appropriate Requirements (ARARs) and complying with them is difficult. Incineration is also a costly remediation method. Further, there is often opposition to the use of incineration because of the belief that incineration emissions are harmful to the environment and the health of the surrounding community. Because of the cost and controversy surrounding incineration, a decision to use it at a site is usually subject to challenge.

To assist the Remedial Project Manager (RPM) and On-Scene Coordinator (OSC) in responding to these challenges and in directing the progress of remedial and removal incineration projects, the Engineering Forum and EPA's Risk Reduction Engineering Laboratory (RREL), have prepared a summary report entitled Issues Affecting the Applicability and Success of Remedial/Removal Incineration Projects.

The purpose of this summary is not to provide an encyclopedic account of all relevant incineration information in one volume. That would be difficult, if not impossible, and would soon become obsolete as the state-of-the-art advances. Rather, this summary is intended to alert the RPM/OSC to issues affecting the successful implementation of incineration projects, and to alert them to both written and human resources that can help to address these issues. The remainder of this paper summarizes the content and key points of the summary report.

BACKGROUND

Incineration has been chosen as the remedial method of choice in 32% of the Records of Decision through FY89.(1) Most of these sites contain soil contaminated with both organics and metals. Incineration has been used for a number of years to treat a variety of waste including contaminated soils. EPA sponsored tests over the last ten years indicate that properly operated incinerators can successfully decontaminate waste without producing highly contaminated residual streams. (2) A large body of knowledge exists regarding how to successfully design and operate an incinerator.

To successfully implement an incineration remedy, it is important to access this body of knowledge. To help provide this access, the Engineering Forum and EPA's RREL developed a Summary for the RPM/OSC concerning issues affecting the successful implementation of remedial/removal incineration projects. This document provides a summary of incineration hardware, design and maintenance practice, ARARs and other compliance issues, vendors, and lists of state, regional, headquarters and other technical experts capable of providing assistance in a number of relevant areas. This paper summarizes the information contained in the summary report.

TYPICAL INCINERATION CONFIGURATION/OPERATION

A typical incineration system includes not just the combustion device, but also the processes necessary to deliver feed, fuel and air to the incinerator, remove ash from the kiln and remove residual hydrocarbons, particulate and acid gasses from the exhaust. Multiple chemical processes are used in an incineration facility. The operation of each of these systems needs to be integrated and controlled so that the entire system runs most efficiently. For this to happen, the entire incineration system must be controlled by a series of process controllers, thus making the entire system sophisticated and expensive.

The figure on the next page is a block diagram of a typical incineration facility. Waste is first processed to remove any large-scale debris such as tree limbs and animal carcasses and to blend it with wastes having different heating values, if appropriate. Feed systems introduce the blended waste into the incinerator and usually consist of combinations of conveyors, weigh hoppers, ram feeders and nozzles (for liquid waste).

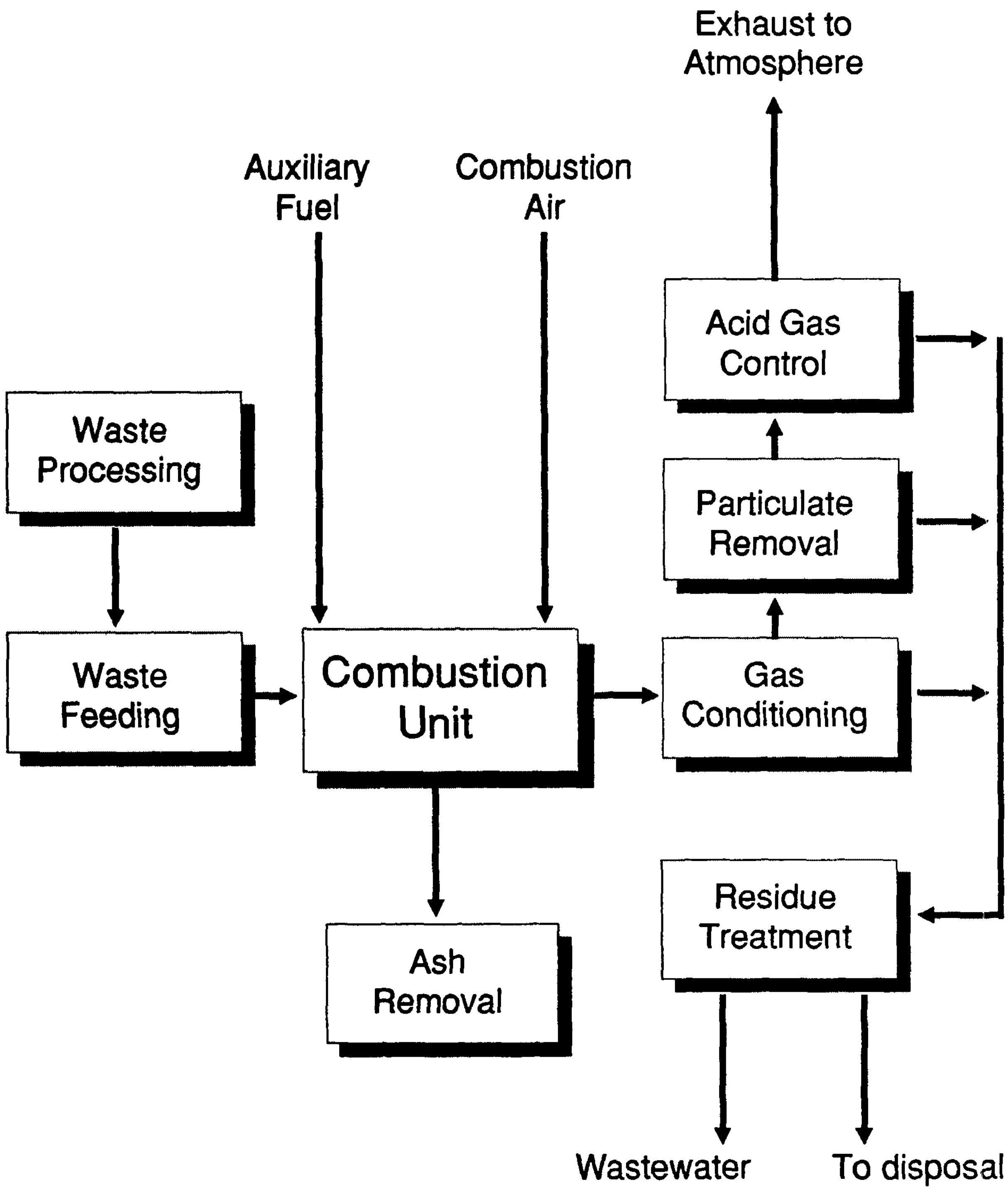
The typical incinerator used at Superfund sites is an 8 to 100 Million BTU/hr rotary kiln operating at 75-200% excess air.(3) Since the waste treated at Superfund sites typically has little heating value (<200 BTU/lb), auxiliary fuel is used to provide the heat needed to volatilize and incinerate the organic contaminants of the waste. Typically, incinerators operate at a gas temperature of at least 2000 ^{o}F. If this temperature is uniformly maintained throughout the rotary kiln and afterburner, emissions of unburned hydrocarbons should be minimized.

Exhaust gas from the incinerator is treated using a similar sized afterburner to complete the combustion of the organic contaminants volatilized from the waste. A venturi scrubber is commonly used to control particulate emissions. Caustic scrubbing in a packed tower is used to control the emissions of acid gasses. Blowdown from these scrubber operations and ash from the incinerator are two waste streams generated by incineration which must be disposed of as hazardous waste and may require additional treatment.
Tables 1 and 2 summarize design and operating characteristics of hazardous waste incinerators.(3)

Regulations call for the incineration process to be monitored closely and for feed to the incinerator to be automatically shut off when conditions indicative of a process upset are observed. Much of the process monitoring occurs at the exhaust stack since the composition of the exhaust gasses is indicative of combustion conditions in the incinerator. In addition, the levels of some of the exhaust gas constituents are limited by some of the ARARs. Table 3 lists some of the continuous emission monitors routinely used and the expected range of concentrations of exhaust gas constituents.(3)

Some of the indicators typically used to trigger a cessation of feed include carbon monoxide in the exhaust gas, low temperature in either the rotary kiln or afterburner, low burner pressure, flame loss and many others. A comprehensive list of parameters which should trigger an automatic cessation of feed is listed in Table 4.(3)

Incineration System Concept Flow Diagram



Source: U.S. Environmental Protection Agency 1988b.

TABLE 1. DESIGN AND OPERATING CHARACTERISTICS OF A TYPICAL INCINERATION SYSTEM[a]

Parameter	Typical values
Rotary kiln	
Operating temperature, °F	
Ashing kiln	1200 to 1800
Slagging kiln	2200 to 2600
Types of waste	
Ashing kiln	•Low Btu waste (e.g., contaminated soils) < 5000 Btu/lb •High Btu waste >5000 Btu/lb
Slagging kiln	•High Btu waste >5000 Btu/lb •Moderate moisture and halogen content •Both drums and drummed wastes
Solids residence time, min	
Ashing kiln	30 to 60
Slagging kiln	60 to 100
Gas residence time, s	1 to 2
Gas velocity through kiln, ft/s	15 to 20
Heat release levels, Btu/ft^3 per h	25,000 to 40,000
Small kiln, million Btu/h	8 to 35
Large kiln, million Btu/h	35 to 100
Kiln loading, % kiln volume	
Ashing kiln	7.5 to 15
Slagging kiln	4 to 6
Kiln operating pressure, in.H_2O	-0.5 to -2.0
Excess air, %	75 to 200
Liquid injection unit	
Operating temperature, °F	1800 to 3100
Residence time, s	Milliseconds to 2.5
Excess air, %	10 to 60
Waste heating value, BTU/lb	≤ 4500
Secondary combustor (afterburner)	
Residence time, s	2
Operating temperature, °F	2200 typical
TSCA wastes	>2250
RCRA wastes	1600 to 2800
Excess air, %	10 to 60

[a] Sources: Tillman, Rossi, and Vick 1990; Schaefer and Albert 1989.

TABLE 2. TYPICAL DESIGN PARAMETERS FOR AIR POLLUTION CONTROL EQUIPMENT ON HAZARDOUS WASTE INCINERATORS[a]

Air pollution control equipment	Typical design parameters
Particulate	
Electrostatic precipitators	SCA = 400-500 ft^2/1000 acfm Gas velocity = 0.2 ft/s
Fabric filters	Pulse jet A/C = 3-4:1 Reverse air A/C = 1.5-2:1
Venturi scrubbers	ΔP = 40-70 in. W.C. L/G = 8-15 gal/1000 acfm
Acid gases	
Packed towers	Superficial velocity = 6-10 ft/s Packing depth = 6-10 ft L/G = 20-40 gal/100 acfm Caustic scrubbing medium, maintaining pH = 6.5 Stoichiometric ratio = 1.05
Spray dryers	Low temperature: Retention time 15-20 s Outlet temperature 250-450°F Stoichiometric ratio (lime) = 2-4

SCA = specific collection area

A/C = air-to-cloth ratio in units of ft/min

L/G = liquid-to-gas ratio

[a] Source: Buonicore 1990.

