TECHNICAL STUDY AND REMEDIAL ACTION FOR DENNY FARM SITE 1, AURORA, MISSOURI

Final Report

September 15, 1980

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Monday, 15 September 1980

Mr. William Keffer
Environmental Protection Agency
Emergency Planning and Response Branch
25 Funston Street
Kansas City, Kansas 66115

Dear Mr. Keffer:

In response to Technical Direction Document (TDD) F7-8006-01 and subsequent modification, Ecology and Environment, Inc., (E & E) is pleased to submit fifty copies of its final report entitled Technical Study and Remedial Action for Denny Farm Site 1, Aurora, Missouri (Document No.: EFSR80-09-0105). This report is based on the preliminary report (EFSR80-07-0104) completed in July, 1980; on further geophysical and engineering studies; on meetings with EPA-Region VII and the EPA Dioxin Task Force; and on participation in the consent negotiations.

This final report is the culmination of an intensive effort by E & E's Special Projects Team coordinated by the National Project Management Office in Arlington, Virginia. Expertise has been drawn from several of the regional offices involved in the Field Investigations Team (FIT) project. E & E appreciates the cooperation of EPA Regional Deputy Project Officers in making FIT personnel available for this important project.

An evaluation was made of the technologies available for meeting the objective of removing the TCDD from the environment. Treatment of the waste by ultraviolet photolysis and by incineration are currently the most promising techniques for final disposal of the wastes. However, these technologies are not yet proven nor are they immediately available.

E & E recommends that the waste and associated contaminated material at Denny Farm Site 1 be excavated and stored in a temporary storage structure to be erected on site until a suitable final disposal option is available. A conceptual design of this solution along with cost estimates are presented in this report. Our estimate is that this will cost approximately $2,486,000 and take six months to execute. E & E recommends that EPA proceed immediately with the final design of the recommended action and select an execution contractor to proceed with the project.

We welcome the opportunity to discuss this report with you. We will provide continued support to you through our Region VII FIT project office and the FIT National Project Management Office to see this project through to a successful conclusion.

Sincerely yours,

Robert J. King
Assistant National Project Manager

RJK:jbs

cc: Paul Nadeau
Roger J. Gray
James Buchanan
Les Greenbaum

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SECTION 1

INTRODUCTION

This report contains the results of an investigation into an uncontrolled hazardous waste disposal site located in Aurora, Missouri. The site, called Denny Farm Site 1, consists of a trench in which an estimated 150 drums of waste material have been buried. These wastes, which are from a hexachlorophene-manufacturing process, have been analyzed and are known to contain the highly toxic chemical TCDD.

The investigation of Denny Farm Site 1 was carried out by Ecology and Environment Inc. (E & E) and included background data acquisition, environmental and geophysical surveys of the site and its environs, evaluation of alternative remedial actions, and preparation of a conceptual plan for a proposed remedial action. This investigation was undertaken at the request of the U.S. Environmental Protection Agency (EPA) to meet the EPA's objective of removing the waste and contaminated material from the environment. A preliminary report was prepared in June 1980; the current report is the final report of E & E's investigations.

Historical information on the Denny Farm Site 1 is presented in Section 2, which includes a discussion of the relationship between Hoffman-Taft, North Eastern Pharmaceutical and Chemical Company (NEPACCO), and Syntex Agribusiness, Inc. NEPACCO, the generator of the waste disposed at the Denny Farm, manufactured hexachlorophene. The chemical process for a chemical intermediate to hexachlorophene was the source of the TCDD, and the wastes from this process were then disposed of in a trench on the Denny Farm.

Section 3 presents a discussion of the thorough research and field investigations previously conducted on the site. This information concerns the general geological and hydrological conditions of the area surrounding the Denny Farm, as well as analytical data on the drum contents. Analytical data determined the presence of TCDD in composite samples as well as soil and water samples obtained from within the partially excavated trench. Additional environmental monitoring included water samples taken at the private wells closest to the site, as well as surface water samples from Calton Creek. Samples were taken from borings around the perimeter of the disposal trench to determine lateral migration of the waste.

Section 4 presents the results of further technical studies on the site and the characteristics of TCDD. Although previous studies had indicated no lateral migration, the potential for off-site migration existed; additional areas were investigated in greater detail to confirm and develop necessary engineering data for the remedial action. The geohydrological investigation provided more precise measurements of the configuration and approximate dimensions of the barrels in the trench. The presence of drums beyond those visually noted by the EPA was also confirmed. More importantly, lateral off-site migration was not detected.

Specific information concerning the type and quantity of waste disposed of in the trench at Denny Farm and the method of disposal are presented in Section 5. Public health and environmental concerns with respect to TCDD and its environmental fate and its toxicological properties are discussed.

Section 6 presents the basis for the remedial approach. This approach may be defined within the context of this report as taking all the necessary steps required--identification, investigation, determination of means and methods, and execution of determined methods--for achieving a satisfactory solution to a specific hazardous waste problem. The means of dealing with hazardous waste, whether the generator is a manufacturer or an uncontrolled waste site undergoing cleanup, include one or more of the following: storage, treatment, and disposal. Various methods may be selected to carry out a given means.

Since those methods and means must be tested to determine their applicability to a particular site, selection criteria have been developed. Generic criteria applicable to any site are proven technology, risk, time, cost, and legal constraints. Site-specific criteria include the characteristics of the waste and of the site.

Section 7 presents the process employed to select those methods which are considered for remedial action application. The first phase

SECTION 2

HISTORY OF DENNY FARM SITE 1

During the 1960s, Hoffman-Taft used its facility in Verona, Missouri, (see Figure 2-1) for the production of 2-4-5-T, a component of Agent Orange. In the late 1960s, Hoffman-Taft sold the Verona facility to Syntex Agribusiness, Inc. In 1969, Syntex sold the equipment in the Verona facility and leased the space to the North Eastern Pharmaceutical and Chemical Company (NEPACCO). From 1969 through 1971, NEPACCO, now defunct, used the Verona plant for the manufacturing of hexachlorophene.

During its tenancy, NEPACCO had a number of process waste streams with dioxin contamination, including still bottom residues, solvent-contaminated waste water, expended filter media, and a recrop liquor. These were either contained or disposed of at a number of locations. One of these locations was the Denny Farm in Aurora, Missouri.

The Denny Farm is located seven miles south of Verona, Missouri, on Highway VV. The farm consists of 160 acres and is located in Section 20 on the Area Location Map (see Figure 2-2). The site of the disposed material from NEPACCO is northwest of the Denny farm house. Access to the site is via the north edge of a pasture and along a dirt logging road. The site is on top of a ridge (see Figures 2-3 and 2-4). A spring-fed pond exists approximately 100 yards west of the site.

In 1979, the Air and Hazardous Materials Division (ARHM) of the Environmental Protection Agency's (EPA) Regional Office in Kansas City, Missouri, Region VII, received an anonymous complaint about the disposal site on the Denny Farm. The complainant made a number of allegations about the waste handling and disposal procedures of NEPACCO.

Surveillance and Analysis Division (SVAN) personnel from EPA-Region VII, accompanied by representatives from ARHM and from the Springfield, Missouri, MDNR office, conducted a two-week investigation of these allegations. The investigation included personal interviews, site reconnaissance, and photography of the disposal site. The investigation team interviewed twenty-five individuals, including people who had worked for NEPACCO as well as officials and employees of Syntex Agribusiness

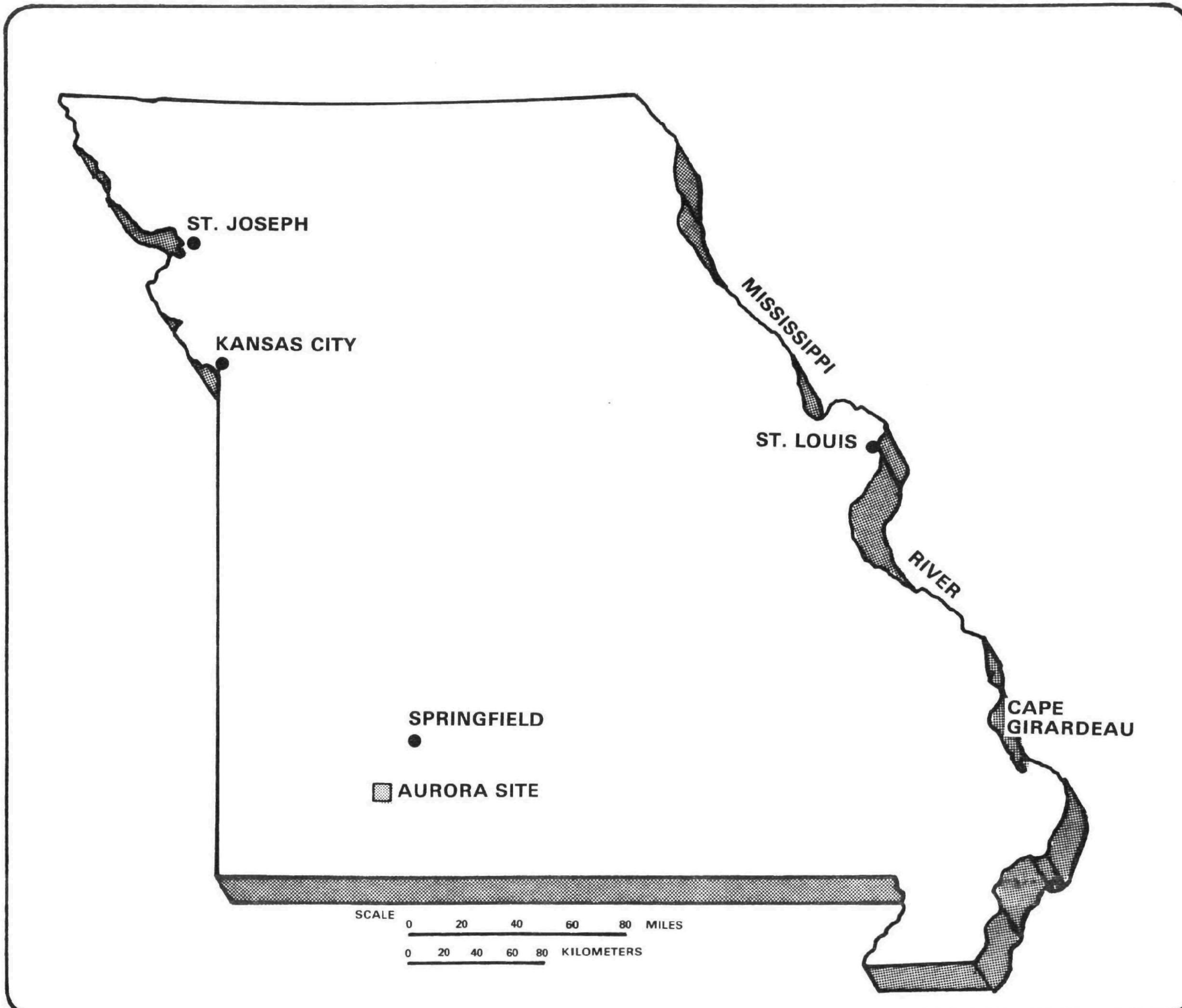

Figure 2-1. Map of Missouri

DENNY FARM SITE 1 AREA LOCATION MAP

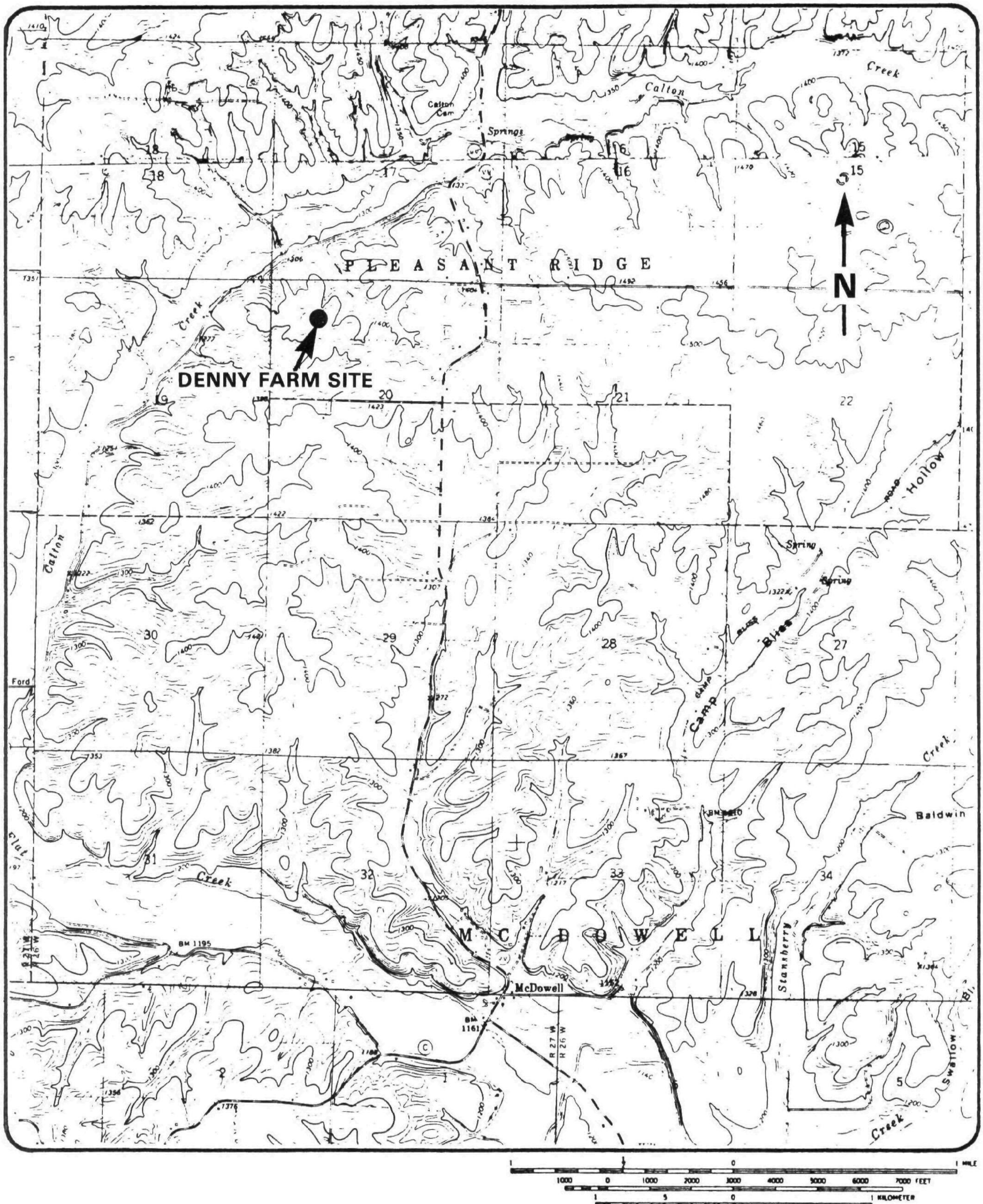

Figure 2-2

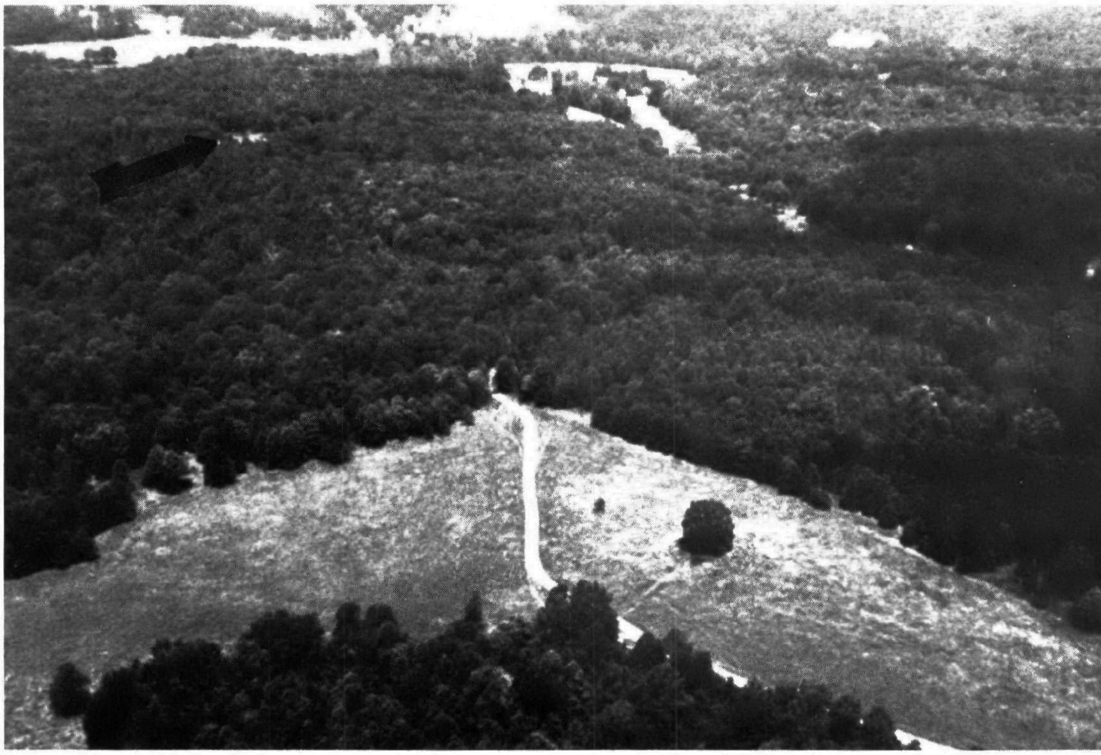

Fig. 2-3. Aerial View of
Denny Farm Site 1 Locale
(viewed to the west-northwest)

Fig. 2-4. Aerial View of
Fenced Disposal Trench
(southwest at top of photo)

Inc. Some of those interviewed were eyewitnesses who reportedly hauled wastes to the Denny Farm, dug the trench, and dumped drums of waste materials into the trench.

On conducting a reconnaissance of the disposal site, investigators noted a depression in the ground about 10 by 53 feet. Investigators also found a mound of excavated soil next to the depression. The excavated material consisted of clay and small rock.

Based upon information obtained from the interviews, it appeared that there were between thirty and one hundred fifty 55-gallon metal caustic drums with lids buried on the Denny farm site. The drums were buried in June, 1971. According to those interviewed, the drums were dumped out of the back of a dump truck and left as they fell. They were then covered with from one to three feet of soil. The most reliable eyewitness stated that the drums were in marginal condition at the time of burial and at least one drum had leaked or spilled when an individual walking around on the top of the drums in the back of the truck fell through one of the drums when the lid gave way.

The EPA investigators concluded after their initial survey that

> . . . It is reasonable to expect that most, if not all, of the drums have rusted through and that the contents have, to a large extent, been absorbed by the surrounding soil. Although from the standpoint of safety, and sampling and analytical procedures, the worst must be assumed--there is (sic) no data, information or rumors to indicate that the contents of this site include high strenght (sic) dioxin contaminated wastes. Based upon all the interviews, the material in this site is reworked liquor or recrop material from which no additional hexachlorophene could be extracted. Whether or not this residue contained dioxin is unknown.

The EPA Regional Office in Region VII prepared a study plan for the the investigation of the Denny Farm disposal site. EPA designated the site as Denny Farm Site 1. The objective of the investigation effort was

> to document the presence or absence of dioxin, its precursors, and/or degradation products and any other hazardous wastes in the buried drums, adjacent soil, and immediate area surrounding the disposal pit.

Implementation of the plan began on 22 April 1980 and lasted for several days.

SECTION 3

PREVIOUS STUDIES OF DENNY FARM SITE 1

INTRODUCTION

As a result of the anonymous complaint received in 1979 by the Air and Hazardous Materials Division (ARHM) of the Environmental Protection Agency's (EPA) Regional Office in Kansas City, Missouri, about the disposal site on the Denny Farm in Aurora, Missouri, several actions were taken. A preliminary investigation was set in motion. The investigation included personal interviews, site reconnaissance, and photography of the disposal site.

Following this preliminary investigation, a study plan was devised for an investigation of the disposal site. The objective of the investigation was

> to document the presence or absence of dioxin, its precursors, and/or degradation products and any other hazardous wastes in the buried drums, adjacent soil, and immediate area surrounding the disposal pit.

The final plan was submitted to EPA authorities on 1 April 1980, and implementation of the plan began on 22 April 1980.

Before any excavation was done on the disposal trench, several bore hole soil samples were collected from the perimeter of the trench (see Figure 3-1 for a sketch of Denny Farm Site 1 and location of proposed bore holes). The purpose of these borings was to document any lateral migration of contaminants from the trench.

As seen in Figure 3-1, two levels of bore holes were planned: one level within five to ten feet of the trench; the other between forty-five to fifty-five feet from the trench. The first level holes were bored. Additionally, one sample bore hole blank was collected at the edge of the pasture leading into the site. This blank was collected for purposes of background and analytical quality control.

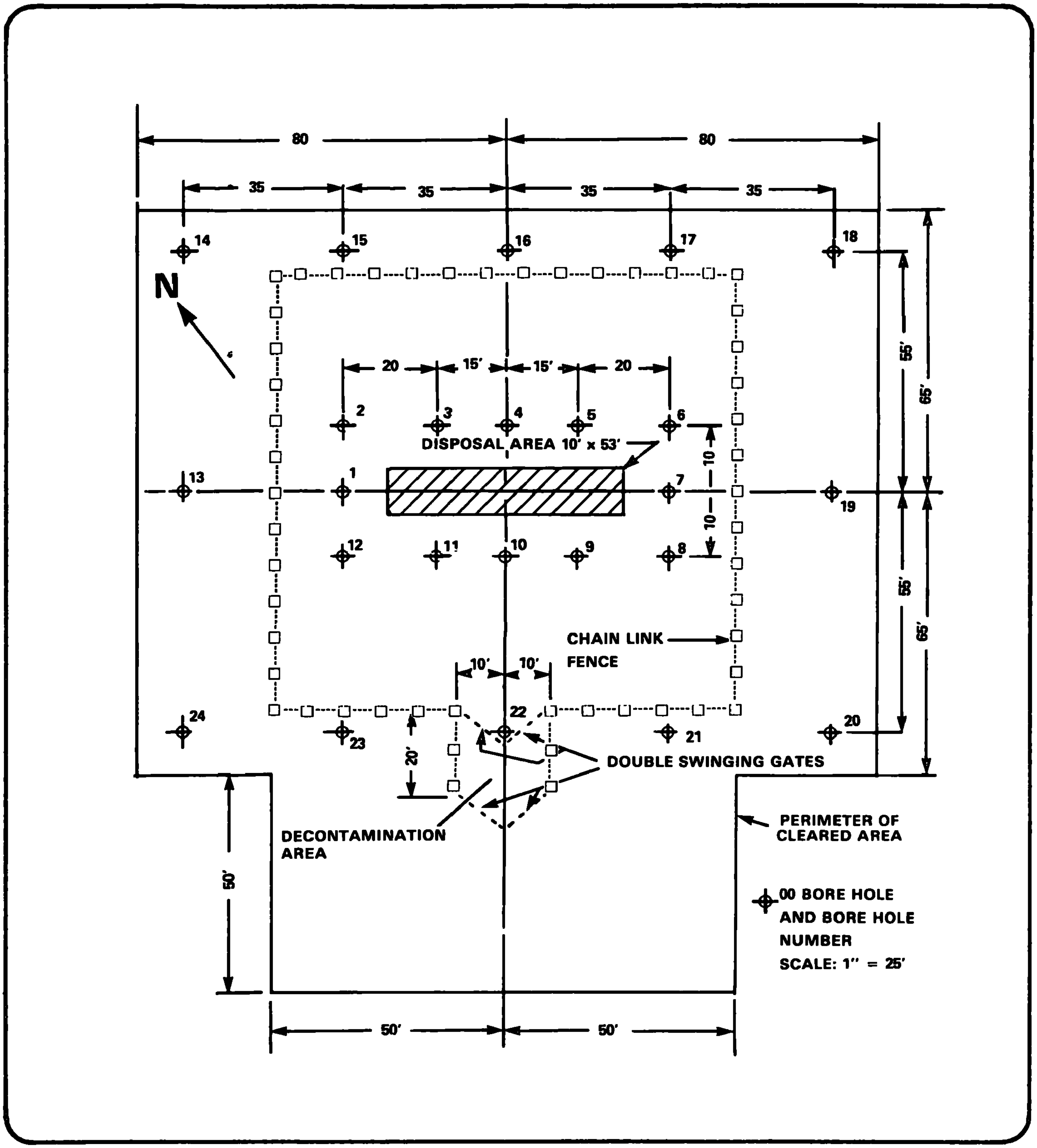

Figure 3-1. Plan View of Denny Farm Site 1

The second level of planned borings--holes thirteen through twenty-four--with the exception of hole twenty-two was not done on the advice of a Missouri Department of Natural Resources, Division of Geology and Land Survey, geologist. There was concern that water percolating through the trench would migrate vertically and cause further contamination.

After the borings were completed, the disposal trench was excavated. Through a careful excavation, thirteen drums were exposed to the EPA investigation team. Several of the drums were found to be empty. Others contained liquid and residues in volumes ranging from near-empty to full. Samples taken from drums and soil in the trench at Denny Farm Site 1 were sent to the EPA-Region VII Laboratory for analysis for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The original analysis of the four samples indicated that three contained between 65 and 100 mg/kg (ppm) of dioxin. The fourth sample contained less than 29 mg/kg TCDD. From these results EPA concluded:

> . . . the information from the GC/MS scans supports the conclusion that the material in the three samples . . . is very similar to the still bottom residue presently being treated by Syntex Agribusiness. The GC/MS scans tentatively identified 2,4,5-trichlorophenol and at least two--and probably three--ethers formed by combination of trichlorophenol with one, two, or three molecules of ethylene glycol. Syntex has stated that trichlorophenol and ethers of the above description are the major constituents of the waste in their tanks. . .

Based on the field investigation, excavation, and results of the sampling, the EPA further concluded that immediate action was necessary to protect human health and the environment. This decision necessitated the development of a short-term response program to minimize and/or prevent the release of contaminants from the site until a method ameliorating the hazard could be determined. An immediate and temporary measure was taken by the EPA with FWPCA Section 311 funding. The disposal trench was capped with an impermeable membrane. Surface water was diverted from the site.

Subsequent to the investigation of the disposal trench, a monitoring program for surface water and groundwater in the general area of Farm Site 1 was developed. A discussion of the sample data follows.

SAMPLING DATA

Groundwater Monitoring

Both on-site and off-site groundwater monitoring were carried out. Initial off-site sampling was conducted during April 1980 and included three wells with the closest proximity to the Denny Farm Site 1: Garnatz-Williams (#4), Katherine Lamp (#5), and Dick Wallace (#13) (see Figure 3-2). Sample analysis was based upon chemical process information and interviews. A false positive due to cross contamination was determined in well #13, while results for wells #4 and #5 were negative for signs of contamination. Further groundwater studies were undertaken on 3 June 1980, following EPA's on-site investigation and sampling at the Denny Farm Site 1. Laboratory results confirmed the presence of TCDD. Subsequently, additional sampling was carried out by EPA: wells #1, #2, #3, #6, #7, #8, #9, #10, #11, and #12.

Sample results revealed the presence of phenolic compounds in wells #3 and #4; 2,4,5-trichlorophenol (TCP) in well #2. Well #13, which originally had a false positive, was sampled again on 5 June 1980. Contamination was not detected.

Results of all the groundwater sampling may be found in Appendix A, Table A-1. All samples taken after 6 June 1980 were analyzed for TCP. None was detected.

Soil Sampling

As previously mentioned, an on-site investigation of the Denny Farm Site 1 was conducted in April-May 1980. A portion of the suspected disposal trench was excavated. Samples of the soil intermingled with drums were obtained for analysis. Additionally, borings were initially installed about the perimeter of the trench (cf. Figure 3-1), and samples were obtained for analysis.

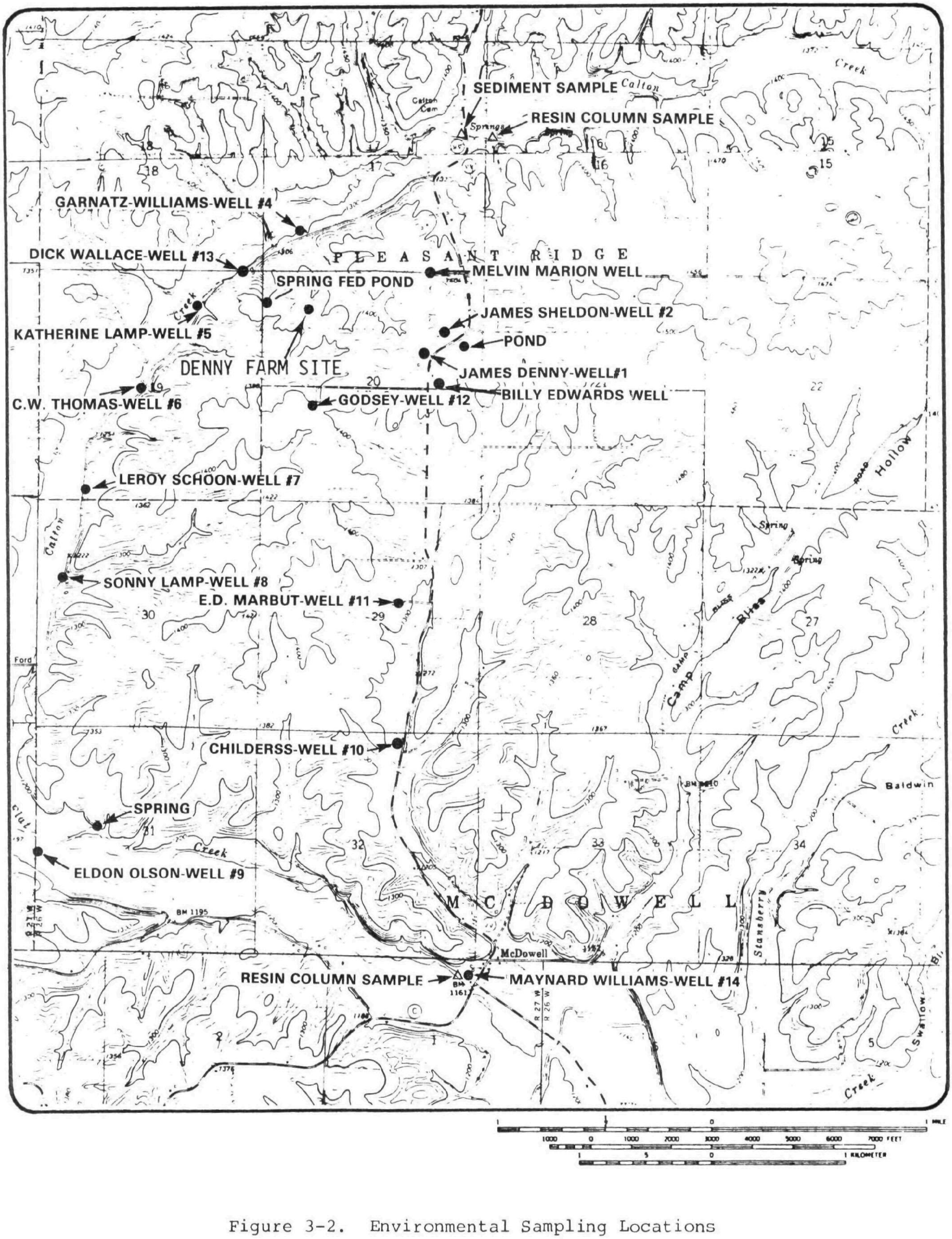

Figure 3-2. Environmental Sampling Locations

Geophysical test methods were subsequently employed to define more accurately the disposal trench as well as surrounding subsurface configurations. Initial findings revealed an anomaly extending from the western end of the trench. Additional borings were installed along the perimeter of the fence surrounding the disposal trench and also within the confines of the suspect anomaly.

Results, as seen in Appendix A, Table A-2, revealed the presence of TCDD in concentrations of 92,000 ppt in the trench. The subsequent geophysical test noted above uncovered that boring #1, originally thought to be along the perimeter of the trench, was in fact part of the disposal trench.

Boring logs and sample results confirmed the existence of an anomaly west of the trench. Data showed the presence of a richer clay layer rather than contaminate soil caused by leachate from the disposal trench.

Soil test results indicate no lateral migration of contaminants beyond the sides of the original trench. The tests, however, do not eliminate the possibility of vertical migration.

Surface Water

Surface waters were sampled to determine both the presence and levels of contaminants. Because of the topographical and geological makeup of the area, contaminated surface run-off and/or groundwater posed a real threat for the contamination of area surface waters.

Two spring-fed ponds, one to the east and one to the west of the disposal trench, were sampled. Sediment and fish samples were taken at twelve different locations. The affinity of TCDD for soils and sediments in addition to its bioaccumulation potential required the sampling. A final sample station on Calton Creek was established for the above samples as well as a resin column sample, i.e., a sample where a large quantity of water is allowed to pass over resin that will attract, concentrate, and retain certain chemical compounds found in the water.

Results indicated that in all cases contaminants were not present to the level of detection. Results of this sampling are show in Appendix A, Table A-3.

Drums (Waste Source)

On 28 April 1980, the EPA-Region VII field investigation team exposed thirteen drums in the excavated disposal trench at Denny Farm Site 1. Eight of the drums were sampled. These samples consisted of multi-layered liquid samples which varied in color and consistency. Some of the sample material was analyzed on a drum-by-drum basis; other portions of the samples were composited.

Wright State University (WSU) prepared a four-drum composite sample based upon volume of waste contained in the respective drums. An additional composite sample was prepared by EPA-Region VII and consisted of sample material from a second set of four drums. This composite sample was forwarded to WSU for analysis.

TCDD, TCP, ethylene glycol, tetrochlorobenzene, and alkylbenzene compounds were tentatively identified. Concentrations of TCDD were confirmed in both composite samples: 319 ppm in the WSU-prepared composite, and 1.3 ppb in the EPA-prepared composite. Results of the drum sampling can be seen in Appendix A, Table A-4.

Table 3-1 presents a summary of the results presented in Appendix A.

TABLE 3-1

SUMMARY OF SAMPLING DATA

Type of Sample	Dates of Sampling	Total Number of Samples	Number of Positive Samples	Contaminants Detected
Groundwater	4/3 to			
Wells and Springs	7/21/80	115	3	TCP, Phenolics
Soil	4/22 to			
Bore Holes	6/16/80	23	1	TCP, TCDD
Trench		1	1	TCDD
Surface Water	6/8 to			
Water	6/18/80	4	0	
Sediment		12	0	
Fish		33	0	
Drums	4/28/80			
Random		4	4	TCP, TCDD
Composite Samples		2	2	TCDD, Toluene, Tetrachlorobenzene, others

SECTION 4

TECHNICAL BACKGROUND INFORMATION

INTRODUCTION

In its investigation of Denny Farm Site 1, Ecology and Environment, Inc., (E & E) has carried out several technical investigations. The purpose of this section is to discuss the technical background information gathered in the areas of geography, demography, climatology, geology, hydrology, and geophysical reconnaissance of the trench.

GEOGRAPHY

The Denny Farm Site 1 hazardous waste disposal site is located on the Denny Farm in Barry County near the town of Aurora, in southwest Missouri. Aurora lies approximately twenty-nine miles southwest of Springfield and twenty-five miles southeast of Joplin.

The Denny Farm is on the west side of county road VV, south of Pleasant Ridge and south-southeast of Calton Creek (see Figure 4-1). The site of the disposal trench is west of the Denny farm house and about three quarters of a mile from county road VV. It is in the northwest corner of section twenty on the area location map (cf. Figure 2-2).

The disposal trench (Denny Farm Site 1) is located on a ridge top in the dissected hills bordering the Ozarks and the rolling plains of the Springfield Plateau. The ridge itself is on a topographically high area bounded by Calton Creek on the north and west, and by the Little Flat Creek on the south.

In this area, the topography and soil relationship is sometimes referred to as the Baxter-Bodine soil association. Baxter areas, i.e., ridge tops, are wooded. They have the potential, however, for being cleared and used as pastures. The Bodine soils exist primarily on the steep hilly areas of the ridges. These hilly areas generally have more chert and are used primarily as woodlands.