TABLE 3. SUMMARY OF CONTINUOUS EMISSION MONITORS[a]

Pollutant	Monitor type	Expected concentration range	Available range[b]	Typical value
O_2	Paramagnetic	3-14%	0-25%	8%
CO_2	NDIR[c]	2-14%	0-21%	8%
CO	NDIR	0-100 ppm	0-5000 ppm	40 ppm
NO_x	Chemiluminescent	0-4000 ppm	0-10000 ppm	200 ppm
SO_2	Flame photometry	0-4000 ppm	0-5000 ppm	Varies by waste
Organic compounds (THC)	FID	0-20 ppm	0-1000 ppm	<20 ppm

[a] Source: Oppelt 1987.

[b] For available instruments only. Higher ranges are possible through dilution.

[c] Nondispersion infrared.

TABLE 4. TYPICAL AUTOMATIC WASTE FEED SHUT OFF (AWFSO) PARAMETERS[a]

Parameter (example value)	Purpose of AWFSO: Excess emissions	Worker safety	Equipment protection
High CO in stack (100 ppm)*	X		
Low chamber temperature* (1400°F for rotary kiln, 1700°F for SCC)	X		
High combustion gas flow (Varies by size)	X		
Low pH of scrubber water (4) (e.g. not less than 6.5)	X		
Low scrubber water flow (Varies by size)	X		X
Low scrubber pressure drop (20 inches W.G. for venturi)	X		X
High scrubber temperature (220°F)			X
Low sump levels (variable)			X
High chamber pressure (positive)	X	X	
High chamber temperature (2000°F for rotary kiln, 2600°F for SCC)	X	X	X
Excessive fan vibration	X	X	X
Low burner air pressure (1 psig)	X		
Low burner fuel pressure (3.0 psig for natural gas)	X		
Burner flame loss		X	X
Low oxygen in stack (3 percent)*	X		
Loss of atomizing media	X		
High stack SO_2*	X		
High waste feed flow	X		
High Opacity >5%	X		

* Rolling averages of these parameters can sometimes be used. (Leonard, Paul comments 10/23/90)

[a] Source: Oppelt 1987.

ARARs

The requirement to achieve **99.99%** Destruction and Removal Efficiency (DRE) is the performance standard which is most often associated with incineration. Although this is an important regulation, it is certainly not the only one which must be complied with. Table 5 is a summary of typical incineration ARARs.(3) This list is not exhaustive. Other ARARs may apply depending upon the process being used and the location of the site. A process that has a water discharge stream, for example, will have to comply with the Clean Water Act and other ARARs pertaining to water discharge. A process which exhausts a gas stream heavily laden with NO_x may have a very difficult time complying with air ARARs in urban areas in Southern California, for example, but may have no trouble at all in more rural areas of the country.

Compliance with the Clean Air Act and the Toxic Substances Control Act typically require permits. On-site remedial/removal actions undertaken at Superfund sites do not require permits. However, all such activities must comply with the substantive requirements of those permits. Determining what those requirements are necessitates close coordination with the appropriate regional, state and local authorities.

In addition to Federal laws, State and Local laws may also constitute ARARs and must be complied with. The CERCLA Compliance With Other Laws Manual (EPA 540/G-89-009) provides a summary of other ARARs which may apply to incineration projects.

FACTORS AFFECTING THE PERFORMANCE OF INCINERATORS

When properly designed, incineration should be able to decontaminate waste to appropriate levels while complying with all ARARs. Since it is impossible to determine with certainty whether ARARs will be met under all possible sets of circumstances, it is necessary to use certain guidelines pertaining to characteristics of the system which most affect the performance of incineration systems.

Of the incineration parameters which most affect performance, compatibility of the feed with the feed system is probably the most important. The feed system must be reliable and capable of continuous operation even when the feed varies widely in size, density, moisture content, and other properties. The feed system must also be capable of reducing the size of the incoming feed if necessary and it must be reliable. A feed system which constantly breaks down will adversely affect the economics of the entire system and will significantly lengthen the time required to complete the remedial/removal action. Other operating parameters which affect performance are listed in Table 6.(3)

Of the waste feed properties which most affect performance, the H:Cl ratio of the key waste components most affects the tendency of the waste stream to form undesirable byproducts during the incineration process. While these compounds are not always formed, other stable byproducts can be formed and emitted even as the original compounds are being oxidized in the incinerator. As key waste components become more chlorinated (i.e as the H:Cl ratio decreases), the byproducts formed become more stable. This means that they are less likely to

TABLE 5. POTENTIAL INCINERATION ARARS[a]

Prerequisite for Applicability	Requirement	Citation
RCRA		
RCRA hazardous waste	Analyze the waste feed to determine physical and chemical composition limits.	40 CFR 264.341
	Dispose of all hazardous waste and residues, including ash, scrubber water, and scrubber sludge, according to applicable requirements.	40 CFR 264.351
	(Note: No further requirements for wastes that are listed as hazardous solely because they exhibit one or more of the characteristics of ignitability, corrosivity, reactivity or because they fail the TCLP leaching test and a waste analysis demonstrates no Appendix VIII constituent is present that might reasonably be expected to be present.) Such wastes may also be exempted if Appendix VIII constituents are not present at significant levels.	40 CFR 264.340
	Performance standards:	40 CFR 264.343
	Achieve a destruction and removal efficiency (DRE) of 99.99 percent for each principal organic hazardous constituent designated in the waste feed and 99.9999 percent for dioxins and PCB contaminated liquids.	
	Reduce hydrogen chloride emissions to 1.8 kg/hr or to 1 percent of the HCl in the stack gas before entering any pollution control device.	
	No release of particulates >180 mg/dscm (0.08 gr/dscf) corrected to 7% Oxygen.	
	Emissions of CO must be <100 ppm and emissions of THC must be <20 ppm corrected to 7% Oxygen.	RCRA Omnibus Authority
	Metals emissions less than those established using the tiered approach outlined in the document "Guidance on Metal and HCl Emissions for Hazardous Waste Incinerators" August 1989.	
	Trial Burn Requirements	40 CFR 270.62
	All residues must meet the RCRA Land Disposal Restrictions	40 CFR 268
	Control fugitive emissions by:	40 CFR 264.345
	Keeping combustion zone sealed; or Maintaining combustion-zone pressure lower than atmospheric pressure.	
	Use automatic cutoff system to stop waste feed when operating conditions deviate or exceed established limits.	40 CFR 264.345

(continued)

TABLE 4-1 (continued)

Prerequisite for Applicability	Requirement	Citation
	Use automatic cutoff system to stop waste feed when operating conditions deviate or exceed established limits.	40 CFR 264.345
	Monitor various parameters during operation, including combustion temperature, waste feed rate, indication of combustion gas velocity, and carbon monoxide in stack gas.	40 CFR 264.347
<u>CAA</u>		
Incinerator burning solid waste, more than 50% of which is municipal-type waste, for the purpose of reducing waste volume by removing combustible matter.	Particulate emissions shall be less than 180 mg/dscm (0.08 g/dscf) corrected to 12 percent carbon dioxide.	40 CFR 60.52

(continued)

TABLE 4-1 (continued)

Prerequisite for Applicability	Requirement	Citation
CAA (continued)		
Air emissions	Remediation activities must comply with the National Ambient Air Quality Standards (NAAQS). Compliance should be determined in cooperation with the appropriate state government agency. An air permit from the state may be required.	40 CFR 50
TSCA	Performance standards:	40 CFR 761.70
Liquid PCBs at concentration of 50 ppm or greater.	2-second residence time at 1200°C (± 100°C) and 3 percent excess oxygen in stack gas; or	
	1.5-second residence time at 1600°C and 2 percent excess oxygen in stack gas.	
	Combustion efficiency of at least 99.90 percent.	
	DRE>99.9999%	
	Rate and quantity of PCBs fed to the combustion system shall be measured and recorded at regular intervals of no longer than 15 minutes.	40 CFR 761.70
	Temperature of incineration shall be continuously measured and recorded.	40 CFR 761.70
	Flow of PCBs to incinerator must stop automatically whenever the combustion temperature drops below specified temperature.	40 CFR 761.70

(continued)

TABLE 4-1 (continued)

Prerequisite for Applicability	Requirement	Citation
<u>TSCA</u> (continued)		
	Monitoring must occur:	40 CFR 761.70
	When the incinerator is first used or modified; monitoring must measure for O_2, CO, CO_2, oxides of nitrogen, HCl, RCl, PCBs, total particulate matter.	
	Whenever PCBs are being incinerated, the O_2 and CO levels must be continuously checked; CO_2 must be periodically checked.	
	Water scrubbers must be used for HCl control.	40 CFR 761.70
Non-liquid PCBs, PCB articles, PCB equipment, and PCB containers at concentrations of 50 ppm or greater.	Mass air emissions from the incinerator shall be no greater than 0.001g PCB per kg of the PCBs entering the incinerator (99.9999 percent DRE).	40 CFR 761.70
	Requirements as listed for liquid PCB's.	40 CFR 761.70
<u>FIFRA</u>	Performance standards:	
Organic pesticides, except organic mercury, lead, cadmium, and arsenic (recommended).	2-second residence time at 1000°C (or equivalent that will assure complete destruction.)	40 CFR 165.8 40 CFR 165.1
	Meet requirements of CAA relating to gaseous emissions.	40 CFR 165.8
	Dispose of liquids, sludges, or solid residues in accordance with applicable Federal, State, and local pollution control requirements.	40 CFR 165.8
Metallo-organic pesticides, except mercury, lead, cadmium, or arsenic compounds (recommended).	Chemically or physically treat pesticides to recover heavy metals; incinerate in same manner as organic pesticides.	40 CFR 165.8
Combustible containers that formerly held organic or metallo-organic pesticides, except organic mercury, lead, arsenic, and cadmium (recommended).	Incinerate in same manner as organic pesticides.	40 CFR 165.9
<u>OSHA</u>		
Remediation activities	All remediation activities must comply with the policies and programs established for worker safety.	29 CFR 1910 29 CFR 1926

[a] Source: U.S. Environmental Protection Agency 1988a and 1989a.

[b] The regulations cited herein may contain special provisions or variances applicable to the specific site under remediation. In all circumstances the actual regulations should be consulted before any decisions are formulated.

TABLE 6. EXAMPLE OPERATING PARAMETERS AND HOW THEY AFFECT PERFORMANCE[a]

Operating parameter	Effect
Temperature	Combustion reactions rates of burning are faster at high temperatures until the rate is limited by mixing. High temperatures can also elevate NO_x emissions.
Combustion gas flow rate	For a fixed chamber volume, the waste constituents remain in the chamber for a shorter time (have a lower residence time) as the flow rate increases. As the combustion gas flow rate increases, gas velocity through the chamber increases. This can result in increased entrainment of solid material (fly ash) and emission of particulates.
Waste feed rate and heat content	As waste feed rate decreases, the heat release in the combustion chamber will decrease and temperature may drop. Waste heat content can affect combustion temperature. Insufficient heat content can result in the need for auxiliary fuel which will adversely affect the economics of the process. Wide variations in heating value of the waste can cause puffing (positive pressure surges) in rotary kilns.
Moisture Content of the Waste	Moisture decreases the heat content of the waste and, as a result, reduces the combustion temperature and efficiency when high moisture waste is burned.
Air input rate	Air supplies oxygen for the combustion reactions. A minimum is needed to achieve complete combustion; however, too much air will lower the temperature (because the air must be heated) and quench combustion reactions due to excessive cooling. The additional air will increase combustion gas flow rate, which then lowers the residence times. Increased air input can increase combustion efficiency by increasing the amount of oxygen available to oxidize organic contamination.
Waste atomization	Atomizing liquid waste into smaller droplets will increase the effectiveness of fuel/air mixing and the burning rate. Waste feed and atomizing fluid (air or steam) flow rates and pressures affect atomization. Suboptimal waste feed and atomizing fluid flows will result in less efficient atomization resulting in the production of larger fuel/waste droplets.
Feed System	Consistent, reliable delivery of waste feed into the incinerator is critical to the efficient operation of an incinerator. The design of appropriate feed systems can be difficult for inconsistent or difficult feed streams.
Mixing/Turbulence	A burner must be selected which induces adequate turbulence into the combustion air/fuel/waste mixture. This promotes good mixing of air and fuel which leads to efficient combustion.

[a] Source: ASME 1988.

be destroyed in the incinerator or afterburner and are more likely to be emitted. Under oxygen starved conditions, the tendency to form byproducts increases. It should be noted that even though combustion byproducts are routinely formed, dioxins and furans have rarely been observed in emissions from hazardous waste incinerators. EPA has sampled a number of incinerators to measure performance relative to the RCRA incineration regulations. As part of that effort samples were taken to determine whether dioxins and furans were formed as byproducts of the incineration process. None were found despite extensive sampling.(2)

Despite the fact that dioxins and furans are seldom formed as byproducts of the hazardous waste incineration process, other byproducts can be formed if incineration performance is suboptimal. Certain failure modes can lead to the incomplete combustion of organic contaminants and, as a result, exacerbate the formation of these combustion byproducts. The byproducts which are formed under these conditions depend largely on the chemicals which are being incinerated. Chloroform, for example, has been shown to form nine different regularly occurring byproducts. Eight of these are short chain (C-1 and C-2) chlorinated hydrocarbons. The other one is hexachlorobenzene. A listing of compounds and the byproducts usually observed from their combustion is included in Table 7. (3)

INCINERATION EXPERTS, VENDORS, AND RODS

The OSC/RPM responsible for directing an incineration project needs access to a wide variety of expertise. Each State and Regional office has incineration experts who are available to advise OSCs/RPMs on incineration issues. These technical specialists are located in each Regional office and are often involved in RCRA incineration permit review. They should be consulted on every incineration project since they can be of great help in providing needed technical support. A list of these individuals is provided in the summary report.

A survey of Superfund related incineration activity around the nation reveals some interesting facts. As of 1989, incineration RODs had been written for sites throughout the nation. Region V had the most incineration RODs (eighteen) while Region IX had the fewest (one). In general, the western United States had fewer incineration RODs than the Eastern and Midwestern parts of the country. The agricultural sections of the country (roughly comprised of Regions 7 and 8) also had relatively few incineration RODs.

If the volume of material requiring incineration is too small to justify the expense of bringing an incinerator on-site, it may be practical to ship the waste to an off-site commercial facility for disposal. The summary report lists eight off-site commercial facilities that may be used for disposal of wastes. Any use of these facilities must comply with the "off-site" policy (OSWER Directive 9330.2-1). Although Region 5 had the most incineration RODs, the largest number of off-site commercial incineration facilities (6) are located in the Southern U.S., specifically in Region 6. Region 5 does, however, have three off-site commercial incineration facilities.

Vendors of mobile/transportable incinerators are located in the regions with the most incineration RODs, with the exception of Region 9. In California, there are 2 mobile incinerator vendors while Region 9 only has 1 incineration ROD. Of the eleven mobile/transportable incinerators identified in the report,

TABLE 7. REACTION PRODUCTS OBSERVED FROM THERMAL DECOMPOSITION STUDIES[a]

Parent (POHC)	Product (PIC)	Condition
Carbon Tetrachloride	Tetrachloroethene	Air atmosphere, t_r* = 2.0 s
	Hexachloroethane	
	Hexachlorobutadiene	
Pentachlorobenzene	Hexachlorobenzene	Air atmosphere, t_r = 2.0 s
Chloroform	CCl_4	o = 0.67, t_r = 2.0 s
	1,2-$C_2H_2Cl_2$	
	C_2HCl_3	
	C_2Cl_4	
	C_2HCl_5	
	C_2Cl_2	
	$C_2H_2Cl_4$	
	C_3Cl_4	
	C_4Cl_6	
	C_6Cl_6	
Chloroform	Carbon Tetrachloride	o=0.76 and Nitrogen
	Trichloroethene	atmospheres
	Pentachloroethane	
	Dichloroethyne	
	Tetrachloroethene	
	Tetrachloropropyne	
	1,1,2,4-Tetrachloro-1-buten-3-yne	
	Hexachlorobutadiene	
Mixture of		
CCl_4 53% (mole)	CCl_4	Pyrolytic, t_r = 2.0 s
$CHCl_3$ 33%	$CHCl_3$	
CH_2Cl_2 7%	CH_2Cl_2	
CH_3Cl 7%	CH_3Cl	
	C_2Cl_2	
	1,1-$C_2H_2Cl_2$	
	C_2HCl_3	
	C_2Cl_4	
	C_2Cl_6	
	C_3Cl_4	
	C_4Cl_4	
	C_4Cl_6	
	C_6Cl_6	
	C_8Cl_8	

a This table was excerpted from a table appearing in a UDRI report on PIC minimization entitled Minimization and Control of Hazardous Combustion Byproducts Final Report and Project Summary prepared for U.S.E.P.A under cooperative agreement CR_813938-01-0 summarizing the results of flow reactor studies conducted at the University of Dayton Research Institute. The complete table can be found in the above listed reference.

seven are rotary kilns, two are infrared incinerators, one is a circulating fluidized bed and one is a conventional fluidized bed. The average size is 30 Million BTU/hr with an average processing cost of $350/ton.(3)

The distribution of on-site public and private sector thermal remediation projects is slightly different than that for the distribution of RODs with most of the activity being located in the Southeastern U.S. (Region 4) rather than the Midwest (Region 5) and the Northeast (Region 2). There is significant on-site thermal remediation activity in California (six sites) despite the fact that there is only one incineration ROD in Region 9. (3)

Of the fifty-one on-site thermal remediation projects identified in the summary report, 53% are finished, 39% are contracted and only 8% are currently ongoing. The average site has 27,000 tons of contaminated material and is being cleaned up with a 34 Million BTU/hr incinerator. The incinerators used at these sites are provided by twenty different vendors with no vendor providing incinerators for more than 12 % of the projects listed. Most of the incinerators (43%) were rotary kilns. The second most frequently used technology was low temperature direct desorption. This was used at 29% of the sites listed. Other technologies used were infrared incineration, high temperature direct and indirect desorption and circulating fluidized bed incineration.

CONCLUSIONS

Because incineration is a controversial and expensive remedial method, completing an incineration project is difficult unless the RPM/OSC has access to the most up-to-date information available. Fortunately, incineration has been used widely and a large body of knowledge about the proper implementation of this technology exists. Access to this information is easiest through consultation with Regional and State incineration experts and with other RPMs/OSCs who have recently or are currently implementing incineration projects. In addition, current literature on incineration, especially ORD publications and OSWER guidance documents can provide in-depth information on selected topics. The summary report summarized in this paper and prepared by the Engineering Forum and the Risk Reduction Engineering Laboratory will help OSCs and RPMs to make effective use of this large body of incineration experience.

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REMEDIATING TCE-CONTAMINATED SOILS: A CASE STUDY OF A FOCUSED RI/FS AND VACUUM EXTRACTION TREATABILITY STUDY

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ABSTRACT

A focused remedial investigation/feasibility study (RI/FS) was conducted for EPA Region III to determine the extent of trichloroethene (TCE) contamination in soils at a former sanitary landfill site and to evaluate alternatives for soil remediation. The investigation revealed high concentrations of TCE (up to 330,000 µg/kg) trapped in a 50-foot-deep vadose zone, and high concentrations of TCE and acetone (up to 840,000 µg/kg) in the saturated soils above bedrock. The overburden soils in the vicinity of the spill areas are between 40 to more than 100 feet deep and were classified as predominately silt. Due to the depth of contamination and potential problems of controlling volatile organic compound (VOC) emissions, a combination of capping and in-situ vacuum extraction was considered to be the most promising alternative for this site.

To evaluate the effectiveness, implementability, and cost of vacuum extraction, a pilot-scale treatability study was performed at the site. Physical and chemical data were collected over a two-week period that allowed for determination

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of the radius of influence of vacuum pressure in various soil units, an evaluation of the effects of key operating parameters and system designs on performance, and an estimation of the time required to remediate the contaminated soils. Subsurface air flow and contaminant removal models were calibrated to the pilot-scale data and used to predict the performance of various full-scale system configurations that included nested vacuum extraction wells, surface capping, and air injection wells. Preliminary costs and designs for full-scale remediation systems were developed.

INTRODUCTION

In 1967, the Heleva Landfill Site began operations as a sanitary landfill, accepting between 250 and 350 tons per day of general mixed refuse from the Allentown, Pennsylvania, area. In addition to the municipal wastes, industrial wastes consisting of chlorinated organic solvents were sent to the site and improperly disposed by dumping the liquids onto the ground in one or more "spill areas." The organic solvents appeared in a neighboring town's water supply wells, alerting citizens and regulatory agencies to a potential public health threat. The landfill was closed in 1981 under consent order because of operational deficiencies, and in 1982 was placed on the National Priorities List (NPL) for hazardous waste sites in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

A focused remedial investigation/feasibility study (RI/FS) was initiated in 1988 to determine the location of the spill area(s) and to evaluate remedial alternatives for the soil that continues to be a source of contamination to the bedrock aquifer. A total of 42 soil borings were drilled during the subsurface investigation to classify soils and obtain soil and water samples for laboratory analyses. The suspected locations of the spill areas are depicted in Figure 1. Quick-turnaround time chemical analysis of target compounds allowed the field team to focus the placement of the soil borings in the potential spill areas, limiting the total number of borings required to define the extent of contamination. The investigation revealed high concentrations of trichloroethene (TCE) trapped in a 50-foot-deep vadose zone, and high concentrations of TCE and acetone in the saturated soils above bedrock. The soils were classified as predominately silt interspersed with sandy silt and lean clay. The depth of overburden soils in the vicinity of the spill areas range between 40 to more than 100 feet. It is estimated that approximately 392,000 cubic yards of soil are contaminated above a TCE remediation goal of 30 $\mu g/kg$.