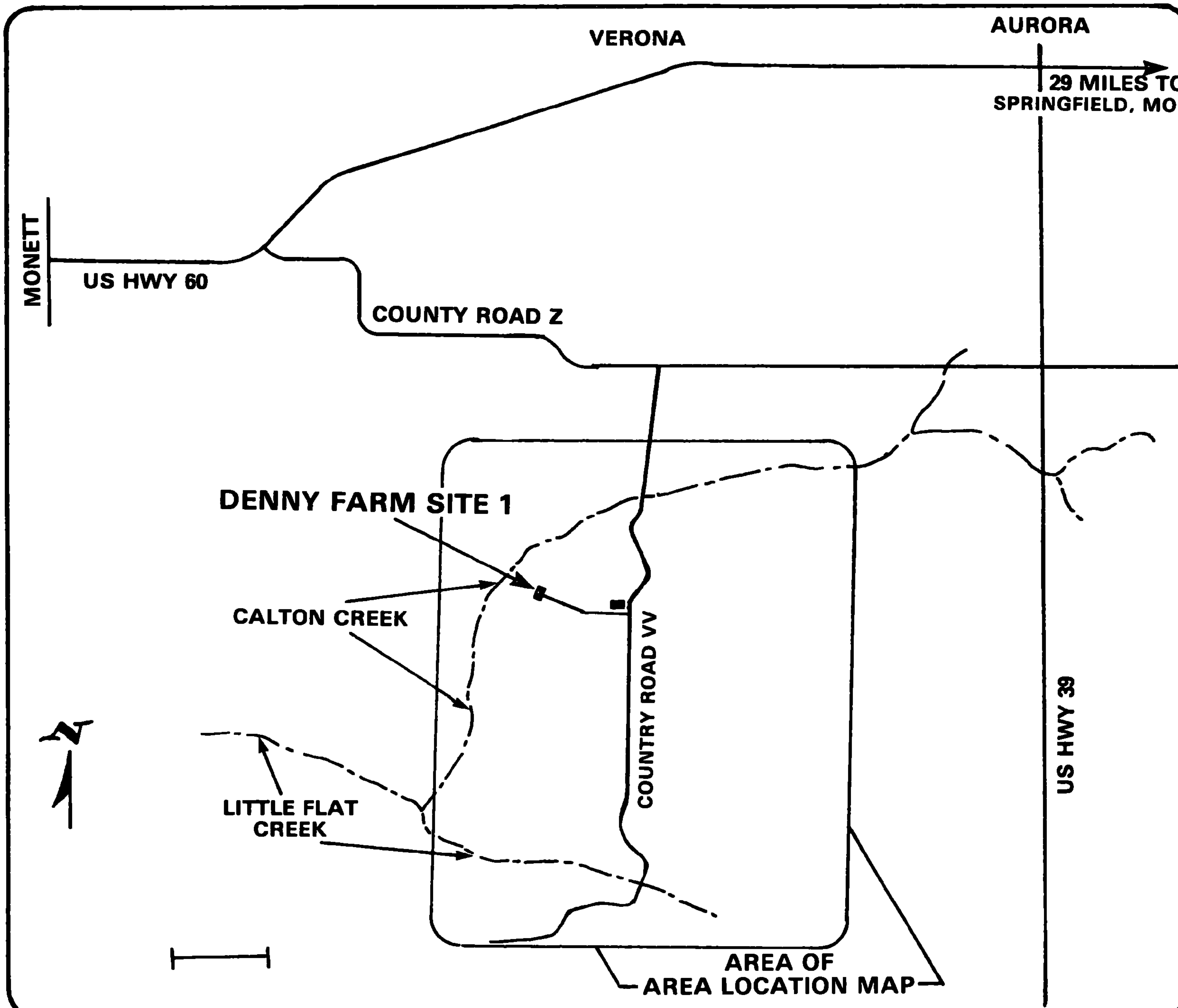

Figure 4-1. Plan View of Denny Farm Site 1 Area

DEMOGRAPHY

Barry County, the location of Denny Farm Site 1, is typically rural. According to 1980 figures, the overall population of Barry County is 24,100. Projections for 1985 indicate that this figure will rise by approximately 1,400 to a total population in 1985 of 25,500.

The town of Aurora, Missouri--the most densely populated area that is closest to Denny Farm Site 1--has a population of 6,200. Aurora Township, in which the town of Aurora is located, has a population of 7,110, including the population in the town of Aurora.

Verona, Missouri, just west of Aurora, has a population of 680.

Both Aurora and Verona are in Lawrence County--about four miles north of the Barry-Lawrence County line. Denny Farm Site 1 is one to three miles south of that county line (1).

CLIMATOLOGY

Officials of the National Oceanic and Atmospheric Adminstration, U.S. Department of Commerce, have compiled valuable climatological data related to the Aurora, Missouri, area (2). The statistics are for the Springfield, Missouri Municipal Airport--the information-gathering station closest to Denny Farm Site 1. The data cover a fifteen-year period.

Prevailing wind direction in the area is always out of the south-southeast year round. Wind speeds are relatively constant throughout the year with a mean hourly speed of 11.6 miles per hour. The general area around Denny Farm Site 1 historically has a high incidence rate of tornado touchdowns. The average tornado damage area has been estimated to be about two square miles. (More detailed information regarding tornadoes can be found in Appendix B of this report.)

Normal temperature averages during the reported period ranged from a monthly low in January of 33.6°F to a monthly high in July of 78.8°F. The yearly average temperature for the period covered was 56.5°F.

Precipitation figures for the observed period show a normal rainfall average of a low in January of 1.96 inches and a high in May of 5.28 inches. The yearly average rainfall for the period covered was 41.08 inches. Figures of snow and sleet precipitation show a low--a "trace" too small to be measured--in October and a high of 3.4 inches in February and March. The yearly average snow and sleet for the period covered was 13.0 inches.

The yearly averages for relative humidity in the area are:

- o Midnight: 78 with monthly ranges from 71 to 85
- o 6 a.m.: 82 with monthly ranges from 77 to 89
- o Noon: 57 with monthly ranges from 50 to 62
- o 6 p.m.: 61 with monthly ranges from 54 to 68

SUMMARY OF GEOLOGY AND HYDROLOGY

The geology and hydrology of Denny Farm Site 1 and its environs were studied by acquisition of existing data and by geophysical exploration. E & E initiated remote-sensing geophysical exploration to determine: (1) local geology/hydrology, (2) boundaries of the barrels and trench, (3) bottom of the trench, and (4) subsurface anomalies in and around the trench. After careful review of the geological/geophysical data obtained, test borings were made to confirm the interpretations and obtain additional soil samples. The geophysical methods used were electromagnetic conductivity, seismic refraction, electrical resistivity, ground penetrating radar, magnetometry, and metal detection.

Following are the conclusions drawn from the study:

- o Movement of fluids out of the trench would occur predominantly in a vertical direction with impetus given by precipitation percolation (negated by impervious cap placed recently) or by a sudden release of large volumes of material due to corroding drums.

- o A great variance of the coefficient of permeability of the soil should be expected with water movement through the soil tending to be slow in the clay and more rapid in the cherty zones. However, movement into the bedrock would be very rapid through any "pipes" (open soil fractures) that may exist under the trench.

- o Upon entering the weathered Reeds Spring Formation, flow or seepage would continue vertically until the water table is reached. Flow would then be lateral but predominately along the joint and fracture patterns. Because of uncertainty as to the precise orientation of the various joints, fractures, and solution cavities, calculations of directions of flow could be accomplished only on a probabilistic basis.

- Some contaminant attenuation would occur with flow through the soil. However, should contaminants move into pipes or sinkholes, little attenuation potential would exist.

- Although sinkholes are common in the vicinity of Denny Farm Site 1, the probability of one forming at any specific point such as under the trench is exceedingly low.

- Conditions are potentially favorable for rapid downward contaminant migration to the groundwater. Although the impervious cap has greatly reduced the likelihood of precipitation percolation dragging the contamination deeper and closer to the groundwater supply, corroded drums could release volumes of fluid into the surrounding soil and movement would begin independently of precipitation. Therefore the local geology of this site has conditions which could be conducive to the seepage of liquid contaminants out of the trench.

- On-site geophysical reconnaissance showed that the trench is approximately 960 square feet in area and 6 to 8 feet in depth. It is estimated that the trench could contain 140 to 150 drums.

GEOLOGY

Regional

Denny Farm Site 1 is situated on the Springfield Plateau on the edge of the Ozark Mountains' foothills, with the Ozark dome about 190 miles east-northeast of the site.

The region represents a section of the Ozark peneplain which had developed in mid-Tertiary times (approximately 30-40 million years ago). With subsequent uplift episodes from mid-Tertiary to present time, the rejuvenated streams eroded downward to maintain gradient and created incised valleys and thereby the existing dissected and rugged conditions.

The area is underlain by the Osagean and Kinderhookian Series of Mississippian Age bedrock. The specific unit in the vicinity of Denny Farm Site 1 is the Reeds Spring Formation, a gray to blue-gray limestone with alternating bands of chert. Thickness of this formation within the area has been reported as 125 feet to about 225 feet in the southernmost portions of the state. In most of the region the Reeds Spring Formation lies conformably on the Pierson Formation. However, the rock that immediately underlies the Reeds Spring Formation in the area of Denny Farm Site 1 is the Compton Formation, a thin-bedded, crystalline, crinoidal limestone with some chert nodules (3). The Compton Formation ranges from 20 to 50 feet in thickness.

The ridge tops are capped with a thin 3-foot veneer of loess, an aeolian-deposited buff silt. The loess is underlain by a red kaolinitic silty clay and silt with numerous angular chert fragments. This soil is residual in nature, the silty clays having been derived from the weathering and disintegration of the underlying parent limestone bedrock and the more resistant chert left behind in the clay matrix. In some instances, the relict fabric of the chert bands is visible in road cuts in the soil as dissected bands of angular chert.

Colluvial erosional processes have prevented ridge sides from developing soil cover; thus bedrock is present at the surface in these areas. Valley soils developed by colluvial infilling are thick, complex mixtures of stratified and non-stratified materials.

Some folding and faulting of the strata occurred, most of it concurrent with the Tertiary uplift episodes. McCraken (1971) reports several structural features in the area, including the eastern end of an east-west-trending normal strike-slip fault with total vertical displacements of 150 feet (4). The end of this fault (Ritchey fault) occurs about five miles north of the site, with the down-dropped block on the south. The north-northwest axis of the Osage-Verona anticline (an upward folding of rock) also exists about three miles east of Denny Farm Site 1.

The uplift, and consequent folding and faulting, created many fractures in the relatively soluble Reeds Spring limestones. Thus, solution activity from groundwater has created a classical karst topography characterized by sinkholes, linear and right-angle valley formation, pinnacle weathering, disappearing streams, springs, and caves.

In many instances, infilling of fractures or solution cavities in the bedrock occurs with the downward percolation of water through the soil at the bedrock interface. Water seepage assisted by mass wasting and gravity gradually enlarges or "stopes" upward the resulting void. This stoping phenomenon continues until the void is within 7 to 10 feet of the surface. At this point, the remaining soil overburden collapses suddenly, forming a 40- to 70-foot-deep hole with nearly vertical walls.

Although sinkholes have developed independent of man's activities, it has been illustrated by Aley et al. (1972) that changes in drainage by either the impoundment of water or by the reduction or lowering of the water table have induced sinkhole collapse (5). Examples of these include the West Plains, Missouri, collapse of 1964 and 1966 in which effluent entered the bedrock-groundwater system when a sinkhole developed under a 49-acre two-cell lagoon. A similar incident occurred at Republic, Missouri, in 1968.

In addition to the rejuvenation of streams and erosion of numerous valleys, gullies have been formed by the sequential linear formation of sinkholes in an uphill direction. This phenomenon is apparent on the Verona, McDowell, and Aurora topographic quadrangle maps as well as in aerial observations and photographs. Many of these linear progressions of sinkhole development, as well as cave development, have been associated with solution and water movements along joint fracture systems within the bedrock. This is illustrated by the linear nature of the area's valley-gully orientation and periodicity, as well as by the right-angle turns observed in Calton Creek west of Denny Farm Site 1.

The solutional processes also lead to pinnacle weathering, which is the enlargement of vertical fractures at the bedrock surface to the point where the fractures actually occupy more space than do the intervening bedrock remnants. These enlarged fractures, commonly up to 20 feet wide at the top and up to 30 feet deep, are usually completely buried by the residual soils and thus not visible on the land surface.

Local

The Denny Farm Site 1 is located atop a northwest-southwest ridge at SE 1/4, NW 1/4, NW 1/4, Sec. 20, T25N, R26W, approximately one-third of a mile south of Calton Creek (cf. Figure 4-1 which outlines the area of the Figure 2-2 area location map). The site is underlain by red, cherty clay soils of the residual nature previously discussed, which grade into the parent material, i.e., the cherty limestone of the Reeds Spring Formation. Typically, this rock is highly fractured and exhibits classical sinkhole development and pinnacle weathering. There is no direct evidence of catastrophic sinkhole development existing within 200 yards of the disposal trench on the Denny Farm. However, numerous recent collapsed sinkholes and piping were observed within a mile of the site.

Little direct hydrological investigation by coring, soil boring, or backhoe excavation had been done in the vicinity of the site prior to June 1980. In April 1980, fourteen soil borings were made by EPA-Region VII around and adjacent to the trench. An attempt was made to sample the soil in the interval 8 to 10 feet below the existing grade. In some cases, auger refusal occurred before those depths were reached. Because of the possibility of penetrating localized pockets of contaminated seepage, no attempt was made to drill deeper to define the soil-bedrock interface. In any case, the purpose of the boring program was to collect and analyze only near-surface samples adjacent to the trench for the presence or absence of dioxin.

However, it was still necessary to ascertain if downward movement of contaminants was possible. In view of the complex geologic conditions discussed above, it was not deemed safe to begin immediately drilling to bedrock in the vicinity of the trench until some of the uncertainties were removed by using geophysical methods that would not disturb the site and trench soils.

Therefore, E & E initiated remote-sensing geophysical exploration to determine: (1) local geology/hydrology, (2) boundaries of the barrels and trench, (3) bottom of the trench, and (4) subsurface anomalies in and around the trench. After careful review of the geological/geophysical data obtained, test borings were then made to confirm the interpretations and obtain additional soil samples.

The geophysical methods used were the following:

- o Electromagnetic Conductivity (EM)
- o Seismic Refraction
- o Electrical Resistivity (ER)
- o Ground Penetrating Radar (GPR)
- o Magnetometry
- o Metal Detection

The EM data were collected along continuous northeast-southwest traverses outside the site proper. Each traverse was 800 feet long and 25 feet apart. Figure 4-2 is a contour interpretation of the EM data. The contours are representative of the electromagnetic conductivity (reciprocal resistivity) of the upper 20 feet of the soil-bedrock complex. The values are a function of the type of soil and bedrock present, the degree of porosity in the soil and bedrock, and the nature of any fluids which may be present in the pore spaces.

By reference to Figure 4-2, several important statements can be made concerning the geology and soils outside Denny Farm Site 1. First, the area surrounding the site has a relatively high conductivity (8-12 millimhos/meter), which diminishes to very low levels in the northeasterly and southwesterly directions (2-4 millimhos/meter). In both of these low-conductive areas, field investigation showed that the soil cover ranges from very thin to non-existent. The limestone bedrock is much less conductive than the overlying soil.

As shown on Figure 4-2, higher conductivity values were found in the areas of Lines AB and CD. Initially it was thought that these anomalies, particularly AB, might be caused by lateral migration of contaminants. However, drilling and sampling of these areas (see Figure 4-3) showed that the anomalies were zones of localized increases in clay and reduction in the amount of chert fragments (7). Apparently the anomalously high conductivities were caused by the higher conductance of the clays, which maintain a higher moisture content. The clay zones containing less chert may be the result of differential weathering of the original bedrock or remnants of clay-filled joints and fractures of the original cherty limestone.