A number of technologies were considered during the development of remedial alternatives, including capping; excavation with either thermal, fluid extraction, or biological treatment; and in-situ vapor recovery processes such as vacuum extraction and

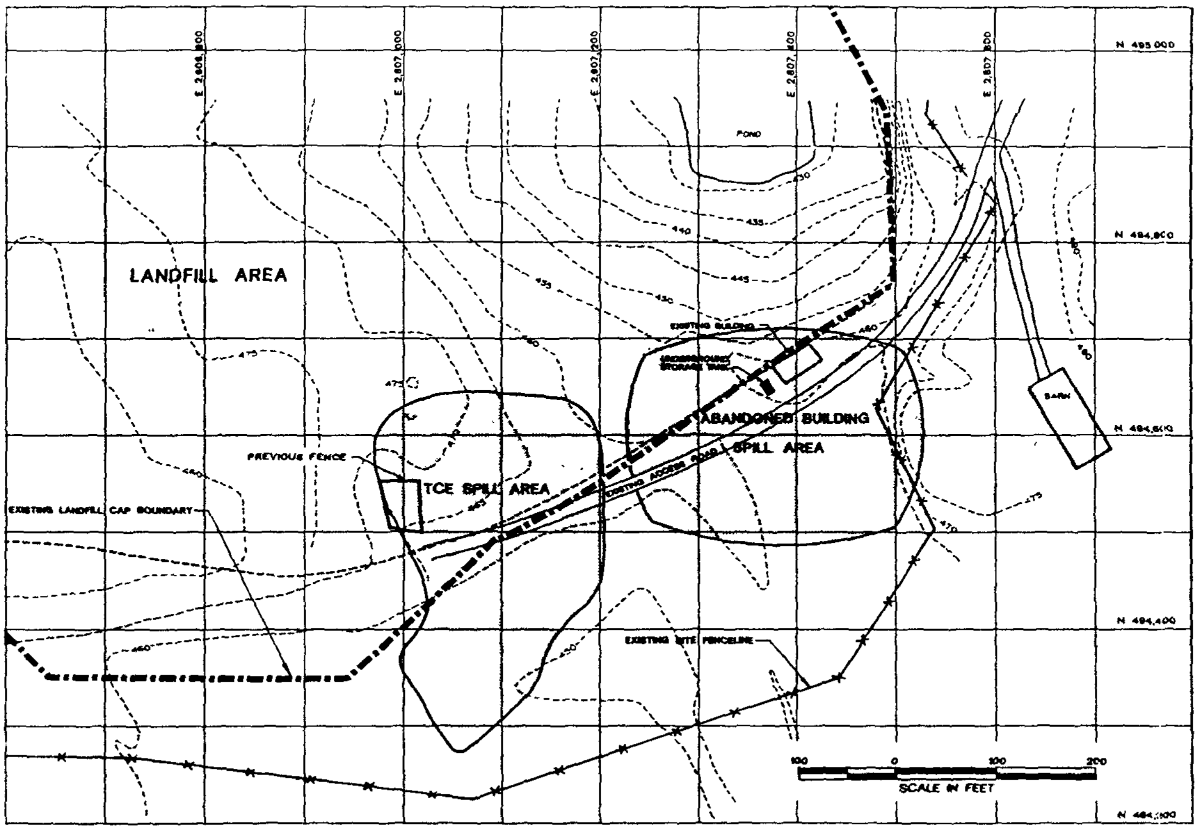

Figure 1. Map of study area showing surface features and suspected boundaries of solvent spill areas.

steam stripping. Due to the depth of contaminated soil and potential problems of controlling volatile organic compound (VOC) emissions during excavation and treatment, capping and in-situ vacuum extraction were considered to be the most promising technologies for the spill areas. In response to a previous Record of Decision (ROD) for the site, a synthetic membrane cap conforming to Resource Conservation and Recovery Act (RCRA) standards was constructed over the landfill area and a portion of the spill areas shortly after the completion of the RI field investigation.

To further evaluate the potential effectiveness, implementability, and cost of vacuum extraction as a remediation technology, a pilot-scale treatability study was performed at the site. Physical and chemical data were collected over a two-week study period that allowed for a determination of the radius of influence of vacuum pressure in various soil units, an evaluation of the effects of key operating parameters and system designs on performance, and an estimation of the time required to remediate the contaminated soils to specified cleanup criteria. Preliminary costs and conceptual designs for full-scale remediation systems were developed.

BACKGROUND

Physical Characteristics of the Site

The overburden soils encountered during the subsurface investigation were predominately silt, sandy silt, and lean clay. Isolated and discontinuous lenses of silty sand with gravel, fat clays, and elastic silts were also encountered. Since the study area was once an open-pit iron ore mine, it is possible that much of the natural stratigraphy has been altered due to reworking of the soils.

A closer look at the engineering characteristics of these soils revealed that the silts and clays are very similar. The permeability of the silt/clay soil at the Heleva Landfill Site was determined in laboratory analyses to have a range of 10^{-6} to 10^{-7} cm/sec. Permeabilities of this nature indicate a "tight" soil matrix. The permeability of the silty sand with gravel soil which occurs in isolated and discontinuous lenses was estimated to be 10^{-3} cm/sec.

Water levels observed during the subsurface analysis generally occurred between 400 and 410 feet above mean sea level, approximately 50 to 60 feet below grade. In some instances, a water level was observed in the sandy lenses above the static water table, indicating localized areas of perched water.

Nature and Extent of Contamination

During the field investigation, soil samples were collected at each sampling location at regular 10-foot intervals and analyzed for VOCs within 24 hours for quick-turnaround time analysis and within 14 days for standard Contract Laboratory Program (CLP) analysis (EPA Method 601/602). A summary of the concentration ranges and average concentrations for all VOCs detected is presented in Table 1.

TCE was the most widespread and prominent soil contaminant detected, at concentrations up to 330,000 μg/kg. By using kriging techniques to statistically correlate data between borings, areas requiring further sampling were identified and eventually two distinct spill areas were delineated. The locations of the spill areas in plan view and kriged estimates of log TCE isoconcentration contour lines are shown in Figure 2. A cross section of the spill areas with kriged isoconcentration lines of TCE contamination is presented in Figure 3. It is noted that the isoconcentration lines do not extend into the landfill or the bedrock since the scope of this focused RI/FS was limited to contaminated natural soils and samples from the landfill and bedrock were not collected.

Biological degradation of compounds such as TCE may have created several "daughter" compounds in the soil where only one compound may have been present initially. The breakdown of TCE to 1,1-dichloroethene (DCE), cis and trans 1,2-DCE, both 1,1 and 1,2-dichloroethane (DCA), vinyl chloride, and chloroethane leads to the production of six additional chlorinated hydrocarbons. DCE was present at more than one-half of the sampling locations along with TCE, but at somewhat lower concentrations (up to 35,000 μg/kg). Vinyl chloride was detected in soil gas samples but was undetectable in nearly all soil samples, although its absence is most likely related to its extreme volatility. Tetrachloroethene (PCE) and 1,1,1-trichloroethane (TCA), which are "parent" compounds of TCE, DCE, and DCA, were also present at about half of the sampling locations, indicating that these compounds were disposed at the site along with TCE.

Acetone was detected at moderate to high levels (up to 840,000 μg/kg) in samples taken from the saturated soil zone. Since acetone is completely miscible in water, it is possible that acetone solutions disposed in the spill areas migrated quickly through the vadose zone and were concentrated in the saturated soil layer. Moderate concentrations of chloroform (up to 3,700 μg/kg), another widely used industrial solvent, were also detected at the site. Fuel-related compounds (benzene, ethylbenzene, toluene, and xylenes) were detected at various locations throughout the site.

Semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs) and inorganic elements were

TABLE 1
SUMMARY OF VOC CONCENTRATIONS IN SUBSURFACE SOILS

Compound	Concentration Range (μg/kg)	Average Concentration (μg/kg)	CRQL (μg/kg)	No. of Detections/ Total No. of Samples
Acetone	15-840,000	20,155	10	32/147
Benzene	2-56	3	5	2/37
2-Butanone	68-9,000	291	10	5/37
Carbon Disulfide	11-11	3	5	1/110
Chlorobenzene	3-58	4	5	5/37
Chloroform	4-3,700	30	5	15/147
1,1-Dichloroethane	4-19	2	5	4/110
1,1-Dichloroethene	10-49	3	5	3/147
Total 1,2-Dichloroethene	2-35,000	583	5	139/282
Ethylbenzene	1-460	10	5	14/147
Methylene Chloride	3-11,000	153	5	11/147
4-Methyl-2-Pentanone	10-150	16	10	4/37
1,1,2,2-Tetrachloroethane	4-4	2	5	1/37
Tetrachloroethene	1-1,700	32	5	65/282
Toluene	0.2-91	2	5	8/147
Total Xylenes	1-1,600	37	5	23/147
1,1,1-Trichloroethane	3-3,400	57	5	70/282
Trichloroethene	1-330,000	8,648	5	181/282
Vinyl Chloride	10-540	11	10	4/147

Note: CRQL = Contract Required Quantitation Limit analyzed for in seven samples taken from the spill areas. In an isolated occurrence, phenol was detected at 4,100 µg/kg. Moderate concentrations of dichlorobenzenes (170 to 8,700 µg/kg) and phthalates (100 to 550 µg/kg) were also detected. There was no pesticide or PCB contamination found. Inorganic elements were typical of average background concentrations for Eastern U.S. soils (Shacklette and Boerngen, 1984), except for raised concentrations of cobalt, iron, and manganese that are likely related to iron ore deposits in this former mine area.

Groundwater samples were obtained using screened stainless steel wellpoints whenever saturated conditions were encountered. The relative distribution of contaminants observed for the soil samples was observed in water samples as well; however, the concentrations in groundwater tended to be much higher. Acetone and TCE were encountered at concentrations up to 1,900,000 and 930,000 µg/L, respectively. Vinyl chloride was also detected at concentrations up to 19,000 µg/L. Several factors may have been responsible for the higher concentrations of VOCs in the water as compared to the soil: 1) the VOCs may have been concentrated at the air/water interface at the top of the groundwater table, 2) the VOCs may have been partially flushed from the vadose zone by percolating rainwater, and/or 3) the measurement of VOCs in the water may have been more accurate than in soil because of the zero headspace in the water sample vials.

Development of Remedial Action Goals

The primary concern at the site is contaminated soils acting as a continuing source of contamination to the bedrock aquifer. Since enforceable federal or state standards have not yet been promulgated for soil contamination, the remedial action goals were based on meeting contaminant-specific Applicable or Relevant and Appropriate Requirements (ARARs) for the groundwater beneath the site. Primary drinking water standards

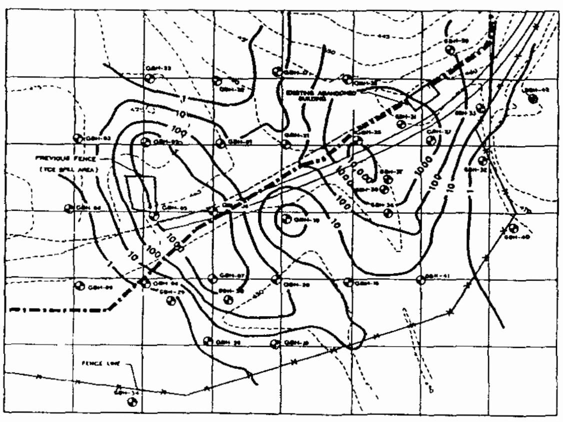

Figure 2. Plan view of site showing locations of soil borings and kriged isoconcentration lines of TCE contamination in soil at 430' MSL, approximately 30 feet below ground surface.

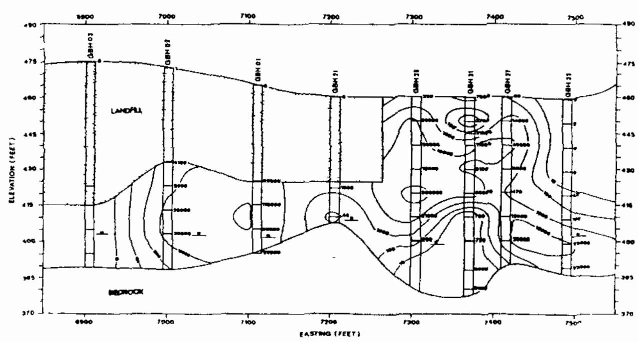

Figure 3. Vertical cross section of spill areas showing kriged isoconcentration lines of TCE contamination.

known as the Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs), developed by EPA in response to the Federal Safe Drinking Water Act, were determined to be relevant and appropriate requirements since the groundwater may be used for drinking water after remediation of the aquifer is complete. The Final National Contingency Plan (NCP) promulgated in 1990 specified that non-zero MCLGs shall be attained by remedial actions for groundwater or surface waters that are current or potential sources of drinking water. When there is no MCL or MCLG set for a contaminant, a calculated level based on the health risk from water consumption can be used. The resulting groundwater protection standards for site contaminants are summarized in Table 2.

A soil cleanup goal was defined as the concentration of a contaminant in the vadose zone soil that remedial alternatives need to achieve to prevent contamination of groundwater above the groundwater protection standards. Cleanup goals for the vadose zone soils were calculated using a combination of the Hydrologic Evaluation of Landfill Performance (HELP) Model (EPA, 1984), the Summers Model (Summers, et al., 1980), and a calculation to determine the effective aquifer mixing depth (Woodward-Clyde, 1988). The HELP Model was used to estimate the rate of rainwater infiltration through natural soils or through a synthetic membrane cap system. The Summers Model assumes that infiltration will desorb contaminants from the soil following equilibrium soil/water partitioning theory. It is further

TABLE 2
GROUNDWATER PROTECTION STANDARDS FOR SITE CONTAMINANTS

Contaminant	MCL (μg/L)	MCLG (μg/L)	Calculated Values Based on Risk (μg/L)
Acetone	NP	NP	3,500
Benzene	5	0	
2-Butanone	NP	NP	1,890
Chlorobenzene	100	100	
Chloroform	NP	NP	100
1,1-Dichloroethane	NP	NP	440
1,1-Dichloroethene	7	7	
cis 1,2-Dichloroethene	70	70	
trans 1,2-Dichloroethene	100	100	
Ethylbenzene	700	700	
Methylene Chloride	5	0	
Tetrachloroethene	5	0	
Toluene	2,000	2,000	
Trichloroethene	5	0	
1,1,1-Trichloroethane	200	200	
Vinyl Chloride	2	0	
Total Xylenes	10,000	10,000	

Note: NP = Not Promulgated

assumed that contaminated infiltration upon reaching the groundwater will mix completely within the mixing zone calculated by the Woodward-Clyde model, resulting in an equilibrium between groundwater and soil contaminant concentrations. The soil contaminants with maximum concentrations greater than or nearly equal to the calculated soil cleanup goals are summarized in Table 3. The cleanup goals would differ significantly if the infiltration rate was reduced by capping the contaminated area. If a synthetic membrane cap is installed (assuming a leakage factor of 0.1 percent), the Summers Model predicts that only TCE, methylene chloride and acetone soil concentrations would cause the groundwater protection standards to be exceeded.

Development of Remedial Alternatives

Potential remedial technologies and process options were identified and screened according to their overall applicability to the conditions and contaminants at the Heleva Landfill Site. The general categories of technologies initially considered were containment, thermal treatment, soil vapor recovery, fluid extraction, biological treatment, and soil dewatering. Process options which required excavation of soil prior to treatment (i.e., incineration, solid- and slurry-phase bioremediation, and soil washing) would be difficult to implement because of the depth of contaminated soils and the public health risks of VOC exposure to site workers and the community during excavation. In-situ process options that require subsurface injection of fluids (i.e., in-situ biotreatment and soil flushing) would not work well with the low permeability soil which would limit the ability to contact contaminated soil particles and recover the contaminated solutions. Process options considered to be the most applicable to the site conditions were capping, vacuum extraction, in-situ steam stripping, and soil dewatering.

Capping the contaminated areas with a composite soil and synthetic membrane liner cap system would be expected to eliminate most of the contaminated infiltration reaching the groundwater. However, capping alone does not comply with the statutory preference for treatment-based alternatives as directed by the NCP. In-situ vacuum extraction was judged to be the best treatment-based technology for contaminated vadose zone soils. In-situ steam stripping or a combination of soil dewatering and vacuum extraction were considered potentially applicable for the treatment of contaminated saturated soils. A combination of capping and treatment-based technologies would greatly reduce the volume of soil requiring treatment since less stringent soil cleanup goals would apply.

Treatability Study Objectives

To facilitate a detailed evaluation of the application of vacuum extraction at the Heleva Landfill Site, an onsite pilot-scale

TABLE 3
SOIL CLEANUP GOALS

Contaminant	Concentration Range in Soil (μg/kg)	Soil Cleanup Goal With No Cap (μg/kg)	Soil Cleanup Goal With Synthetic Membrane Cap (μg/kg)
Acetone	15-840,000	410	715,000
Benzene	2-56	20	NG
2-Butanone	68-9,000	460	NG
Chloroform	4-3,700	170	NG
1,1-Dichloroethene	10-49	20	NG
Total 1,2-Dichloroethene	2-35,000	180 (cis)	NG
		320 (trans)	NG
Methylene Chloride	3-11,000	2	4,100
Tetrachloroethene	1-1,700	100	NG
Trichloroethene	1-330,000	30	59,000
1,1,1-Trichloroethane	3-3,400	1,600	NG
Vinyl Chloride	10-540	6	NG

Note: NG = No Goal, calculated cleanup goal is greater than highest observed concentration

treatability study was performed. The treatability study was designed to satisfy several objectives:

- Radius of Influence--to determine the radius of influence of vacuum pressure in various soil units at the site.

- Operating Parameters--to evaluate the effects of key operating parameters on system performance, including vapor extraction rate and vacuum pressure.

- System Configuration--to evaluate the effects of various system components and configurations on system performance, including capping and air injection wells.

- Remediation Time--to estimate the length of time required to remediate the contaminated soils to the soil cleanup goals.

- Cost--to evaluate the major cost items associated with a full-scale system.

Pilot Test System Configuration and Installation

An area approximately 20 by 50 feet in size was selected within the limits of a spill area for performing the treatability study. Soil borings in this area revealed a soft silt to a depth of 20 feet, a relatively coarse layer of slightly silty, coarse to fine sand between the 20- to 25-foot depth, and stiff silt with varying amounts of sand and gravel below 25 feet. Soil moisture was visually classified as "moist to wet" from a depth of 10 to 25 feet, and a noticeable decrease in soil moisture was observed below 25 feet. The water table was encountered at a depth of approximately 50 feet.

Based on this geological stratification, the recommended installation for the vacuum well/vapor probe network consisted of two vertical vacuum extraction wells nested in a single borehole and 13 vapor probe monitoring points nested in four additional boreholes. The nested vacuum well configuration was a shallow well screened between 5 and 18 feet below grade, and a deep well screened between 30 and 45 feet below grade. The presence of the coarse to fine sand layer was a primary factor in determining the screen intervals for the vacuum wells. Due to the potential for short circuiting of air through the more permeable sand layer during vacuum extraction operations, a bentonite seal was installed between the two well screens over the entire depth of the sand layer to isolate the two wells. Vapor probes were installed in four boreholes located 4.75, 8, 15, and 47 feet from the vacuum wells to measure vacuum pressure and soil gas contaminant concentrations at discrete depths and at a range of distances from the extraction well. A cross section depicting the placement of the vacuum extraction wells and vapor probes is shown in Figure 4.

The pilot test system was assembled and installed adjacent to the vacuum extraction wells. The system included a 15-cfm liquid ring vacuum pump, a 10-cfm rotary vane oil-less vacuum pump, two air/water separator drums, six 200-pound canisters of activated carbon, and associated meters, gauges, valves, fittings, and piping. A schematic diagram of the pilot-scale extraction test system is presented in Figure 5.

Treatability Study Procedures

Following assembly and installation, the pilot-test system was activated and operated over a 14-day period. The shallow well was tested over the first 10 days and the deep well was tested

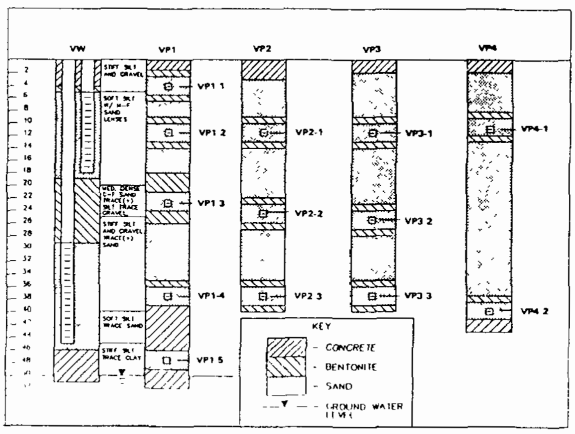

Figure 4. Schematic diagram of vacuum extraction well (VW) and vapor probe monitoring well (VP) construction.