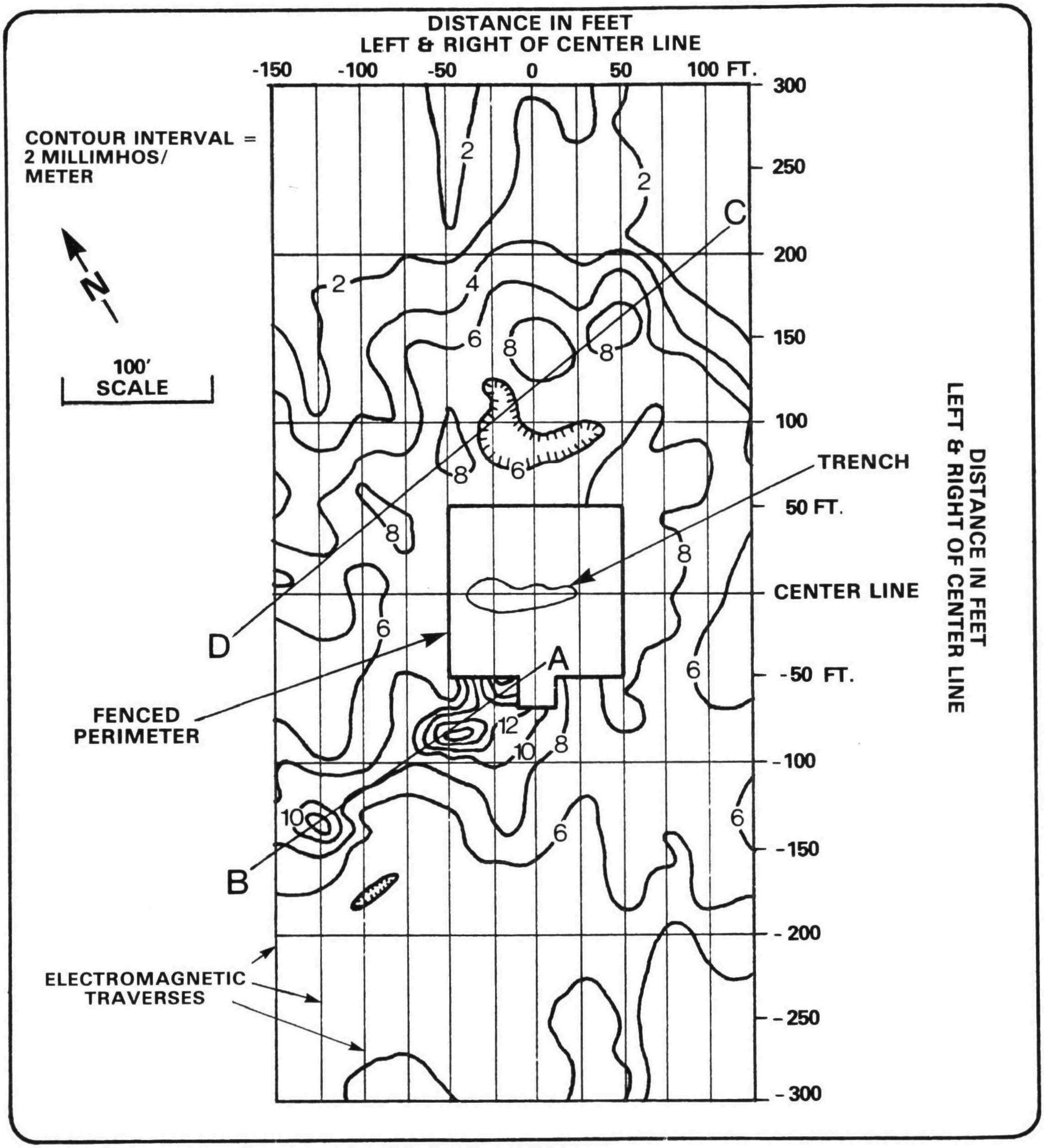

Figure 4-2. Contour Plot of EM Data

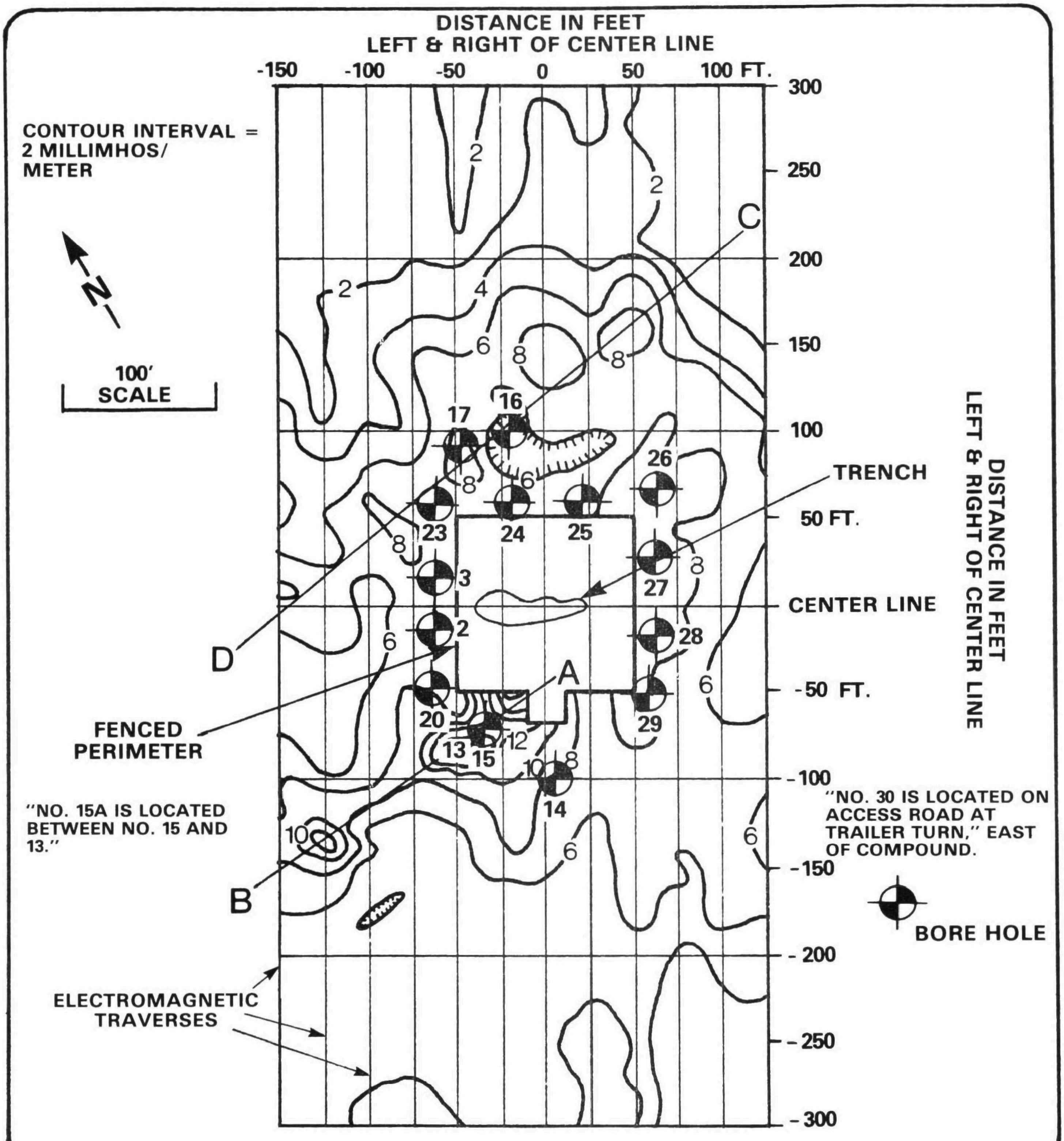

Figure 4-3. Bore Hole Locations

Laboratory analysis of the soil samples was conducted by the U.S. Environmental Protection Agency Surveillance and Analysis Division in Kansas City, Kansas. Results of the soil samples tested have been negative for those samples taken the week of July 14 through 19, 1980, in the area surrounding the fence (cf. Figure 4-3).

The results of the geophysical tests and subsequent ground-truth borings indicate a three-layer system of overburden. The upper horizon consists of loess, which is a buff, low plastic silt. Because of the nature of deposition (aeolian), silt size, and low moisture content, low seismic velocities were recorded (less than 1,000 feet per second). The ground-truth borings confirmed an average thickness of 2 to 3 feet within the compound clearing, with a localized thickening to 6 feet near the southwest corner of the fence and an absence of loess about 25 feet south of the fence gate. The loess cap thins locally toward the slopes, away from the site, where erosion has removed the soil.

Also occurring locally are Pennsylvanian-aged boulders of a fine-grained, iron-oxide-cemented sandstone. These boulders occur along the east side of the fenced area and in sporadic areas surrounding the ridge downslope in gullies (6). It was postulated from visual observations that the sandstone might underlie the site and that because it is permeable, it might conduct surface-water percolation to the ponds occurring west of the site. However, no evidence of a sandstone layer was observed in the ground-truth borings around the fence.

It is likely that during Pennsylvanian time the channel sands were deposited in valleys incised into the Mississippian rock. Following lithification and later uplift, the surrounding Reeds Spring Formation had weathered into a residual soil, but the more resistant sandstone boulders (as on the east fence, south end) were left to rest on the surface (7).

The second layer of overburden consists of residual red silty clay and chert fragments. The fine-grained fraction varies locally from "MH" to "CH" according to the Unified Soil Classification System. The soil was characterized by X-ray diffraction methods as containing "very fine (clay sized) quartz kaolinite/chlorite and geothite minerals. It is notable that these deeper and very old soil clays were extremely disordered (poorly crystalline) as established by their poor X-ray reflections. . . ."(6). This horizon is also characterized by low seismic velocities, albeit somewhat higher than those of the upper loess horizon. Seismic velocities ranged from 2,400 to 3,500 feet per second. Seismic and resistivity methods indicated that the residual clays, which are about 11 to 16 feet thick along the west fence line, thicken to 29 to 37 feet along the east fence line. This was fairly well corroborated by the ground-truth borings.

Ground penetrating radar detected an additional thin soil horizon about 3 feet below grade. This layer was interpreted to be the fragipan layer described in discussion with Dr. J. Hadley Williams (3) and in various publications on Missouri soils and geology. This zone was considered important because its normally low permeability could play a role in controlling shallow drainage. Radar data showed that the zone is generally broken and dissected but occurs as a continuous layer in the vicinity of the west and north corner of the site fence. Augering, auger sections, and split-spoon sampling were used in the borings to define the fragipan layer (see Appendix C for details of soil borings). However, no definite layers were found. It is likely that the fragipan occurs as a poorly developed and dissected subtle layer so that it is not observable by normal drilling procedures. As such, it does not seem to be significant in controlling drainage.

The lowermost horizon encountered represents the top of the highly weathered and fractured Reeds Spring Formation. The presence of residual float rock somewhat isolated a short distance above the parent bedrock indicates that the distance to relatively unweathered bedrock could be an additional 10 to 30 feet below the top of the weathered zone. This horizon consists of chert and cherty limestone, which the augers refused to penetrate during drilling. The drilling characteristics about 2 to 3 feet above the refusal depth indicated that a high amount of weathering has probably occurred. This interpretation is supported by the fact that the highest seismic velocity measured was 6,000 feet per second. Velocities in massive rock or limestone usually exceed 10,000 feet per second.

Using Borings #21, #25, and #28 (see Figure 4-3) as references, the bedrock surface of the lowermost horizon encountered slopes to the east at an angle of approximately 8^{o} from the horizontal.

A single deep boring was drilled about 300 feet south-southeast of the site along the access road (7). At that location (Boring #30), massive gray white chert was encountered in a layer from 35 feet to 47.4 feet below grade. A combination of diamond coring and tri-cone roller rock bits were used. This zone probably represents a surface of the Reeds Spring Formation which has been only moderately weathered. Core recovery was very low and averaged about 50% in the upper 4 feet, with most of the deeper penetration requiring the use of rock bits. The lower depths of bedrock (below 44 feet) represent a relatively unweathered competent surface, as shown by the increase in core recovery (100%) at that depth and the slow rate of core water loss.

During field inspections of the geology, joint patterns were observed along Calton Creek in the lower portion of the Reeds Spring Formation. The primary joint pattern trended northeast to southwest, with a secondary pattern trending northwest to southeast (see Figure 4-4). As shown in the figure, Calton Creek negotiates two right-angle turns north of the site, indicating structure-controlled flow, probably along joints or fractures. The rectilinear trend of the gullies and valley as seen in aerial photographs also indicates joint-controlled features in northwest-southeast and northeast-southwest trends.

Evidence of past sinkhole development was apparent from the large circular depressions observed on the ground in the valley about 700 feet northeast of the site and along the west side of Calton Creek about one quarter mile north of the point where Calton Creek flows into Little Flat Creek. In addition, the cirque-like headwalls of some of the gullies indicate that they originated from the coalescing of paleosinks (3) (see Figure 4-5).

Small sinkholes/pipes 2 to 5 feet in diameter have also developed as the result of water-percolation piping. These features have been observed along the gullies surrounding the site and about 30 feet southwest of the southwest fence corner (4" diameter). During the field

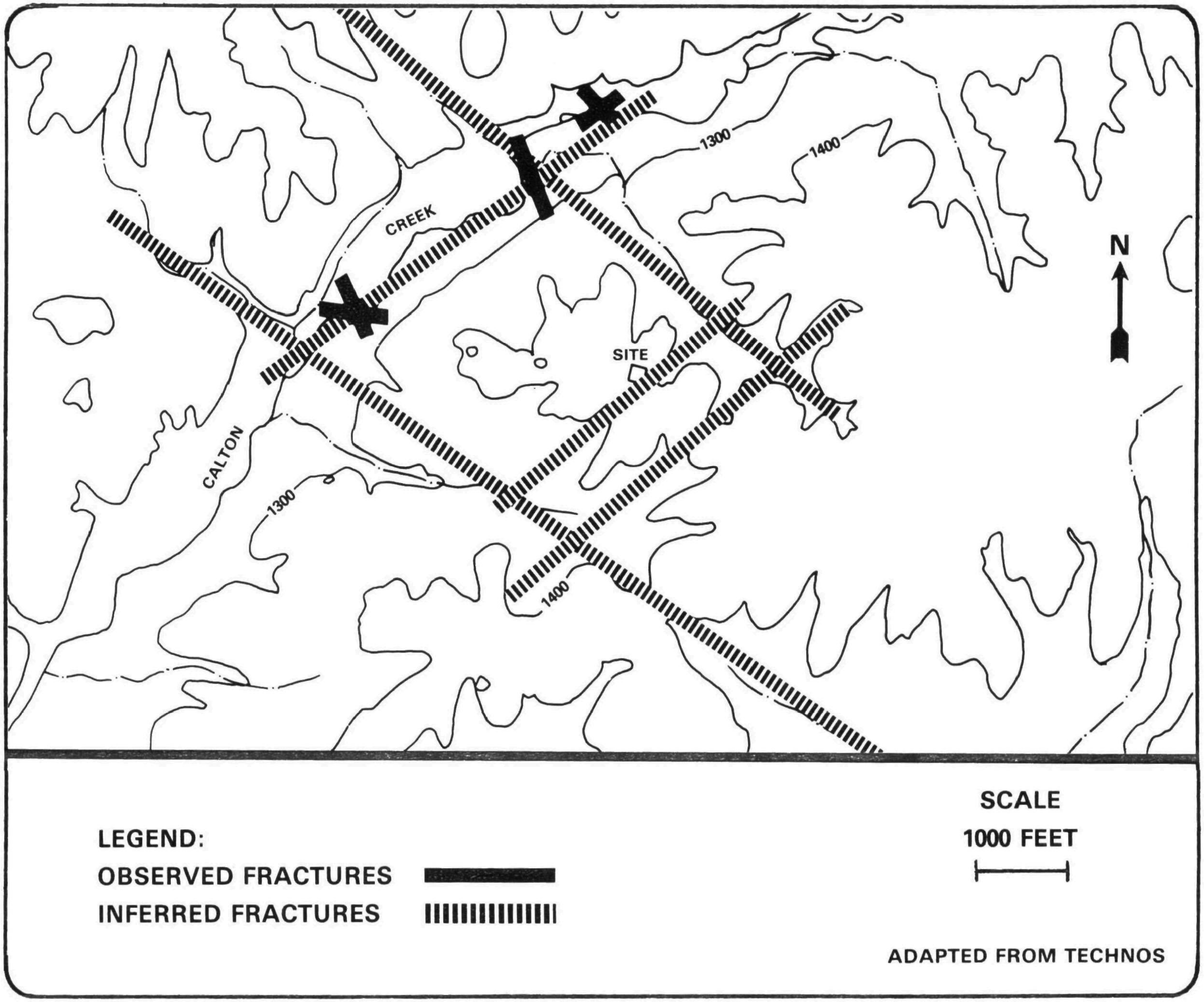

Figure 4-4. Fracture Patterns

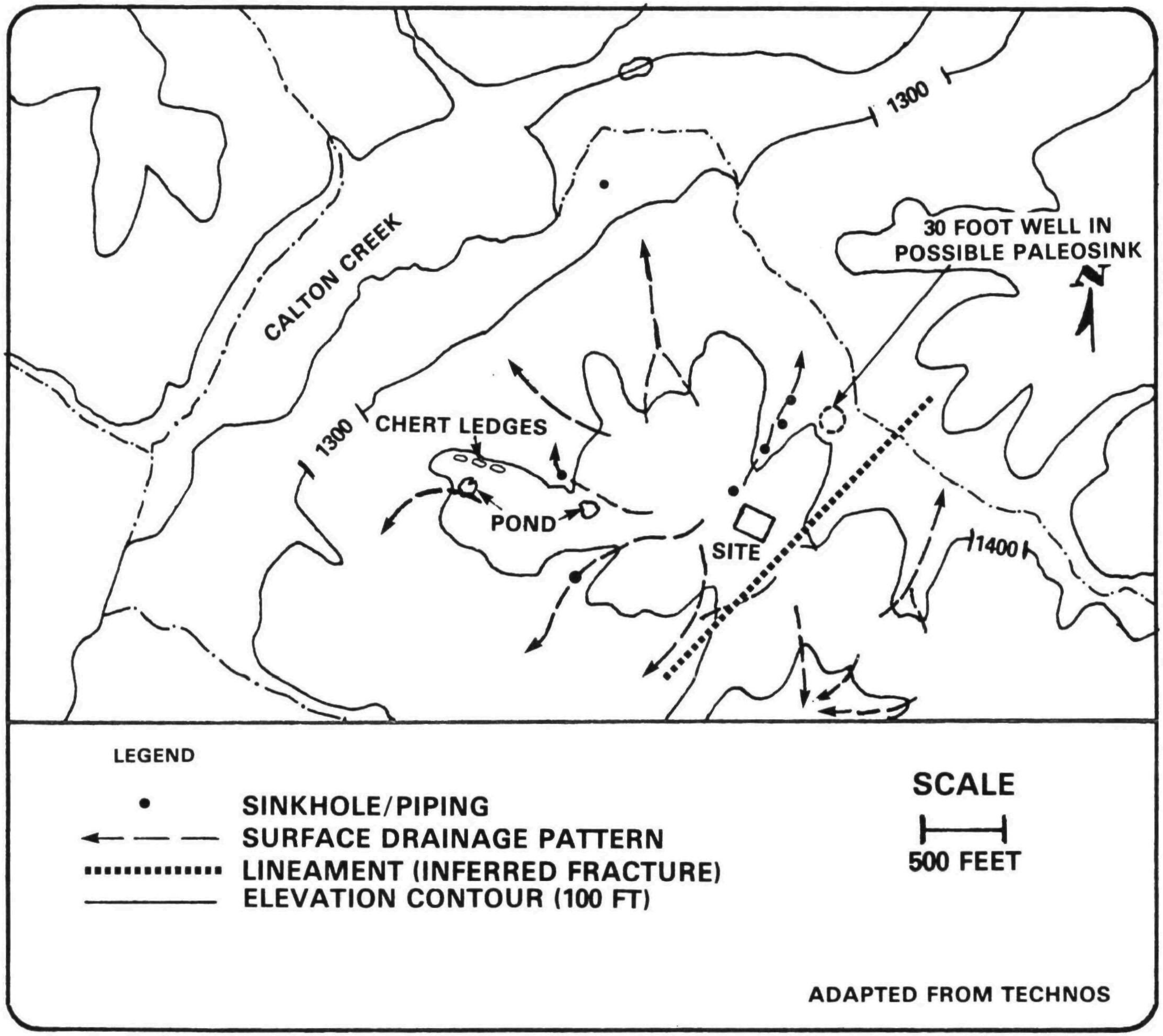

Figure 4-5. Selected Geologic Features

geophysical survey, traverses were made with the ground penetrating radar around the perimeter of the fence and along the access road. Results indicated that piping and downward percolation of precipitation probably occur at the site.

No caves were found or are known to exist in the immediate vicinity of Denny Farm Site 1. The closest known cave is Stansberry Cave located at SE 1/4, SW 1/4, R26W, T25N, about 3 miles east-southeast of the site.

HYDROLOGY

Denny Farm Site 1 is located in the White River drainage basin in southwestern Missouri. Precipitation in this area averages approximately 45 inches per year. Half of this amount is evapo- transpired back to the atmosphere, while most of the remainder infiltrates the water table. A small amount runs off as surface drainage.