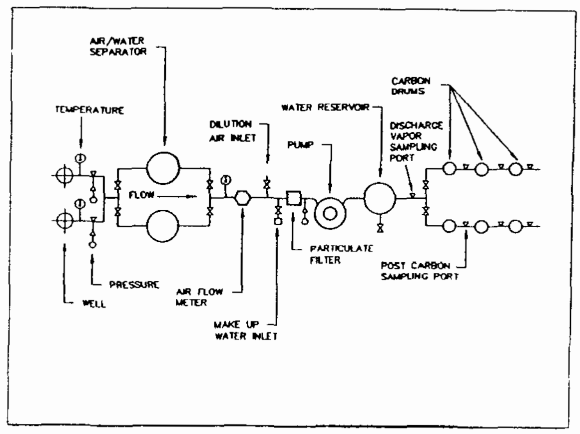

Figure 5. Schematic diagram of the pilot-scale vacuum extraction test system.

over the final four days of the study period. Three air flow rates were utilized during each test to produce data for calibration and verification of subsurface air flow models. The time-weighted average air flow rates for the shallow well tests were 7.0, 11.0, and 12.9 cfm, and for the deep well tests, 4.6, 5.1, and 7.2 cfm.

Vacuum extraction system operating parameters were recorded on a daily basis. The operating parameters included wellhead vacuum, wellhead flow rate, flow meter temperature, wellhead temperature, and vacuum at the pump. Vacuum readings were taken at each vapor probe location at least once per day.

Samples were collected for VOC analysis at regular intervals during the course of the treatability study from the vapor probe soil gas, wellhead soil vapor discharge, carbon canister vapor discharge, and air/water separator drain water. Onsite analysis of vapor samples was performed with an HNU Model 321 Gas Chromatograph equipped with an 11.7 eV photoionization lamp (GC/PID). Sample screening was performed with a hand-held Thermo Environmental Instruments Model 580A OVA total organic vapor analyzer equipped with an 11.8 eV lamp (TECO 580A). Water samples and vapor samples for confirmational analysis were analyzed by an offsite laboratory by EPA Methods 601/602 and T01/T02, respectively.

All field sampling and analyses were performed in accordance with strict quality assurance/quality control (QA/QC) procedures. QA/QC procedures for the GC/PID consisted of routine analysis of field blanks, standards, and duplicate samples in order to monitor the instrument's performance. Calibration of the TECO 580A was checked on a daily basis against a known standard of PCE.

DISCUSSION

Treatability Study Results

The relationship between vacuum levels and flow rates observed at the wellhead is depicted in Figures 6 and 7. As expected, best-fit lines plotted through the data points show a slightly curvilinear relationship of diminishing flow rates at higher operating vacuum pressures.

Vacuum pressure was observed in at least one vapor probe at each borehole location over the test period at levels ranging from 0.005 to 3.1 inches of water during the shallow well test, and from 0.005 to 0.45 inches of water during the deep well test. Vacuum pressure was not detected at several probes over the first five days of the shallow well test; it is likely that condensation in the Teflon tubing connected to the vapor probes may have been blocking the lines and interfering with vacuum reading. Corrective measures were taken by injecting 150 ml of air into the tubing 30 minutes prior to measuring vacuum at each of the probes. Readings taken after clearing the tubing were generally more stable and consistent than those observed prior to clearing the lines. Vacuum pressure was consistently not detectable at several probes in boring VP1 which was closest to the extraction well. Since these probes were expected to have the highest vacuum pressure, it was concluded that some of the vapor probes in this borehole may have been sealed off from the surrounding soil during installation from smearing of the borehole walls with wet, clayey soil as the augers were withdrawn.

Contaminant discharge concentrations for the shallow and deep wells are shown in Figures 8 and 9, respectively. The total target VOC concentration in the shallow well ranged from a maximum of 11,787 ppm (v/v) on the fifth day of the test to a minimum of 3,082 ppm on the ninth day of the test. For the deep well, total target VOC concentration ranged from a maximum of 9,072 ppm at the start of the test to a minimum of 4,073 ppm at the completion of the test. As expected, the primary constituent in each wellhead discharge vapor sample was TCE. The other prominent target VOCs detected were cis-DCE, total xylenes, TCA, chloroform, ethylbenzene, PCE, and toluene.

Soil gas sampling of the vapor probes was performed before and after the treatability study to verify that vacuum influence had been achieved and to determine the effects of vacuum influence on local soil vapor composition and concentration. TCE was again the most prominent VOC detected in all probes. The percent reduction of TCE at the vapor probes ranged from 72 percent at VP1-2 to 55 percent at VP3-1. Similar concentration decreases were observed for other target VOCs with the exception of chloroform which remained relatively unchanged.

Air Flow and Contaminant Removal Modeling

Proprietary computer models were used to evaluate air flow and contaminant removal characteristics of the soil units in the vadose zone at the Heleva Landfill Site. A description of the theoretical development of the models has been presented by Baehr, Hoag, and Marley, 1989. The soil units identified at the test site--an upper soil unit of soft, sandy silt between the surface and approximately 20 feet deep, a discontinuous five-foot-thick sand unit at a depth of between 20 and 25 feet, and a lower soil unit of stiff silt extending from a depth of 25 feet to below the water table (approximately 50 feet)--were modeled as a two-layer system with surface and water table boundaries and an intermediate boundary layer or lens.

Air flow modeling was used to determine the relative intrinsic permeability tensors of the soil units through which air flow occurs and to simulate system performance. Calibration of the 2-D, radially symmetric form of the air flow equations with the

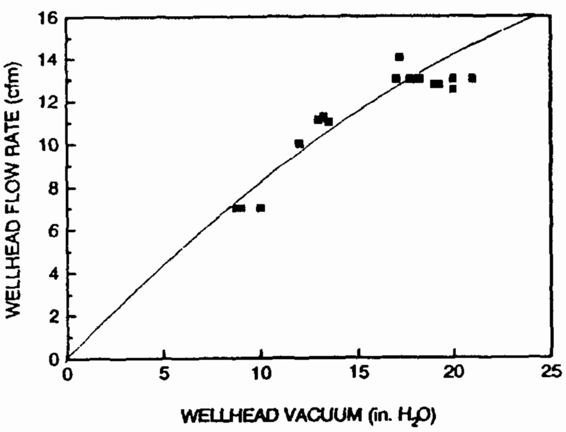

Figure 6. Shallow vacuum extraction well flow rate as a function of vacuum pressure in inches of water.

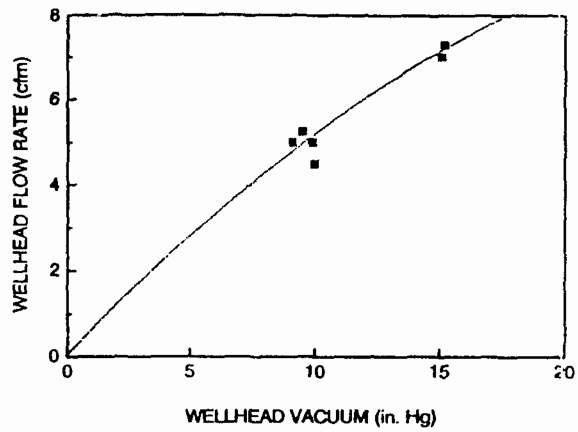

Figure 7. Deep vacuum extraction well flow rate as a function of vacuum pressure in inches of mercury.

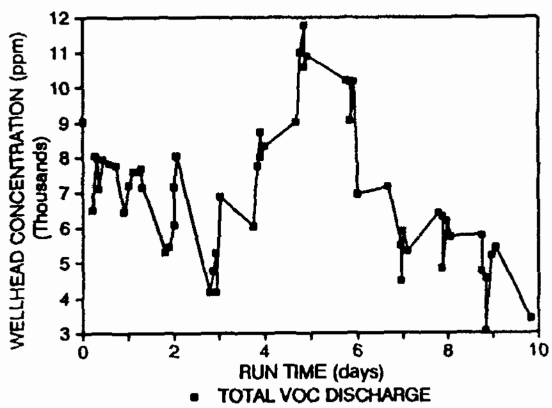

Figure 8. Results of GC/PID chromatographic analyses of the shallow vacuum extraction well vapor discharge over the 10-day test period.

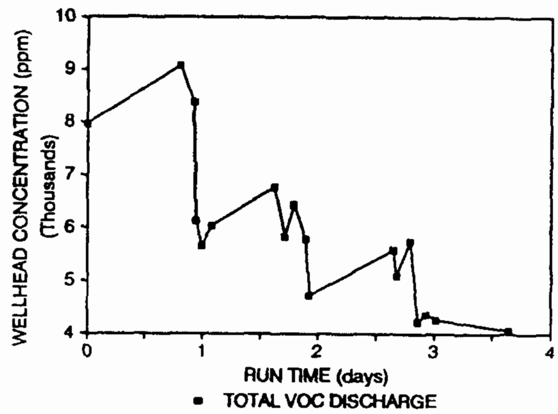

Figure 9. GC/PID results for the deep vacuum extraction well vapor discharge over the four-day test period.

steady-state physical data obtained during the pilot test allowed determination of the horizontal (K_r) and vertical (K_v) intrinsic permeabilities of the upper soil unit; the calculated values were 2.29×10^{-8} cm^2 and 1.0×10^{-8} cm^2, respectively. Soils displaying an intrinsic air permeability value in this range are considered to be moderately permeable. In addition, the model provided an evaluation of the equivalent vertical intrinsic permeability of the boundary at the soil surface. The calculated value was 1.0×10^{-8} cm^2. The surface boundary condition is an important parameter that can significantly influence the achievable radius of vacuum influence, the air flow pathways, and the vacuum developed at the well. The value of the permeability of the surface boundary condition calculated for this test area indicates that the surface is relatively permeable and that significant air flow to the well from the atmosphere occurs within the near field of the well. The K_r and K_v values for the lower soil unit were calculated to be 3.9×10^{-10} cm^2 and 1.0×10^{-10} cm^2, respectively. Soils displaying an intrinsic air permeability value in this range are considered to have a low permeability approaching the limits considered effective for the application of vapor extraction technology, where significant secondary porosities do not exist. The K_v value of the intermediate boundary lens was calculated to be 4.5×10^{-8} cm^2. Since the boundary lens appeared discontinuous, it is important not to lend too great an emphasis on its significance with respect to projected full-scale system performance.