Groundwater movement in the area generally parallels the surface drainage. In many geological terrains this generalization can be useful even at a site-specific level. However, in fractured limestone terrains, the density and orientation of fractures, as well as the degree of their solution enlargement, can vary greatly over very small distances. For example, yields from wells in limestones may vary by several orders of magnitude in holes drilled only a few feet apart. Therefore, prediction of directions and rates of local groundwater movement is difficult.

The Denny Farm Site 1 trench is located very near the topographic high point of the ridge approximately 150 feet above Calton Creek. Immediate surface drainage (cf. Figure 4-5) is to the east into a swale opening into a tributary valley, which then opens to Calton Creek. The drainage of Calton Creek flows south into Little Flat Creek about two and a half miles from the site. Flat Creek flows east-southeast to the James River and then south to the Table Rock Lake reservoir on the White River. The drainages cover a distance of roughly forty miles.

It should be noted that little actual surface flow occurs in any of the swales, gullies, and tributaries. There are seldom any defined channels, wet or dry, in any of them. The soils and bedrock in these swales are so permeable that precipitation cannot run off the surface; instead water percolates downward to the water table and then moves laterally as groundwater to a more regional discharge point such as Calton Creek. Even on the tops of ridges, which are covered with a thick mantle of clayey soil, infiltration readily occurs. This phenomenon was observed firsthand by field personnel conducting the geophysical field work. During June 1980, several thundershowers deposited an estimated 3 inches of precipitation on the site. During these storms, the water puddled over most of the relatively flat ridgetop surface. Within an hour after the rain had stopped, the water in the puddles had soaked into the soil. The high percolation rate was also apparent during aerial reconnaissance of the area with Dr. Williams, who pointed out several unsuccessful attempts to create farm ponds.

Once precipitation enters the soil in the vicinity of the trench, it moves predominantly vertically. The fragipan layer would have little effect on vertical movement because of its dissection, variable presence, and shallow occurrence with respect to the anticipated trench base. Some lateral movement would occur along the thicker relict chert horizons bounded by the clay-rich lenses encountered (7). However, because of the discontinuity of both the relict structures and the clay lenses, the basic movement is vertically downward. This is further borne out by the absence of springs on the hillsides in the immediate area and by the absence of stream flow in the swales running off the hillsides.

It is also apparent from the flow of Calton Creek as well as other tributaries that the amount of surface flow is controlled by the jointing and fracturing of the Reeds Spring Formation. Certain segments of Calton Creek have no flow and are colloquially referred to as "losing." Other segments of the creek that do have flow are referred to as "gaining" (see Figure 4-6). Recent dye tests (8) on the creek show good hydrologic connections between successive losing and gaining segments. In one instance, dye released on a gaining segment was soon picked up in a well adjacent to the next downstream gaining segment. Apparently, the dye had moved rapidly through the bedrock in the intervening losing segment. It should be noted that this rapid subsurface movement occurs within one-third mile of the Denny Farm Site 1.

Rapid infiltration of surface waters can occur through zones of piping within the soil horizon or through sinkholes. Because of the

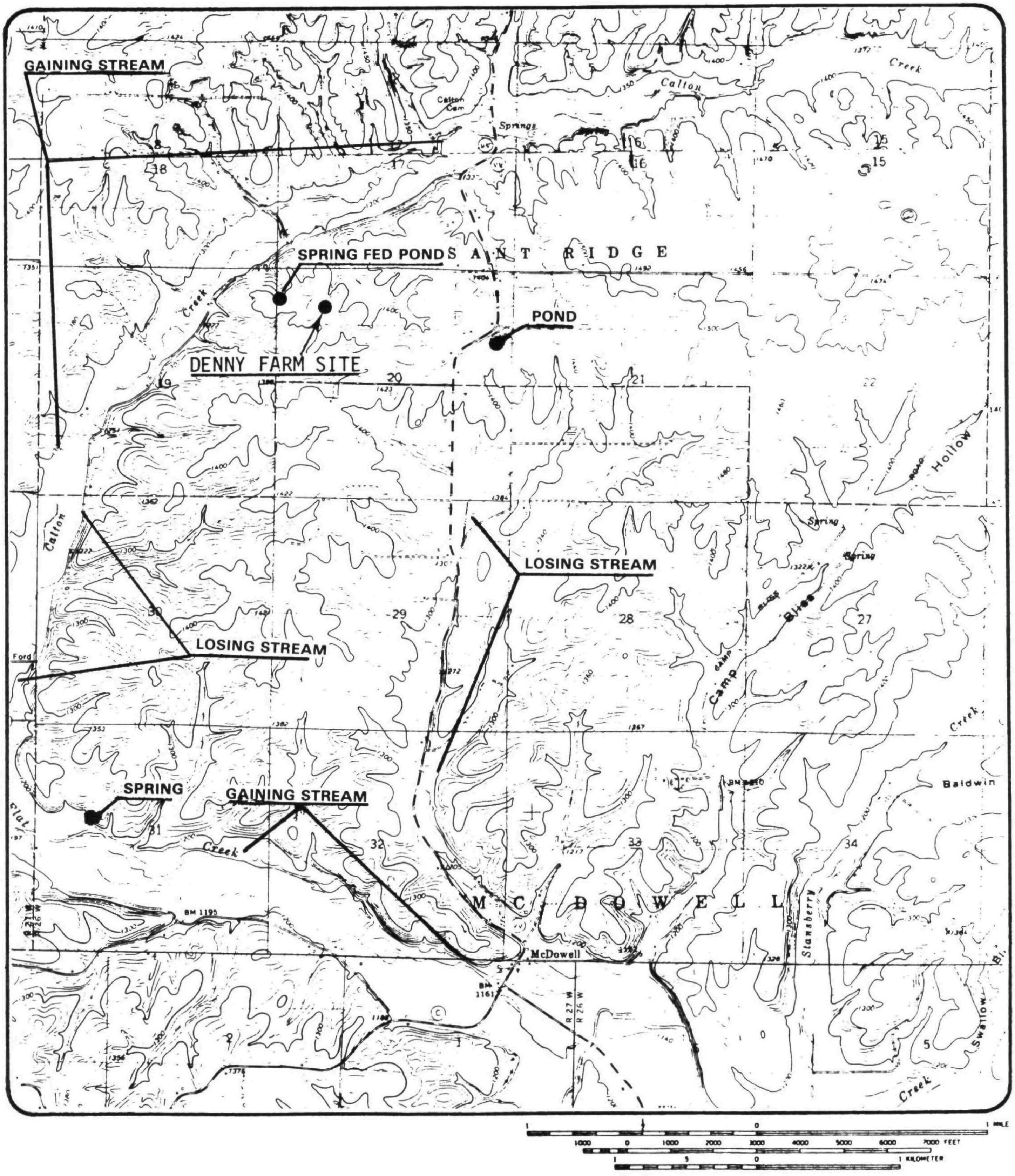

Figure 4-6. Gaining and Losing Stream Locations

vertical voids in these structures, water can be directed very quickly to the fractured weathered Reeds Spring bedrock and to the water table. Williams and Vineyard have compiled a list of geologic indicators in which subsidence or collapse may occur in karst terrain (9). This list is reproduced below:

- Collapses are more likely to occur in residual soil ranging in thickness from 40 to 100 feet (12-30 m)

- Collapses are more apt to occur in residual soil retaining the fabric of the parent material; collapses are uncommon in colluvial deposits or in alluvium deposited by gaining streams

- Collapses are more likely to occur where the clay fraction has low plasticity (MH; A-7-5), common to kaolinitic and halloysitic clays

- Collapses are not common where a poorly drained surface soil exists even if this surface soil is underlain by other features typical of collapse indicators

- Collapses are more apt to occur in losing streams and watersheds than in gaining, but are as common to the uplands or slopes as floodplains of losing areas

- Sinkholes per se are not normally indicative of land surface failure by catastrophic collapse

- Collapses are more frequent in areas underlain by limestone, dolomite, and gypsum, but have been reported in other types of bedrock

- Cave systems developed along the soil-bedrock contact are common in areas having a history of land surface failure by collapse

- o Cave passageways are periodically or continuously drained by streams

These conditions are essentially satisfied by the geologic conditions observed at Denny Farm Site 1. However, the absolute likelihood of a sinkhole developing at any particular location is still very low.

Within the compound clearings, no water was observed in the borings which would be indicative of a perched water table. The deepest boring was drilled 47.4 feet below grade (or about 60 feet below the existing grade of the compound area), and the water table was not encountered. It is estimated that the water table is about 114 feet below the site. This assumes a local water-table gradient of 3%, which is typical in karst or solution-developed terrain (8).

In summary, the borings indicate that the lateral movement of fluids from the trench is unlikely. The fragipan layer has little effect on vertical movement because of its dissection, variable presence, and shallow occurrence with respect to the anticipated base of the trench.

The EM anomalies investigated were attributed to a higher clay and moisture content. It can be inferred, then, that any seepage from the trench would flow around zones of high clay and low permeability and seep into more pervious zones (pockets or dessication cracks) (8). Due to the lack of continuity of the high-plastic clay layer, flow or seepage would occur laterally for a short distance before encountering a more pervious horizon of cherty, clayey silt, or chert fragments. At that point, vertical movement would continue. The above scenario of seepage out of the trench, to this point, assumes that similar soil conditions exist under the trench as were encountered in the borings.

The coefficient of permeability of the soil would vary depending on the viscosity and temperature of the materials leaving the base of the trench, the grain size distribution, dry density, and stress history. However, it would probably range from 10^{-3}cm/sec (fine sands and inorganic silts, stratified clay deposits) to 10^{-7}cm/sec (homogeneous clays below zone of seasonal volumetric change). By using these permeabilities and assuming a constant head and no piping, it can be estimated that after nine years, the leachate boundary could be as shallow as 1 foot (10^{-7} cm/sec) or could have reached bedrock (10^{-3} cm/sec). Again, this does not take into account piping.

Although the sandstone was observed as a float rock outcrop along a few of the gullies surrounding the ridge, it was not observed in any of the borings drilled during this program. Therefore, it is unlikely that seepage from the trench would occur toward the west ponds through the sandstone extrapolated to underlie the trench (6). The geophysical and geological studies which have been performed in the past two months have been centered on both general and site-specific conditions. Contamination has not been detected in the wells which surround the site and have been continually monitored by EPA/SVAN Region VII (cf. Figure 3-2). This simply means that contaminants have not arrived at those points. The possibility still exists that the water table can become contaminated.

Therefore, it is a distinct possibility that liquid contaminants or leachate could emanate from the trench and reach the groundwater and surface waters because of the following conditions:

- o Variable but predominately high permeability of overburden "soils"
- o Evidence of piping in the immediate vicinity
- o Highly fractured, permeable, and soluble bedrock
- o Remote possibility of catastrophic sinkhole collapse
- o Evidence of fracture-controlled drainage

GEOPHYSICAL RECONNAISSANCE OF THE TRENCH

Besides the geophysical reconnaissance and soil exploration outside the Denny Farm Site 1 perimeter, E & E used similar remote sensing techniques within the fenced area to define the trench,its contents, and the subsurface geology in more detail. In addition to delineating the environmental conditions of the site, data were necessary for the conceptual design effort for remedial action. Obvious concerns about the site were

- o Establishing the trench boundary and depth
- o Defining the spatial distribution and number of drums buried
- o Defining the subsurface conditions around and below the trench
- o Identifying any potential movement of material from the trench

Originally, the trench was thought to be delineated by the 1-foot-deep surface depression as 53 feet long by 10 feet wide. However, the on-site studies conducted in June 1980 using magnetometers and metal detectors led to the conclusion that the area occupied by the drums, and thus the size of the trench, is somewhat larger. Figure 4-7 illustrates this area (shaded). It is 960 square feet, i.e., 80% larger than the original estimate (outlined). The shaded area as shown on Figure 4-7 does not indicate the boundary of the original excavation, but rather the edge of the outermost drums regardless of the depth. Metal detector data indicate that, in addition to the buried drums in the trench, smaller metallic debris is present over much of the area.

The depth of the trench, as determined by ground penetrating radar (GPR), is between 6 and 8 feet. The trench, as shown on the ground penetrating radar plot (see Figure 4-8) appears to be shallower to the south and deeper with steeper sides to the north. The GPR data also show that the eastern end of the trench is shallower than the western end. The arrow in Figure 4-8 locates the deeper portion of the trench. The smaller anomalies indicated on the traverse of the trench are probably associated with reflection from the drums.

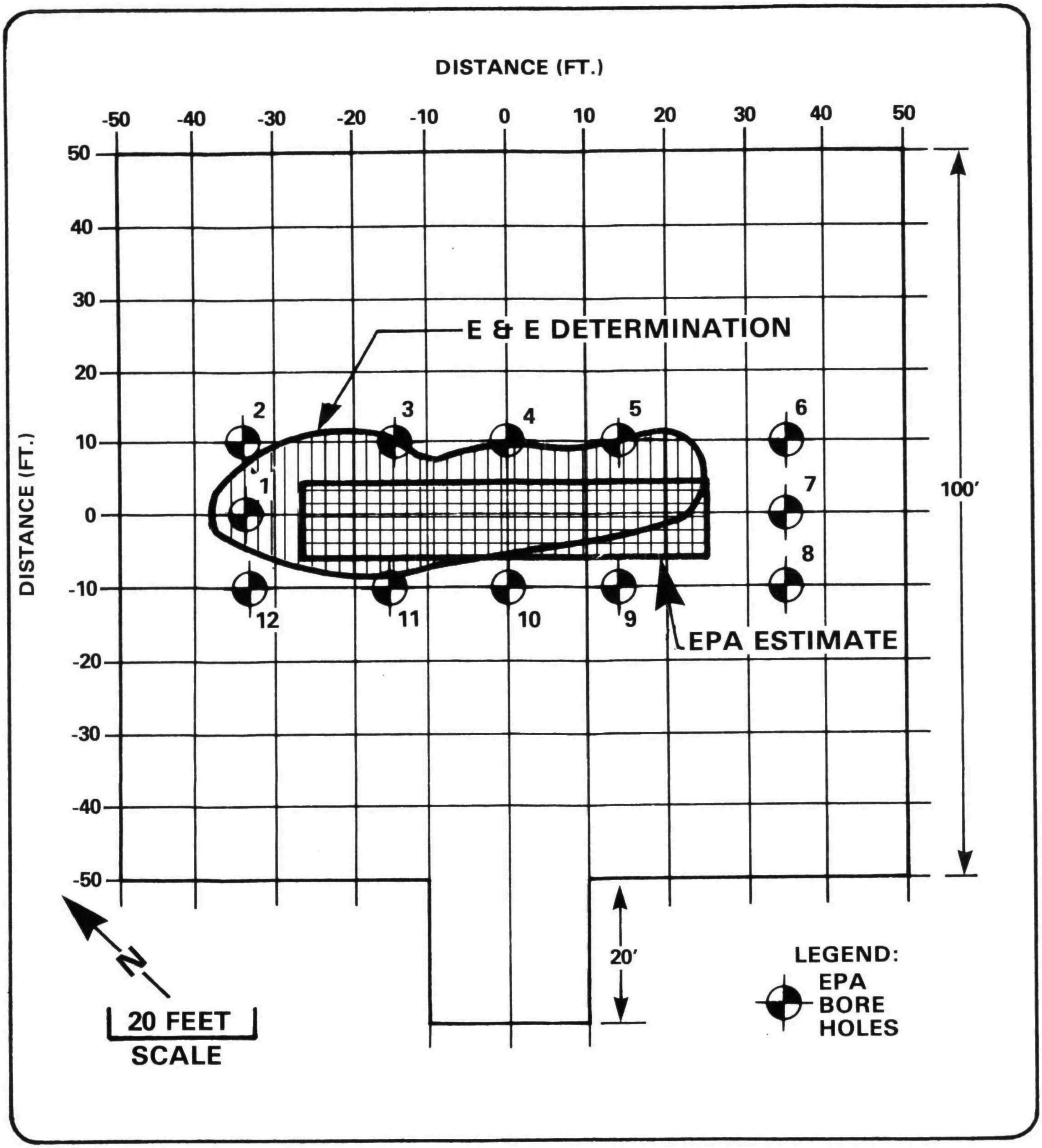

Figure 4-7. Plan View of Drum Distribution

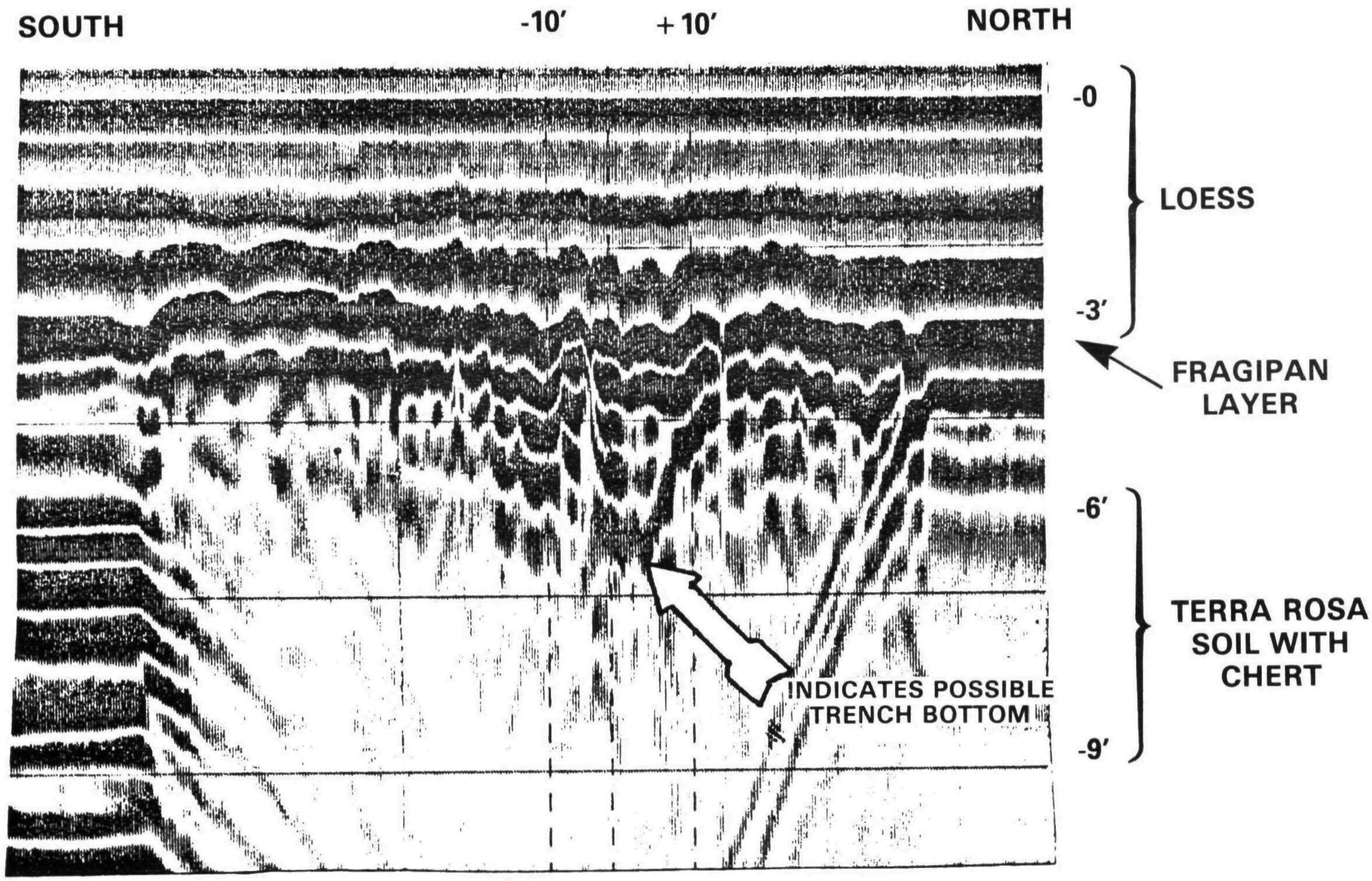

Figure 4-8. Radar Traverse - South to North of Disposal Trench

Resistivity measurements were also made within the perimeter; however, limited data were collected and are thought to be influenced by the metallic drums. From these measurements, the bottom of the trench was estimated to be less than 10 feet from the surface, which basically confirms the GPR data.

Based on the GPR, metal detector, and magnetometer data, E & E estimates that the trench could contain approximately 140 to 150 drums. Furthermore, from magnetometer data, the concentration of drums increases from east to west. This conclusion is also supported by the GPR data. In addition, the GPR data show the existence of a discontinuous soil horizon approximately 3 feet below the surface; this horizon is suspected to be the fragipan horizon.

Electromagnetic and resistivity data from inside the perimeter of the site could not be applied to data outside because of the presence of the fence and metallic materials within the perimeter. Therefore, the lateral migration of materials could not be confirmed, nor could the condition of the trench bottom.

REFERENCES FOR SECTION 4

1. Telephone conversation with Mr. Harmon Chapman, Transportation Planner, Southwest Missouri Local Government Advisory Council, Republic, Mo.

2. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. Climates of the States (Volume II). Port Washington, New York: Water Information Center, Inc., 1974.

3. Personal communication with J. Hadley Williams, Missouri Department of Natural Resources.

4. McKracken, Mary L. Structural Features of Missouri, Report of Investigation No. 49. Rolla, Mo.: Missouri Geological Survey and Water Resources, 1971.

5. Aley, Williams, and Masello. Groundwater Contamination and Sinkhole Collapse Induced by Leaky Impoundments in Soluble Rock Terrain. Rolla, Mo.: Missouri Geological Survey and Water Resources, 1972.

6. Technos, Inc. Report of Geological and Geophysical Investigation, Denny Farm Hazardous Materials Site, Barry County, Missouri. Report prepared for Ecology and Environment, Inc., July 1980.

7. Ecology and Environment, Inc. Results of Recent Borings Conducted at Farm Site No. 1, Verona, Missouri. FIT Region VII, July 1980.

8. Williams, J. Hadley. Hydrologic Aspects of the Farm Dump Near Verona, McDowell Quadrangle, Barry County, Missouri. Report through Missouri Department of Natural Resources, Engineering Geology Section, June 4, 1980.

9. Williams, J. Hadley and Vineyard, Jerry D. Geologic Indicators of Subsidence and Collapse in Karst Terrain in Missouri. Rolla, Mo.: Missouri Department of Natural Resources, Division of Geology and Land Survey.

10. Personal communication with Richard Benson, Technos, Inc.

UNCITED REFERENCES

Bohm, Rex A. Correspondence to Dan Harris, U.S. Environmental Protection Agency, Surveillance and Analysis Division, Region VII through Missouri Department of Natural Resources, Subsurface Geology and Oil and Gas Section, December 11, 1979.

Rowe, N. and Koenig, J. The Stratigraphic Succession in Missouri. Volume XL, 2nd Series, Missouri Geological Survey and Water Resources, 1961.

Missouri Geological Survey. Geologic Map of Missouri. 1:500,000, 1979.

Scrivner, C.L., Baker, J.C., Miller, B.J. Soils of Missouri. University of Missouri Extension Division.

Terzaghi, K. and Peck, R. Soil Mechanics in Engineering Practice. 2nd Edition. John Wiley and Sons, Inc., 1967.

U.S. Department of Agriculture, Soil Conservation Service. Soil Survey Interpretations, Clarksville Series and Wilderness Series.

U.S. Geological Survey. McDowell Quadrangle. Missouri, 1:24,000, 1972.

Williams, J. Hadley. Summary of Geologic Conditions at the McDowell Dump Site, Barry County, Missouri. Report through Missouri Department of Natural Resources, Engineering Geology Section, May 13, 1980.

SECTION 5

SITE CHARACTERIZATION

INTRODUCTION

The hazardous waste site in Aurora, Missouri, identified as Denny Farm Site 1 can be characterized by consideration of three elements: the methods used for disposing of the waste, a description of the waste, and public health and environmental concerns. Such characterization is the purpose of this section.

METHODS USED FOR DISPOSING OF THE WASTE

As noted in Section 2 of this report, the North Eastern Pharmaceutical and Chemical Company (NEPACCO) caused a trench to be dug on the Denny Farm near Aurora, Missouri, for the disposal of chemical wastes. Once the trench was dug, a truck backed up to the trench and haphazardly dumped some 150 drums of chemical waste into the trench. The drums were left as they fell. No attempt was made to make an orderly disposition of the drums. The trench was then filled in with between one and three feet of soil. No attempt was made to line or cap the trench.

When the trench was first reported to EPA-Region VII and the initial investigation was carried out, it was thought, because of surface depression, that the trench was 10 by 53 feet in dimensions--a fairly regular rectangle. Subsequent investigations by Ecology and Environment, Inc. (E & E), have determined that the trench is irregular in shape, somewhat the shape of a paramecium, and measures 20 by 65 feet.

Initially, the depth was undetermined by the EPA-Region VII investigation. Based on E & E's investigation with electromagnetic detectors, the trench depth has been estimated at 6 to 8 feet.

DESCRIPTION OF THE WASTE

Denny Farm Site 1 contains some 150, 55-gallon drums with chemical waste in liquid, sludge, and tarry residue forms; water that has leaked into the trench and accumulated there; and contaminated intermingled soil.

In more specific terms, known waste components (confirmed by analysis) at Denny Farm Site 1 are: tetrachlorodibenzo-p-dioxin (TCDD), 2,4,5,-trichlorophenol (TCP), toluene, xylene, tetrachlorobenzene, and ethylene glycol. Other suspected components of the contaminated wastes are: benzene ethers, benzene, phenol, chlorinated phenols, polychlorinated biphenyls, chlorinated benzene, sodium hydroxide, sulfuric acid, carboxylic acid, formaldehyde, and hexachlorophene.

PUBLIC HEALTH AND ENVIRONMENTAL CONCERNS

SUMMARY

Evaluation of the public health hazards associated with a chemical waste site requires consideration of the toxic potency of the chemical spoils. Also important in such assessment are those physical characteristics of the waste that affect dispersal and longevity of the hazard in the environment.

The overwhelming toxic feature of the Denny Farm Site 1 is the presence of tetrachlorodibenzo-p-dioxin (TCDD) in amounts exceeding 300 mg/l in the liquid waste material. This compound is one of the most poisonous chemicals known, an orally administered dose being lethal to the most sensitive test animal, the guinea pig, in concentrations less than 2 μg/kg of bodyweight. A comparable toxic dose in humans would be 140 μg, based on a body weight of 70 kg. This amount of pure TCDD would be barely visible to the human eye. In addition to being toxic if ingested, TCDD is also capable of penetrating the skin though absorption and is thus poisonous via dermal contact. In rabbits, the dermal lethal dose is about 2.5 times the oral dose.

The above toxicity discussion is based upon acute or short-term exposure situations. Unfortunately, TCDD levels required for toxic activity are much reduced in long-term or chronic exposures. This fact is supported by laboratory data that report toxic effects in guinea pigs at dose levels as low as 0.008 μg/kg administered on a weekly basis. The scientific literature describes diverse harmful effects from long-term exposure that include cancers, fetal deformity, and suppression of immunity response systems.

Presently, there are no established "safe levels" of TCDD exposure to humans in food or drinking water, but the 300 mg/l (ppm) measured level in the Denny Farm Site 1 wastes is 300 million times more concentrated than values being discussed as tolerable to humans. This fact generates concern about the health hazards presented by the disposal site in terms of the toxicity potential.

The solubility of TCDD in water is only 0.2 μg/l. This fact plus laboratory findings that indicate a strong attachment affinity between the toxin and soil particles results in its low mobility in soil moisture. Several reports by independent investigators have found that TCDD disappears at a moderate rate in soils, the calculated half-life being about one year. The low mobility in soil moisture and its lack of prolonged persistence make TCDD a rare contaminant of groundwater at distances removed from the pollutant source. Environmental contamination from dioxin is usually detected by analysis of stream sediments, to which it binds, and of aquatic and terrestrial organisms which bioaccumulate it.

Two factors that complicate the hazard evaluation of the Denny Farm Site 1 are the lack of predictability of limestone karst involvement in providing a conduit for water contamination, and the unknown solubilizing effects afforded by the other organic liquid co-pollutants present in the waste trench. Conceivably, these site characteristics could singly or jointly provide abrupt and high-level contamination of groundwater. Such an occurrence could be devastatingly harmful to humans and animals living in the area.

Evaluation of the hazards presented by Denny Farm Site 1 entails consideration of the acute and chronic toxicity of the chemicals known to be present on the site and their respective environmental fates. Environmental fate assessment includes consideration of mobility, persistence, metabolism, and bioaccumulation potential. All these factors interact to comprise the danger imposed upon the public adjacent to the disposal area and personnel involved in cleanup.

Historical data on the Denny Farm Site 1 indicate that 55-gallon drums containing the waste materials were dumped from a truck directly into an open trench. Based on an estimated 150 drums buried within the defined limits of the trench, a general assumption can be made that the initial waste volume dumped into the excavation would equal roughly 8,250 gallons. This also assumes that each drum was completely full at the time of disposal.

Table 5-1 lists chemical wastes known to be present in the trench. The presence of these wastes is based on conclusive analytical results from EPA. Also noted in the table are other chemicals suspected to be present in the waste due to their association with the manufacturing process for hexachlorophene. This information was derived by reviewing and reconstructing the synthesis scheme for that process.

Quantitative analysis on a four-drum composite sample taken by EPA revealed TCDD present at 319 mg/l. It should be noted that this sample was not homogeneous at the time of analysis. Therefore, this value may not be representative of the entire sample. It may be arguable that levels higher that this reported value may exist in different components in the trench. At any rate the sample evidence indicated alarmingly high TCDD levels within the confines of the trench.

Although the most toxic isomer (2,3,7,8-TCDD) has not been confirmed through analysis, it is of assumed presence based on its known and well documented association with the production of 2,4,5-trichlorophenol. Isomer anaytical studies are underway at Wright State University to confirm 2,3,7,8-TCDD presence in the waste. Although it is likely that numerous other hazards exist at Denny Farm Site 1, this report concentrates on hazards associated with the TCDD isomer because the toxic potential it provides is over a million-fold higher than any of the other chemicals known or suspected to be in the wastes. This evaluation is based on acute toxicity data. Furthermore, it will be seen that the remedial alternatives presented in this document will provide for containment of all chemical wastes.

Toxicological Considerations of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)

A. Acute and Chronic Toxicity in Animals

One of the major health concerns with TCDD contamination is that it is one of the most potently toxic substances known in mammalian species. Depending on the species, the acute and chronic toxic doses generally

TABLE 5-1

COMPOUNDS OF KNOWN OR SUSPECTED PRESENCE

AT DENNY FARM SITE 1

COMPOUNDS

- TETRACHLORODIBENZO-p-DIOXIN (TCDD)*
- 2, 4, 5-TRICHLOROPHENOL (TCP)*
- TOLUENE*
- XYLENE*
- TETRACHLOROBENZENE*
- ETHYLENE GLYCOL*
- BENZENE ETHERS
- BENZENE
- PHENOL
- CHLORINATED PHENOLS
- POLYCHLORINATED BIPHENYLS
- CHLORINATED BENZENE
- SODIUM HYDROXIDE
- SULFURIC ACID
- CARBOXYLIC ACID
- FORMALDEHYDE
- HEXACLOROPHENE

show a wide variation in the submicrogram to microgram range. As an example, the following values have been excerpted from recent literature:

Species	Dosage Regimen	Toxic Dose
Rhesus Monkey	Single Oral LD_{50}	70 μg/animal
Guinea Pig	Single Oral LC_{50}	2 μg/kg
Mouse	Single Oral LD_{50}	284 μg/kg
Rabbit	Dermal LD_{50}	275 μg/kg
Rabbit	Oral LD_{50}	115 μg/kg

An interesting feature of short-term toxicity tests with TCDD is that they have revealed an unusual temporal dependence, i.e., acute toxicity tests are always run for a time interval of a few days. Tests with TCDD reveal mortality in a time range of five days to several weeks. This prolonged interval and the variety of TCDD-induced tissue anomalies across the species investigated have thus far confounded attempts to determine the exact cause of death.

B. Carcinogenicity

A two-year chronic toxicity and oncogenicity study of TCDD has been completed in rats by Kociba and co-workers (1). Ingestion of 0.1 μg/kg/day caused an increased incidence in carcinomas of liver, lungs, and mouth while decreasing the incidence of tumors of the uterus; pancreas; and pituitary, mammary, and adrenal glands. Tissue samples from animals at this dose level contained 24 ppb TCDD in the liver, and 8.1 ppb in fat. Interestingly, the increased incidence of tumors in the lungs and liver at the high dose of this study occurred only in female rats while the oral-nasal tumors were significant in males. The authors also noted that at this dosage the animals manifested other signs of significant toxicity including increased mortality; decreased weight gain; depressed erythroid parameters; increased excretion of porphyrins and aminolevulinc acid; as well as evidence of liver damage determined by elevated serum activities of alkaline phosphatase, gamma-glutamyl transferase, and glutamicpyruvic transferase. At dosages ten and one hundred times lower than 0.1 μg/kg/day, the chronic toxicity of TCDD diminished to nothing and there were no sigificant increases in identifiable carcinomas when compared to the control animals. Thus, it was concluded that during this two-year study in rats, no increase in tumors occurred at dosages of TCDD causing slight or no manifestations of toxicity. This suggests that the increased incidence of cancer observed at high-dose levels may be due to increased cell death and replacement, since an increase in cell turnover during constant exposure to cellulary toxic compounds provides increased opportunity for spontaneous carcinogenesis. It should also be re-emphasized that TCDD decreased the natural incidence of tumorigenesis of some organs in this study and that another study (2) using the two-state initation/promotion test demonstrated that the TCDD exhibited potent anticarcinogenic effects on papillomas induced by demethybenz(a)anthrene.

C. <u>Teratogenicity; Fetotoxicity; Reproductive Effects</u>

TCDD is fetotoxic at maternally toxic doses in rats, mice, and monkeys (3). In mice, doses of 1 µg/kg/day or greater consistently produce fetal defects such as cleft palate and kidney anomalies. At doses lower that 1 µg/kg/day no teratogenic or fetotoxic effects occurred, establishing that there is a "no effect" dosage. It has been established (4,5) that chronic dosages of 1 µg/kg/day or higher have effect on the reproductive capacity of rats and monkeys. Yet the increased abortion rates occur at dosages which again are maternally toxic. Barsotti et al. (4), using rhesus monkeys, concluded that the debilitating toxicity seen at the dosage used (2 µg/kg) may have caused the reproductive dysfunctions seen. The authors also found that the surviving animals returned to a normal reproductive status once they were removed from the exposure to TCDD. In another study (6) which determined the effect of TCDD on three generations of reproduction in the rat, it was concluded that 0.001 µg/kg/day had no effect while 0.01 and 0.1 µg/kg/day clearly affected normal reproduction. These data correlated well with the chronic toxicity and tumorigenesis study in this species. That is, overt toxicity correlates with the effect. In summary, a review of the literature indicates that TCDD is teratogenic and does affect reproduction in animals, but it also demonstrates that there is clearly a "no effect" dosage level.

D. Other Chronic Effects

Guinea pigs receiving doses of TCDD of 0.008, 0.004, 0.002, and 1.0 µg/kg body weight per week were affected (7). All animals receiving 1 µg/kg levels died or became moribund. They all exhibited atrophy of the lymphoid organs, lymphopenia, and severe loss in body weight. Additionally, cell-mediated immunity was suppressed at levels of 0.002 and 0.004 µg/kg. At the extremely low dose of 0.008 µg/kg/week, guinea pigs showed significant reduction in lymphocyte number.

E. Human Effects

Probably the best data on human response are the findings from the Seveso incident in Italy (8). A study of the human exposure from this incident divided persons into two groups labeled Zones A and B. In Zone A the average contamination was 50 µg/sq.m. for the 447 inhabitants studied. Zone B was comprised of 362 inhabitants with 3 µg/sq.m. exposure plus 156 plant workers of the factory where the explosion occurred. Chloracne was the major and most consistent effect. The peripheral nervous system studies revealed subclinical signs in 10% of the people living in the area of highest contamination. There was no correlation between the neurological findings and chloracne. Transient signs of liver damage without functional disorder occurred in 10% of both groups. The immunologic responses of the two populations were not impaired. There was no increase in fetal deaths, birth defects, or growth retardation out of the 7,350 births occurring in the first two years after the incident. Chromosome examinations did not reveal any changes from the normal pattern. Thus, the author concluded "that man has a higher degree of tolerance to TCDD than a direct extrapolation from animal data would suggest." The conclusion is supported by the data gathered on the one exposed person who died during this study. The body of a 55-year-old woman who died seven months after exposure from pancreatic carcinoma unrelated to the accident was analyzed, after autopsy, for TCDD. The woman had been exposed to TCDD from the explosion and had lived in a contaminated area (162-1847 µg/sq. m.) for fifteen days. The total body burden of TCDD was calculated to be 40 µg at the time of death. Of course, she had to have eliminated some TCDD in the seven-month interval between exposure and death. Even though the amount eliminated cannot be calculated, the analysis indicates that the people comprising this study accumulated large amounts of TCDD without exhibiting any serious adverse effects thus far. It should also be noted that the amount of TCDD absorbed was 1000 to 3000 times higher than the tolerable amounts calculated using rat or guinea pig acute toxicity data.