The calibrated air flow model was verified by utilizing the model to project system performance under a secondary air flow rate and comparing the projections with the observed field data. The model calibration and verification results for the upper soil unit are shown in Figures 10 and 11, respectively. The calibrated and verified air flow model was used in the simulation mode to predict the effective radius of vacuum influence, the vacuum distribution in the subsurface and the air flow pathways that would be observed under a variety of system conditions. The predicted soil vacuum pressure distribution in the upper soil unit over the range of flows from 7 to 120 cfm is shown in Figure 12. The operating vacuum of the well for different flow rates is read from where the curves intersect the y-axis (at a radial distance of zero feet). It may be observed that at the maximum air flow rate of 120 cfm, the operating vacuum is in excess of 0.6 atmospheres, or 18 inches of mercury. By reducing the design flow to 100 cfm, a more readily operable vacuum of less than 15 inches of mercury is predicted. Due to the significant mass of contaminants considered to be distributed within the upper soil unit, the most cost-effective and highest practical flow rate is desired. A 100-cfm design flow rate per well is recommended. The effective radius of vacuum influence is site-specific and was defined as the limit of vacuum levels approaching atmospheric conditions. At soil vacuum pressures approaching atmospheric pressure, it can be observed from Figure 13 that the radius of influence of the vacuum extraction well in the upper soil unit is in excess of 50 feet for the simulated air flow rates. An effective radius of influence of 50 feet at a design flow rate of 100 cfm was used in the full-scale conceptual design. Similar analysis of the lower soil unit yielded an effective radius of vacuum influence of 8 to 10 feet at a recommended flow rate of 7 cfm.

As previously stated, the surface boundary condition can have a significant influence on the achievable air flow rates, air flow pathways and on the effective radii of vacuum influence of an extraction well. A decrease in the permeability of the surface boundary (i.e., capping) may increase the radius of influence; however, the increased radius of influence is generally accompanied by a significant decrease in the air flow rate from

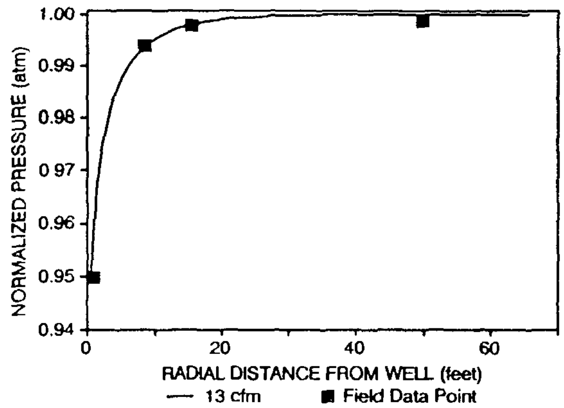

Figure 10. Air flow model calibration for the upper soil unit.

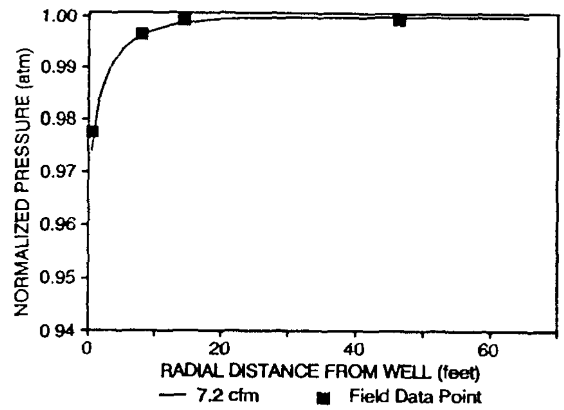

Figure 11. Air flow model verification for the upper soil unit.

the well under the same operating vacuum. Figure 14 presents plots of the predicted operating vacuum and pressure distribution for an extraction well in the upper soil unit under an operating air flow rate of 50 cfm, where the surface boundary is simulated as being capped. The upper and lower curves represent the operating conditions for caps having equivalent vertical intrinsic air permeabilities of 1.0×10^{-10} cm^2 and 1.0×10^{-12} cm^2, respectively. As expected, the plots demonstrate the significant increase in the operating vacuum from 0.8 atm (uncapped) to 0.53 atm (1.0×10^{-12} cm^2 cap) and the significant increase in the effective radius of influence from 50 feet (uncapped) to greater than 100 feet (capped). In general, spacing extraction wells in excess of 200 feet on center has the potential to introduce significant reductions in remediation efficiency due to potential significant variations in soil properties at this scale and due to potential extended remediation time periods from lower air flow rates. Based on the model and cost benefit analysis at this site, capping the surface is not expected to improve the overall efficiency of the full-scale conceptual design.

Air injection was also considered as part of the full-scale design due to the predicted, limited achievable radius of vacuum influence and the significant levels of contaminants observed in the lower soil unit. Simulations were performed to predict the operating pressures and pressure distribution in the lower soil unit under a range of air injection rates. The predicted pressure distribution in the lower soil unit over a range of air injection rates from 20 to 70 cfm is presented in Figure 15. From the plot, it may be observed that an operating pressure of up to 2.9 atm is predicted at the well. The plot shows that, in the region of one atmosphere, an effective radius of vacuum influence of 12 to 13 feet is achieved. Although the radius of influence is not substantially increased over the vacuum extraction case, the achievable air flow rate and contaminant removal potential are enhanced. A configuration of wells in the

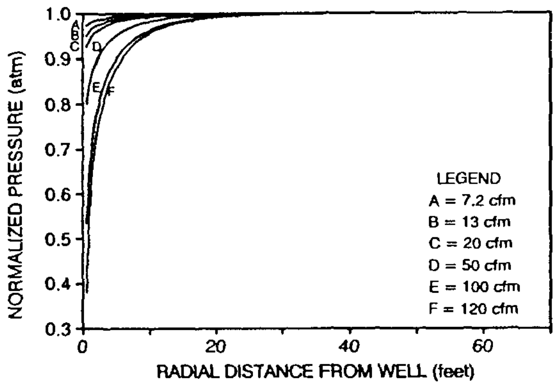

Figure 12. Predicted vacuum levels that would be observed at the wellhead over the range of achievable air flow rates in the upper soil unit.

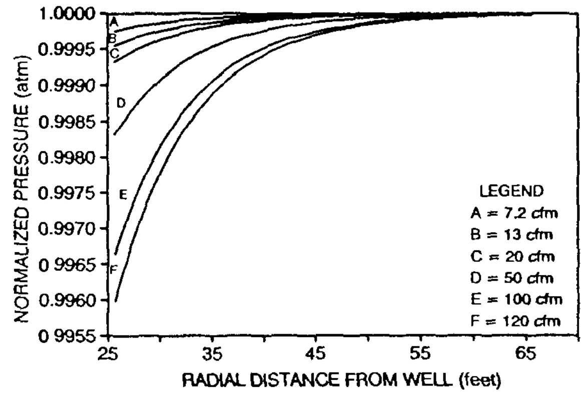

Figure 13. Predicted radii of influence for the range of achievable air flow rates in the upper soil unit.

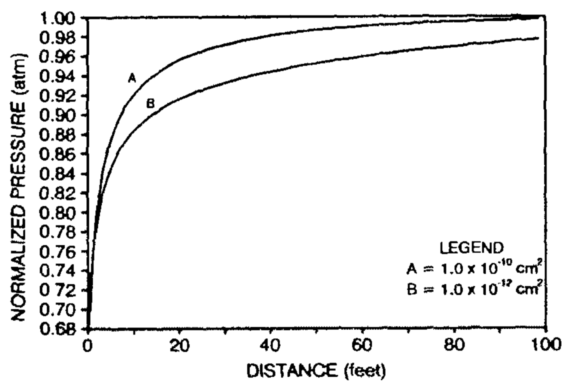

Figure 14. Predicted operating vacuum and pressure distribution for the upper soil unit with a cap installed over the surface.

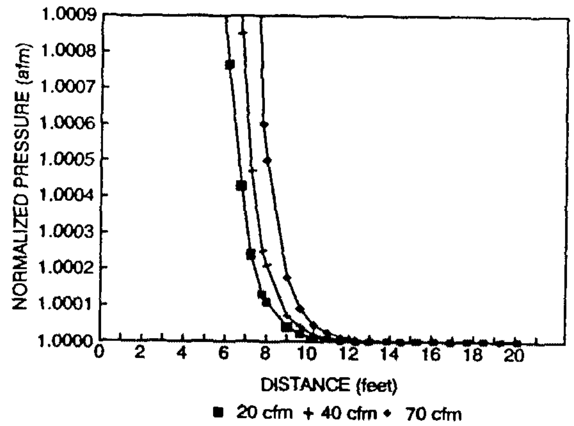

Figure 15. Predicted pressure distribution and radii of influence of air pressure in the lower soil unit over a range of air injection rates.

deep soil unit and flexibility in the design of the manifolding system will allow reversal in well operation (i.e., extraction wells may be used as injection wells and vice-versa), and an effective radius of influence of 12 to 13 feet at air flow rates of 7 cfm (extraction) and up to 70 cfm (injection) is achievable.

A semi-empirical contaminant transport model was used to evaluate the vadose zone soil units with regard to contaminant removal characteristics. The contaminant discharge data as displayed in Figure 8 present a curve which is atypical of the standard vapor extraction system discharge plot. This type of curve is generally associated with the misalignment of the vapor extraction well with respect to the center of mass of the contaminants within the well's zone of influence. The existence of a second peak at approximately five days into the test run most likely represents the lag time for transport of the vapors from the center of contaminant mass to the extraction well. In predicting the removal of the contaminants from the upper zone, the initial four days of data were not utilized since the data from the second peak forward would be more representative of the behavior of the full-scale system, and the initial four-day time frame would represent an insignificant time period in the prediction of the total time to achieve the soil cleanup goals. Contaminant discharge from the lower soil unit, shown in Figure 9, presents a more typical vapor extraction system discharge plot when the extraction well is placed near the center of mass of the contaminants within the zone of vacuum influence of the well.

The contaminant transport model was used to extrapolate a discharge curve from the field data to estimate the time required to achieve the soil cleanup goals for specific site contaminants. Figures 16 and 17 present theoretical graphs of contaminant removal for the shallow soil unit at a design air flow rate of 100 cfm, utilizing an initial mass of contaminants within the radius of influence of the extraction well corresponding to the highest concentration of soil contaminants observed at the site. The model predicted that the time to achieve the cleanup criteria at an extraction well for TCE, DCE, and methylene chloride would be approximately 120, 40, and 30 days, respectively. Due to its lower volatility and mole fraction, PCE is predicted to be removed more slowly and take approximately 160 days to achieve the cleanup goal. In the lower soil unit, the projected remediation times for the maximum contaminant concentrations detected during the RI investigation are 60 days for DCE, 40 days for methylene chloride, and up to five years for TCE and PCE. Vacuum extraction is generally not as effective for extracting highly water soluble VOCs such as acetone and 2-butanone. It is expected that unless acetone and 2-butanone are present as a free phase, additional measures such as groundwater extraction and treatment techniques may be required to remove these contaminants from the soil.