Environmental Fate of Farm Site Pollutants

Evaluation of the significance of environmental contamination of a particular toxin requires knowledge of its environmental mobility, persistence, and bioaccumulation potential. Poisons that lack these characteristics, even though highly toxic, have reduced impact as pollutants.

Reports in the science literature describe the environmental mobility and persistence of TCDD. One study (9) using 34 ppm TCDD showed loss of less than 0.3% of the total after elution with 150 ml of water through a sandy loam soil column 2.5 cm in length. This lack of mobliity through the soil is due to TCDD having extremely low water solubility (0.2 µg/l) and a tenacious binding affinity, particularly in soils having a high ion-exchange capacity because of clay or organic content. This strong affinity is illustrated by the rigorous extraction methods required to remove dioxins from soils comtaminated with known concentrations. Often efficient extraction is only achieved by extracting the soils with boiling organic solvents for long periods.

Several investigators (10,11,12) have found the environmental half-life of TCDD in soils to be about one year. The mechanism of destruction is thought to be microbial, but no one has been successful in attempts to isolate microbes capable of efficient TCDD breakdown in vitro. There is an apparent negative correlation between the degree of in vitro microbial degradation and the extent of dioxin chlorination. Since TCDD is a heavily chlorinated isomer, it was not susceptible to attack in laboratory studies.

In a field study (13), no TCDD residues were detected in soils that had recieved repeated applications of TCDD-contaminated 2,4,5-T at a rate of 1,000 lbs/acre/year over a seven-year period. The destruction of surface applications of TCDD is probably due largely to its photolability to ultraviolet light. One study reported 100% loss of TCDD in methanol solutions irradiated with simulated sunlight for a 24-hour period (14).

In evaluating the possibility of TCDD movement at the Denny Farm Site 1, one must recognize typical disposal-site features which could promote migration. The site contains large concentrations of dioxin relative to an agriculturally-contaminated area, and the toxin is mixed in an undefined matrix of organic liquids. Conceivably these organic wastes could increase TCDD movement by effectively increasing its water solubility and by tying up the soil binding capacity. However, it is felt that these effects will be minimal in increasing soil migration, if the clay soils are continuous and sufficiently deep to accommodate the total binding load. The known organics present in the site are also of low water solubility and would not be expected to increase greatly the solubility of the dioxin. Also, the rapid dilution of these organics in the soil as migration proceeded would prevent maintenance of high dioxin load over long distances.

In summary, dioxin contamination of groundwater at sites removed from the source is unlikely. Low water solubility and tenacious soil binding largely account for this lack of mobility. Environmental spread is more apt to occur in the form of contaminated soil particle movement either by wind or surface water erosion. Consequently, a likely place to detect the movement of dioxin is in surface waste sediments where soil surface fines can accumulate. Additionally, aquatic animals are documented accumulators of TCDD in apparently uncontaminated waters and could provide additional evidence of dioxin contamination. It is suggested that benthic organisms and associated predator species be sampled in Calton Creek and any other surface waters near the site as a check for dioxin migration.

Because of lower mammalian toxicity, the other organic pollutants at the Denny Farm Site 1 have received less scientific attention in terms of environmental fate. Trichlorophenol has the greatest water solubility of the known organic pollutants on the disposal site, and it is present in the highest concentrations. Therefore, it would apparently possess the largest potential for environmental movement via groundwater flow. Monitoring of groundwater in the area for TCP contamination has thus far been negative, indicating the absence of groundwater pollution from the organic wastes. However, this monitoring does not absolutely rule out the possibility that groundwater pollution has occurred in the past or even is presently a problem in channelized water flows not confluent with the monitoring wells. There are no direct scientific data available on the soil-binding characterisitics or bioaccumulation potentials of TCP or the other known waste organics in the disposal pit. Their common aromatic structures would predict a high probability of similarity with dioxin, i.e., moderate to high soil affinities and bioaccumulation potentials. The comparatively low mammalian toxicities associated with these chemicals, however, reduce the potential for detrimental public health impact relative to dioxin.

<u>Public Health Routes of Exposure</u>

Exposure to the resident population near the site could occur through a number of different pathways as shown on Figure 5-1. The most probable route would be by ingestion of contaminated water or food or by dermal or respiratory contact with contaminated soil or other particulate matter. Accurate evaluation of the risk associated with dermal contact with contaminated soil particles is difficult due to a lack of knowledge regarding the partitioning characteristics of the organics, especially

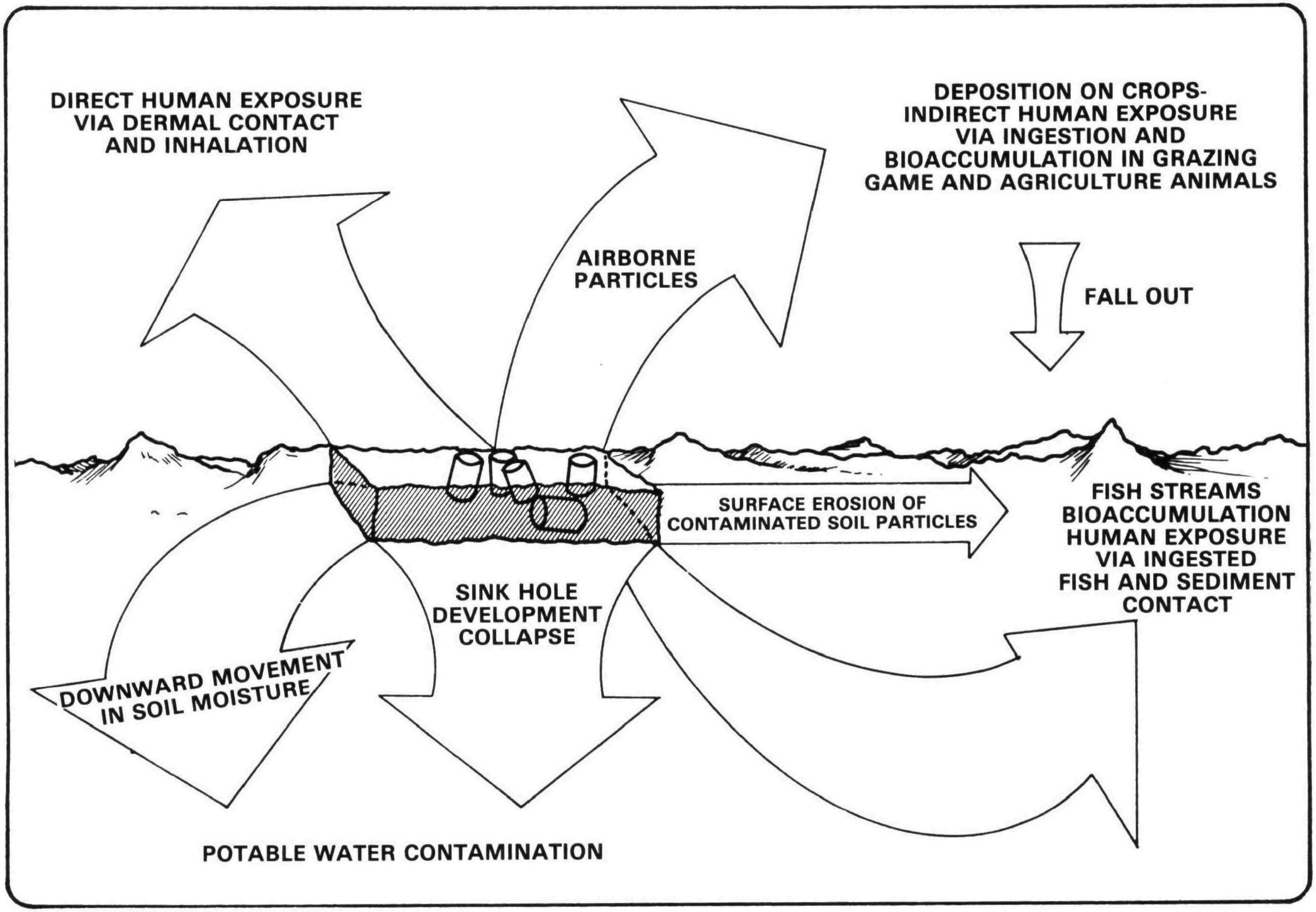

Figure 5-1. Exposure Routes of TCDD to the Public

TCDD, between human skin and soil. It would undoubtedly depend upon the degree of soil contamination, nature of pollutant mixture, soil type, and extent of exposure. Additionally, potential for contaminated soil movement would be maximum following soil disturbance in and over the disposal trench. The soil would then exist in a loosely packed and friable state, being more readily translocated by air and water. Since the trench was covered with ground vegetation prior to the recent opening, it is likely that soil-borne contamination has been low. Future plans involving soil disturbance must consider control of soil-borne spread, i.e., dust and surface erosion control. An additional site feature minimizing airborne spread is the density of tree and shrub vegetation around the site that serves to retard wind and to filter aerial particulates.

Ingestion of food produced in the area that might be directly or indirectly contaminated with soil-carried pollutants is also of concern. The most probable exposure route of this sort would come from eating fish taken from streams with contaminated sediment. Dioxins are known to concentrate in aquatic organisms and this contamination in fact represents a frequent indication of TCDD movement from a concentrated source. Plants do not translocate accumulated dioxins or other nonaqueous soluble organics in appreciable quantities. Contamination of agricultural crops would occur via surface retention of airborne particulates. Grazing animals could conceivably accumulate TCDD or other dioxins from ingestion of contaminated plants, thus serving as an indirect human exposure source in the form of milk and meat products.

With regard to worker safety, the same routes of exposure apply. Obviously, the risk is increased. Due to the high toxicity of TCDD isomers, the most stringent safety procedures are warranted during activities in and around the opened site. This includes use of fully encapsulated rubber suits, SCBA, and thorough decontamination of personnel and equipment as discussed in Appendix D.

Acceptable Cleanup Levels

The assessment completed during this study (Section 4) warrants total removal of the drum contents and heavily contaminated soils.

However, a determination of the acceptable TCDD level in the soil remnants remains to be determined. Ideally, a zero-contamination level is desired for TCDD. In view of the low mobility of this substance in soil, this level of cleanup may be obtainable. The final decision on an acceptable cleanup level currently is the purview of EPA. Several factors, however, should be taken into consideration in establishing this level, These include:

- o Detectable limits of TCDD. (This will also affect sample turnaround time.)
- o Turnaround time required for sample analysis. This time directly affects excavation and the length of time the trench must be kept open.
- o The possibility of cross-contamination due to the amount of manpower and equipment in and around the trench.
- o Mobility of dioxin in soil.
- o Known acute and chronic toxicity data.

REFERENCES FOR SECTION 5

1. Kociba, R. J. et al. Results of a two year chronic toxicity and oncogenicity study of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in rats. Tox. App. Pharmacol. 46:279-303. 1977.

2. Berry, D. L., et al. Studies with chlorinated dibenzo-p-dioxins, polybrominated biphenyls, and polychlorinated biphenyls in a two-stage system of mouse skin tumorigenesis; potent anticarcinogenic effects. Ann. N.Y. Acad. Sci. 320:405-414. 1979.

3. Smith, F.A., et al. Teratogenicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in CF-1 mice. Tox. Appl. Pharmacol. 38: 517-523. 1976.

4. Barsotti, D. A., et al. Hormonal alterations in female rhesus monkeys fed a diet containing 2,3,7,8-Tetrachlorodibenzo-p-dioxin. Bull. Environ. Contam. Tox. 21:463-469. 1974.

5. Courtney, D. C. Mouse teratology studies with Chloridobenzo-p-dioxins. Bull. Environ. Contam. Tox. 16:674-681. 1976.

6. Murray, F. J., et al. Three generation reproduction study of rats given 2,3,7,8-Tetrachlorodibenzo-p-dioxin. Tox. Appl. Pharmacol. 50:241-252. 1979.

7. Vos, J. G., et al. Effects of 2,3,7,8-Tetrachlorodibenzo-p-dioxin on the immune system laboratory animals. Environ. Hlth. Perspect. 5:125. 1973.

8. Reggiani, G. Estimation of the TCDD toxic potential in the light of the Seveso accident. Arch. Toxicol. Suppl. 2:291-302. 1979.

9. Matsumura, F. and Benezet, H. J. Studies on the bioaccumulation and microbial degradation of 2,3,7,8-Tetrachlorodibenzo-p-dioxins. Environ. Hlth. Perspect. 5:253. 1973.

10. Helling, C. S., et al. Chlorodioxins in pesticides, soils, and plants. J. Environ. Qual. 2: 171. 1973.

11. Kearney, P. C., et al. Tetrachlorodibenzo-p-dioxin in the environment; sources, fate and decontamination. Environ. Hlth. Perspect. 5:273. 1973.

12. Young, A. L., et al. Fate of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) in the environment: Summary and decontamination recommendations. USAF Technical Report USAFA-TR-76-18. 1976.

13. Woolson, E.A., et al. Dioxin residues in Lakeland sand and bald eagle samples. Advances in Chemistry Series, No. 120, Chapter 12. American Chemical Society, Washington, D.C., 1973.

14. Crosby, D. G., et al. Environmental generation and degradation of dibenzodioxins and dibenzofurans. Environ. Hlth. Perspect. 5:259. 1973.

UNCITED REFERENCES

Bughman, Robert and Meselson, M. Analytical method for detecting TCDD (Dioxin): Levels of TCDD in samples from Vietnam. Environ. Health Perspectives, No. 5:27. 1973.

Bently, P. W., Vaughn, W. K., and Neal, R. A. Effect of alteration of rat hepatic mixed-function oxidase activity on the toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin. Tox. Appl. Pharmacol, 45:513-519. 1978.

Crow, K. D. Effects of dioxin exposure. Lancet 2:82. 1977.

Drinking Water and Health. National Academy of Sciences, Washington, D.C. 1977.

Giovanne, S. Q. et al. Effects of pretreatment with 2,3,7,8-Tetrachlorodibenzo-p-dioxin on the capacity of hepatic and extra-hepatic mouse tissues to convert procarcinogens to mutagens for Salmonello typhirium auxotrophs. Tox. Appl. Pharmacol. 50:229-239. 1979.

Goodman, L. S. and Gilman, A. E. The pharmacologic basis of therapeutics, 5th Ed., New York: MacMillan Publishing. 1975.

Harris, M. W., et al. General biological effects of TCDD in laboratory animals. Environmental Health Perspectives, No. 5:101. 1973.

Kenkyujo, K. G. S. Toxic and Hazardous Industrial Chemicals Safety Manual, International Technical Information Institute. 1976.

Kimbrough, R. D., et al. Epidemiology and pathology of the tetrachlorodibenzodioxin poisoning episode. Arch. Environ. Health 27:77-86. 1977.

Laporte, J. R. Effects of dioxin exposure. Lancet 1:1049. 1971.

McConnell, E. E., et al. The comparative toxicity of chlorinated dibenzo-p-dioxins in mice and guinea pigs. Tox. Appl. Pharmacol. 44:335-356. 1978.

McConnell, et al. Toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin in rhesus monkeys following a single oral dose. Tox. Appl. Pharmacol. 43:175-18&. 1978.

Miller, R. A., et al. Toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) in aquatic organisms. Environmental Health Perspectives, No. 5:177. 1973.

Neal, R. A., et al. Studies on the mechanism of toxicity 2,3,7,8-tetrachlorodibenzo-p-dioxin. Ann. N.Y., Acad. Sci. 320:204-213. 1979

Patty, F. A. Industrial Hygiene and Toxicology, 2nd Edition, Volume 2. York: John Wiley & Sons. 1963.

Schiffs, L. Diseases of the Liver, 4th Edition, Lippincott Publishing Co. 1975.

Schwetz, B. A., et al. Toxicology of chlorinated dibenzo-p-dioxins. Environmental Health Perspective, No. 5:87. 1973.

Verschueren, K. Handbook of Environmental Data on Organic Chemicals. New York: Nostrand Reinhold Co. 1977.

SECTION 6

REMEDIAL APPROACH METHODOLOGY

INTRODUCTION

In order to proceed with any remedial action for a hazardous waste site, it is necessary to devise an appropriate methodology. The purpose of this section is to communicate to the reader the remedial approach methodology that has been designed by Ecology and Environment, Inc., to determine the most effective means for solving the waste disposal problem at Denny Farm Site 1. This methodology is summarized in Figure 6-1. Application of the methodology to the specific situation at Denny Farm Site 1 will be found in Sections 7 and 8 of this report.

STATING THE OBJECTIVE

As with any task, the most important--though often the most frequently forgotten--first step is setting the task's objective. Simply stated: What is the desired result of the work that will be done in this task? The answer to that question is critical. Without it, the specific work to be done cannot be determined. Furthermore, the more specific the answer is, i.e., the more specific the statement of the objective, the more helpful it is in determining the work to be done.