Preliminary Conceptual Design

The preliminary conceptual design parameters for a full-scale vacuum extraction system at the Heleva Landfill Site are summarized in Table 4. Based on the information developed for the field investigation, the preliminary design is presented under the assumption that the soil properties and contaminant composition and distribution are relatively consistent throughout the areas of the Heleva Landfill Site designated for remediation. It is more realistic, however, to assume that within the designated remediation areas, localized high and low levels of contamination and varying soil conditions will exist. Where these conditions are observed in the field, it is important to be flexible and to consider diverging from the conceptual design with particular respect to the spacing of the wells,

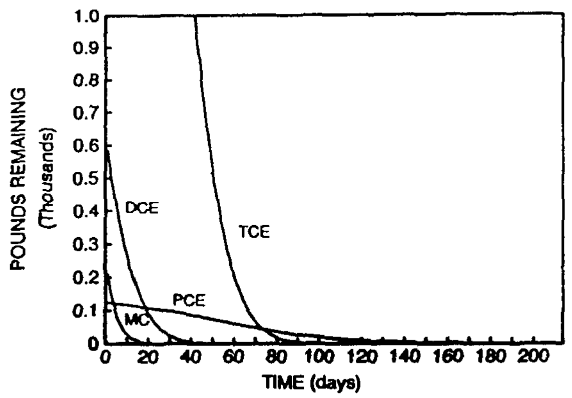

Figure 16. Theoretical graph of time vs. removal of TCE, DCE, PCE, and methylene chloride at a design air flow rate of 100 cfm.

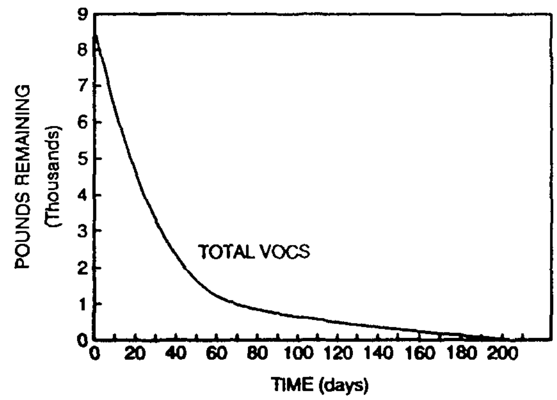

Figure 17. Theoretical graph of time vs. total VOC removal at a design air flow rate of 100 cfm.

the use of air injection points, and the prediction for time to achieve the specified cleanup goals for these localized areas.

From the air flow analysis, utilization of air injection wells within the deeper soil units at the Heleva Landfill Site would tend to increase the effective radius of influence of the wellpoints and enhance VOC removal through the higher air flow rates achievable within the soil system. However, preliminary estimates indicate that the relative costs associated with the widespread utilization of air injection could be significant. Further, the application of air injection would also transfer the deep soil unit contaminants into the capture zone of the shallow soil unit vapor extraction wells and therefore may prolong the period of operation of the shallow wells. Assuming field observations made during the full-scale installation would demonstrate localized variations in soil properties and contaminant composition and distribution, the utilization of air injection points would only be recommended for the "hot spots" of the deeper soil unit.

Based on the results of the pilot study, air control equipment would be required for treatment of the vapor discharge from the vacuum extraction system. During the treatability study, vapor phase carbon was found to be effective in providing air emission controls for all of the VOCs identified during the test. The amount of carbon required for the full-scale systems would be directly related to the amount of VOCs to be removed by the system. A rough estimate of the amount of carbon required can be based on a carbon adsorption capacity of 10 percent by weight. The potential magnitude of contamination at the Heleva Landfill Site warranted the consideration of onsite regeneration techniques as opposed to offsite regeneration and/or disposal.

The estimated costs to install and operate a full-scale vacuum extraction system for the shallow and deep soils is summarized in Table 5. This estimate was prepared assuming an intermediate

TABLE 4
PRELIMINARY DESIGN PARAMETERS

Parameter	Shallow Soil	Deep Soil
Radius of Influence	50 feet	8 to 10 feet
Air Flow Rate	100 cfm	7 cfm
Vacuum Pressure	15 in. Hg	15 in. Hg
Remediation Time	1 year	5 years
Cost*	$17/cubic yard	$88/cubic yard

* Estimated cost for remediating soils to 1 mg/kg TCE

range soil cleanup goal of 1,000 µg/kg for TCE with a corresponding volume of 57,870 cubic yards of shallow soil and 48,520 cubic yards of deep soil requiring remediation. The shallow system would include a total of 11 wells on 100-foot centers with a 100-cfm pump at each well. The deep system would need a total of 156 wells on 20-foot centers manifolded to 11 vacuum pumps with 100-cfm capacity. The unit costs for treating shallow and deep soils are $17 and $88 per cubic yard, respectively.

Analysis of Remedial Alternatives

Vacuum extraction and other appropriate technologies were developed into a series of remedial alternatives for the site that ranged from no action to complete treatment of all contaminated soils. A major factor that had to be considered was how the remedial options would work along with a recently completed RCRA cap located over the landfill area and approximately 50 percent of the spill areas. Due to the reduced contaminant migration potential under the cap, the higher cleanup goals presented in Table 3 could be applied to contaminated soils under the cap, requiring less treatment to be performed. Another consideration was saturated soils above bedrock that retain approximately 40 percent of the VOC contamination and essentially all of the acetone and 2-butanone detected at the site. Vacuum extraction cannot draw air through saturated soils and, therefore without dewatering, would appear to be ineffective for remediating this contaminated area.

From the range of remedial alternatives, a remedy that includes extending the existing landfill cap over the contamination source areas, dewatering the saturated soils above bedrock, and using vacuum extraction to remediate the "hot spots" of contaminated soil that exceed the soil cleanup goals when a synthetic membrane cap is in place was recommended. Dewatering the saturated soils would be evaluated through pilot testing during the Remedial Design phase before determining the conceptual design. The present worth cost of this alternative is estimated to be two million dollars, much lower than similar alternatives without a cap extension that ranged from 22.6 to

TABLE 5
COST ESTIMATE FOR VACUUM EXTRACTION SYSTEM

Item	Shallow Soil	Deep Soil
Capital and Equipment Costs		
Vacuum Extraction System		
Vacuum Well Installation	$94,230	$1,836,207
Well Manifolding	$60,029	$1,001,490
Vacuum Equipment	$132,480	$255,280
Equipment Staging Areas	$100,000	$200,000
Subtotal Capital Costs	$386,739	$3,292,977
Air Control Equipment		
Carbon with Offsite Regeneration	$192,500	$179,900
Canisters	$40,000	$40,000
Subtotal Air Controls	$232,500	$219,900
Subtotal Capital and Equipment	$619,239	$3,512,877
Contingency at 20%	$123,848	$702,575
Total Capital and Equipment	$743,086	$4,215,453
Operation and Maintenance		
Monthly Costs		
Electric	$5,569	$5,528
Operator/Maintenance	$7,900	$7,900
Analytical	$3,000	$3,000
Reporting/Oversight	$1,300	$1,300
	$17,769	$17,728
Subtotal Annual O&M	$213,225	$212,736
Contingency at 20%	$41,645	$42,547
Total Annual O&M	$255,870	$255,283
Demobilization		
Allowance	$50,000	$100,000
Total Demobilization	$50,000	$100,000
NET PRESENT VALUE assuming 5% discount rate, 1 year of O&M for shallow and 2 years of O&M for deep soil	$991,613	$4,254,091
Estimated Cost Per Cubic Yard	$17	$88

39 million dollars. The recommended alternative is expected to be completed within two years, as compared to five years for an alternative based on dewatering and vacuum extraction treatment without a cap extension.

A phased approach was recommended for implementing a combination vacuum extraction and dewatering system. During the initial phase, the shallow vacuum extraction system and several dewatering wells would be installed. In a later phase, the remainder of the dewatering wells, the deep vacuum extraction system, and the cap extension would be installed. The reasons for a phased approach are several. First, the installation and operation of the shallow system would allow for identification of the more highly contaminated areas and for any necessary debugging of the full-scale system operating parameters. Second, the shallow soils are projected to achieve the cleanup criteria within one year, whereas the deep soils and soils above bedrock may require up to five years, hence the overall project may be extended by only one year while valuable operating knowledge is gained. Third, the operating equipment used for both the shallow and the deep systems are similar and savings in capital costs could be achieved by utilizing the same equipment for the shallow and the deep systems. Fourth, the dewatering system would require a more detailed subsurface investigation and pilot-scale testing before the full-scale design is performed. Once the dewatering system is functioning properly, vacuum extraction of the saturated soil zone could be initiated.

SUMMARY

A field investigation of the Heleva Landfill Site delineated two distinct solvent spill areas contaminated with chlorinated hydrocarbons and ketones. The use of quick-turnaround analyses and statistical correlation of data between borings (kriging) allowed the field team to focus the placement of borings in the potential spill areas, reducing the total number of borings required to define the extent of contamination. Soil cleanup goals were developed based on a combination of modeling techniques to predict the concentration of contaminants in soil that would correspond to acceptable groundwater quality beneath the site. Remedial technologies capable of achieving the soil cleanup goals were evaluated. Due to the depth of contamination and problems associated with controlling exposure to VOCs, in-situ vacuum extraction and surface capping were considered to be the most applicable remedial technologies for this site.

A systematic evaluation of the parameters involved in operating a vacuum extraction system was conducted by performing a pilot-scale field study and utilizing air flow and contaminant transport models to evaluate the results. It was determined that the vacuum extraction process could successfully remove VOCs from the sandy silt soil matrix in the shallow soil (from ground surface to 25 feet) but VOCs were more difficult to remove from the deep stiff silt soil strata (25 feet to 50 feet below ground surface). The vacuum extraction wells in the shallow strata would be capable of achieving an effective radius of influence of approximately 50 feet at an optimal vapor extraction rate of 100 cfm and a corresponding wellhead vacuum pressure of 15 inches of mercury. Vacuum extraction wells in the deep strata would be capable of achieving an effective radius of influence of about 10 feet at an optimal vapor extraction rate of 7 cfm and a corresponding wellhead vacuum of 15 inches of mercury. It is expected that if the saturated soil above bedrock (50 to 70 feet below ground surface) were dewatered, the air flow and chemical removal characteristics would be similar to the lower vadose zone soils.

ACKNOWLEDGEMENT

The authors wish to sincerely thank Ms. Carol A. Royal for her enthusiasm and effort in preparing and reviewing the manuscript.

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