A simple example will make the above notion clear. There is a vast difference between the following statements of an objective for Denny Farm Site 1:

- Objective A: To clean up Denny Farm Site 1
- Objective B: To remove TCDD and associated contaminated material from the environment at Denny Farm Site 1

Objective A is clearly too vague. "To clean up" can mean many different things, e.g., to dig up and remove the drums that were dumped at Denny Farm Site 1; and then to fill up the pit, level the site, and

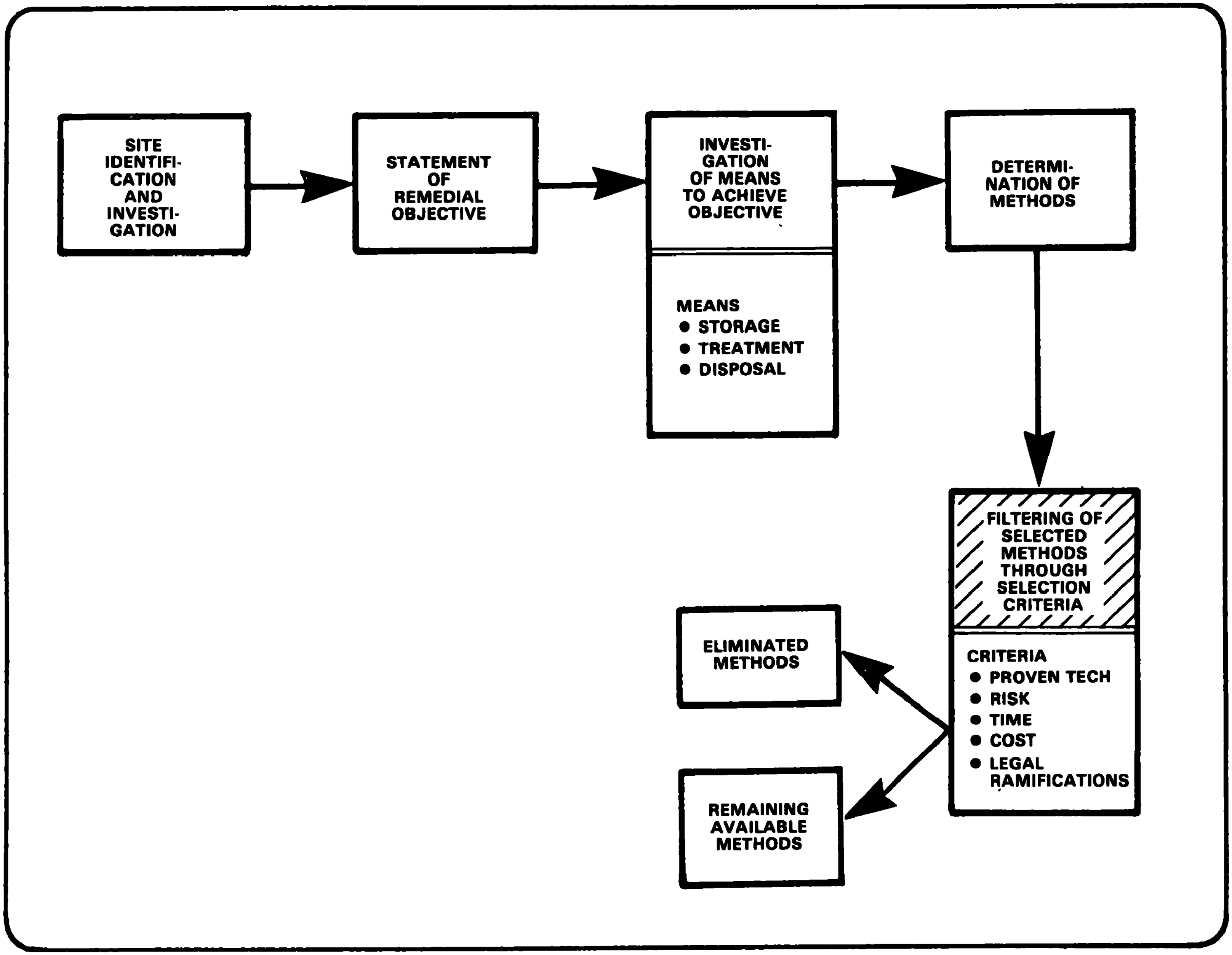

Figure 6-1. Flow of Remedial Approach Methodology

plant grass. "To clean up" can be defined any way one wants to define it.

Objective B is much more specific and paradoxically calls for a more far reaching and widespread delineation of subtasks (specific work) for its accomplishment.

Stating the objective is, therefore, of paramount importance and the sine qua non first step of a remedial approach methodology.

DETERMINING THE MEANS

Once the objective has been clearly stated, the next step is to determine the means for achieving the objective. In the instance at hand, those means have been determined by Federal regulation.

The Federal Register (Volume 45, Number 98) of 19 May 1980 presents three means that are legally available for the management of hazardous waste materials: disposal, storage, and treatment. Thus, any remedial approach for the handling of hazardous waste materials is limited to one or a combination of these three federally regulated means.

These legal means are defined as follows:

- Disposal: "the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground waters (sic)."

- Storage: "the holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere."

- Treatment: "any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume."

Thus, at present, anyone involved in providing a remedial approach for solving problems arising from hazardous wastes has the means defined by Federal regulation.

METHODS

With the means for remedying a hazardous waste problem established, various methods to be used in each one of the means can be examined. As might be expected, methods are extremely varied and of greater or lesser complexity.

Without attempting to be exhaustive, several methods can be listed here for each of the available means noted above.

Disposal

The definition of disposal as given in the Federal Register cited above really appears to cover a variety of disposals: accidental, careless, intentionally destructive, and controlled. Obviously, in discussing disposal as a remedial approach, one is talking about controlled disposal. The definition also suggests some of the methods needed in the use of this remedial means:

- o excavation
- o transportation
- o burial

Connected with controlled disposal is the notion of a disposal facility. "Disposal facility" is defined by the Federal regulations as: "a facility or part of a facility at which hazardous waste is intentionally placed into or on any land or water, and at which waste will remain after closure."

Storage

When storage is being explored as a possible means for remedying a hazardous waste problem, a number of potential methods can be given consideration: on-site or off-site storage, above-ground or underground storage, type of storage facility, etc. Each of these presents it own set of methodological components, for example:

- o engineering design
- o excavation
- o structure design
- o construction

Treatment

The presently available methods for the treatment of hazardous waste materials are three:

- o chemical, e.g., UV photolysis
- o biological, e.g., biodegradation
- o physical, e.g., incineration

CRITERIA

Once the means and various methods have been listed, it is necessary to apply certain criteria which further delineate the appropriateness of any one or combination of means. The criteria are applied to the methods that comprise the means. At a minimum, the following criteria are applicable:

- o proven technology
- o risk
- o time
- o cost
- o legal ramifications

Proven Technology

The question that must always be asked is whether a technology that is being presented for solving the problem is proven, i.e., is there sufficient scientific evidence to demonstrate that it works effectively.

For example, is it accepted by the scientific community that UV photolysis is an effective method for the treatment of dioxin-contaminated waste?

Risk

Whatever the remedial approach that is being considered, a risk analysis must be performed that takes into account the methods under study. The purpose of this risk analysis is to answer satisfactorily questions that arise concerning the health and safety of the public and the protection of the environment.

Time

This criterion must be applied in order to ascertain whether the methods being considered can be used and still meet any time constraints placed upon the remedial approach in the statement of the objective. For example, if the objective states that certain results must be accomplished within sixty days, any method under consideration requiring more than sixty days would be eliminated (unless the time requirement stated in the objective is changed).

Cost

The need to apply this criterion is obvious and needs no explanation.

Legal Ramifications

When considering any method in a remedial approach to a hazardous waste site, Federal, State, and local regulations must be investigated and applied. Again, the criterion is obvious.

Once the various remedial approaches and methods have been subjected to scrutiny by the application of agreed upon criteria, some means and methods will undoubtedly be eliminated for application to a particular site. The remaining available means and methods may then undergo whatever discussions are deemed necessary to arrive at an appropriate and acceptable approach for the required remedial operation.

SECTION 7

EVALUATION OF REMEDIAL ACTIONS

INTRODUCTION

This section contains the results of an evaluation of the remedial action alternatives potentially available for removing the TCDD waste and associated contaminated material at Denny Farm Site 1 from the environment. In accordance with the Resource Conservation and Recovery Act (RCRA), 40 CFR 260, there are several general means for dealing with hazardous waste: disposal, storage, and treatment. A number of methods are possible in each of these categories, and the method chosen for dealing with any particular uncontrolled hazardous waste site is dependent on site-specific conditions and the objectives of the planners involved. The objective of the project, as directed by the EPA, was the development of a remedial action plan, in conjunction with an engineering assessment of Denny Farm Site 1, to minimize and/or eliminate the impact to the public and the environment from the TCDD-contaminated waste at the site.

During the course of this study, the available methods for meeting this objective were first evaluated in relation to the environmental and demographic characteristics of Denny Farm Site 1 and the characteristics of the waste material buried in the trench. Further evaluation criteria were applied to various methods depending on their compatibility with the site and waste characteristics. These criteria included cost, risk, time, proven technology, and legal ramifications.

Table 7-1 presents a summary of the alternative remedial action methods, along with the various selection criteria (generic and site specific) that were investigated for each method. Evaluation continued until a criterion indicated that the method in question should not be further considered. The asterisks on the table indicate that the particular criterion was considered, but in no way do the asterisks indicate whether that investigation was carried out to completion. Also, no weight has been assigned to the asterisks with respect to positive or negative impact on the particular remedial method.

TABLE 7-1

SUMMARY OF ALTERNATIVE REMEDIAL ACTION METHODS

	EVALUATION CRITERIA							
METHOD	Site Charac.	Waste Charac.	Proven Tech.	Cost	Risk	Time	Legal	Other
Disposal								
As is	*	*			*			
Monitoring wells	*	*			*			
Designated facilities		*	*			*		*
Deep well injection		*	*		*			*
In-situ containment	*	*	*			*		
Treatment								
U.V. photolysis		*	*			*		
Solidification (Chemical)		*	*	*				*
Biological treatment		*	*			*		*
Incineration--land		*	*			*	*	
Incineration--ocean		*	*			*	*	
Encapsulation			*	*		*		
Carbon		*	*			*		
Solidification (Physical)		*	*	*				
Storage								
Designated facilities		*	*					
On-site	*	*	*	*	*	*	*	*

*Indicates that the particular criterion was considered, but in no way does it mean that investigation was carried out to completion.

Definitions

The following definitions are quoted from 40 CFR 260 (1).

"Disposal" means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including groundwaters.

"Storage" means the holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere.

"Treatment" means any method, technique, or process, including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

Required Information

The complexities of any given site are such that site-specific remedial actions must be developed. First of all, basic information is required to characterize the site with respect to existing and potential hazards both to workers and the public.

Identification of the wastes present, whether from records, actual chemical analysis, or investigation will provide some insight as to the options available. The waste at Denny Farm Site 1 has been identified through a combination of investigation and chemical analysis as TCDD-contaminated waste from a hexachlorophene-manufacturing process (see Appendix A). The quantity of waste within the disposal trench has been estimated at approximately 150 drums without an established concentration.

In determining the existing and potential hazards, it is essential to have information on the toxicological effects on human beings, flora, and fauna, in addition to information on the environmental fate of the wastes involved. TCDD has a high acute toxicity, is mutagenic, and has been considered to be very persistent and to bioaccumulate in animals.

The mobility of a compound in the environment is determined by the physical and chemical characteristics of the compound in question as well as those of the environment.

The hydrology and geology of the area in which an uncontrolled hazardous waste site is located may either help or hinder remedial actions. The intricate relationship of the two must be carefully scrutinized to determine the existence or probability of migration of the contaminant off site.

Aurora, Missouri, is located in an area known for its karst geology, which is characterized by solution cavities and the free mixing of surface and groundwater. Additionally, the soils in the area consist of clay lenses and cherty soils with as much as a 30% gravel content. Therefore, it is highly probable that the retention of liquids in the soil matrix is quite low.

Indirect geophysical methods have been used to define the limits of the disposal trench at Denny Farm Site 1. These tests have confirmed the shape of the trench and its approximate depth and have indicated that lateral migration beyond the trench walls has not occurred. The vertical migration of the chemical waste and/or leachate has not been determined to date. The negative results obtained from the borings and indirect geophysical measurements should not be construed to indicate that vertical migration has not occurred.

REMEDIAL APPROACH

The remedial approach initially entails a review of available means and those methods applicable to each means that have a potential application to the uncontrolled hazardous waste site in question. Consideration of off-site versus on-site methods and existing versus new facilities must be taken into account during the evaluation of the means and methods (Figure 7-1).

This section reviews the methods evaluated and provides the reasons for eliminating those which are not appropriate for Denny Farm Site 1. Those methods which were singled out for more in-depth review are discussed in the next section.

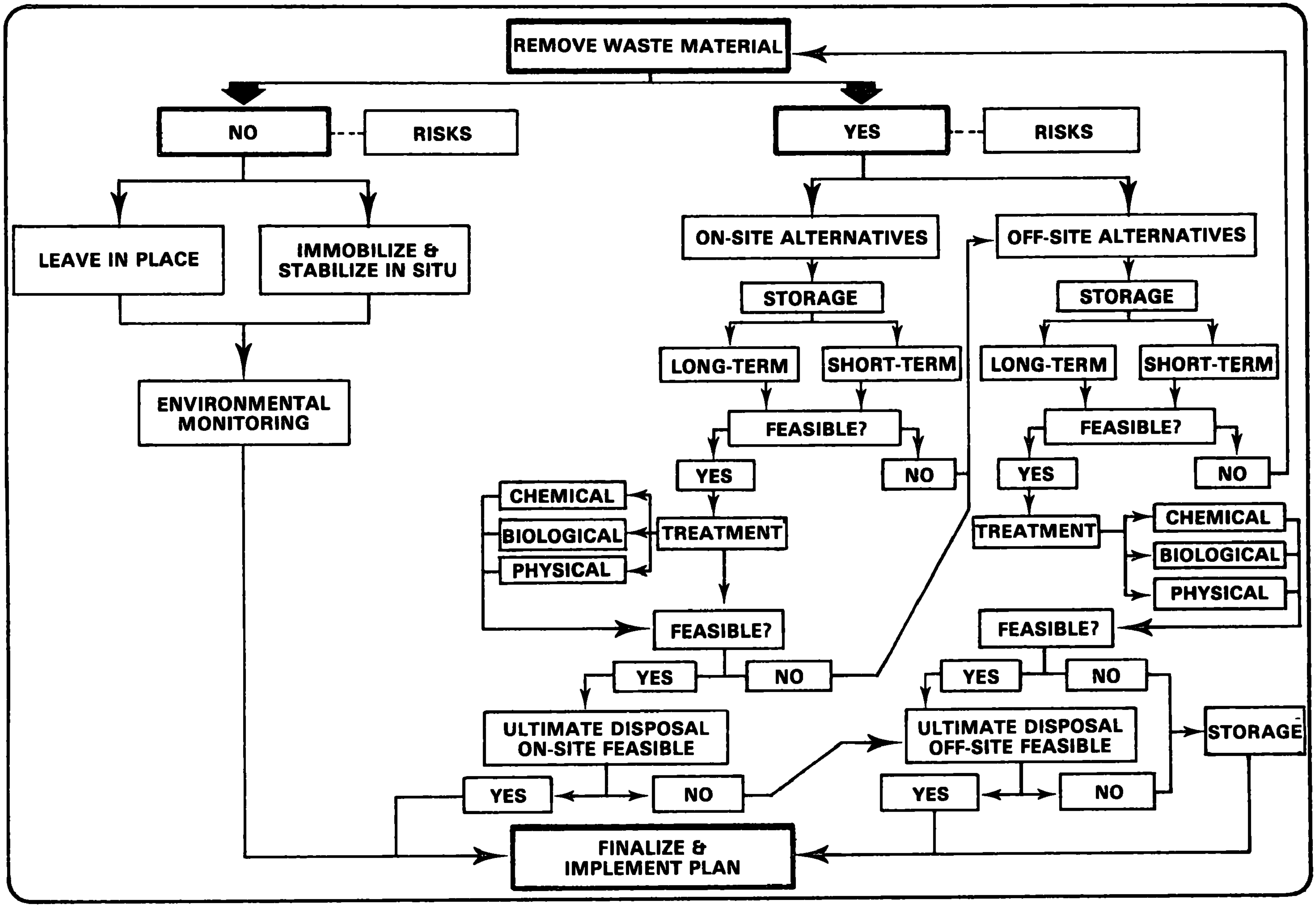

Figure 7-1. Evaluation of Alternatives for Remedial Action

Disposal

Disposal may be achieved by any number of methods; however, in all cases, the potential release of the waste to the environment must be considered.

A. Uncontrolled Disposal

The two possibilities considered included (1) no action and (2) leaving the waste buried but installing monitoring wells. Use of monitoring wells to identify off-site migration would be contingent upon a complete geohydrological investigation of the area to determine the proper siting of these wells. Use of this approach would also be contingent upon the fact that the wells were indeed properly sited and could detect any off-site migration of contaminants.

These two options offer no protection to the environment or to the population at risk and at best offer an early warning system comprised of monitoring wells. Since this approach is not in line with the objective as set forth by the EPA, this method has been eliminated.

B. Controlled Disposal

Controlled disposal is carried out in designated federal, state, or private facilities which meet a minimum requirement of primary containment. This containment may consist of one or more of the following: synthetic liners, grouts, slurry walls, or natural soils. The facilities operate under the RCRA guidelines.

The majority of commercially designated facilites have refused to accept the waste either because of the facility design or the public and political sensitivities associated with receiving TCCD-contaminated waste. Although several facilities did agree to consider accepting the waste, this avenue is not currently being pursued (Table 7-2).

Deep well injection is a controlled disposal method currently employed at various locations throughout the continental United States. It must be emphasized that the geohydrological status of the area must be sufficiently determined prior to the use of this method. Although this method releases hazardous waste to the environment, it does so at such depths and locations that these wastes are not expected to contaminate groundwater resources utilized by the public.

TABLE 7-2
COMMERCIAL STORAGE/DISPOSAL FACILITIES

Company and Address	Contact	Comments
Newco Chemical Waste System of Ohio 5092 Aber Road Williamburg, Ohio	Mitch McGee, Tech. Rep. (513) 793-3090	Landfill can handle dioxin-contaminated waste. Will not dispose of liquids or sludge (Minimum flashpoint of 150°). Ohio EPA approves disposal on case-by-case basis.
New Chemical Waste System, Inc. 4526 Royal Avenue Niagara Falls, New York	(716) 285-6929 (716) 731-3281	Will handle dioxin (see above). New York approves disposal.
Waste Management of Alabama, Inc. P.O. Box 1200 Livingston, Alabama	Ed Brashier (205) 652-9531	Although the facility design is such that dioxin-contaminated waste could be taken, political and public relation aspects are deterrents to acceptance
SCA Chemical Services, Inc. 1500 Balmer Road Model City, New York 14107	(716) 754-8231	Does not handle dioxin-contaminated waste.
Wes-Con, Inc. P.O. Box 564 Twin Falls, Idado	(208) 834-2275	Will not handle dioxin.
Chem-Nuclear Systems, Inc. P.O. Box 1269 Portland, Oregon 97205	Sandy Davis (503) 223-1912	Will not handle dioxin wastes.
Casmalia Disposal 539 Ysidso Road P.O. Box 5275 Santa Barbara, California 93108	Jim McBride (805) 969-4703	Will handle dioxin-contaminated waste. State has not approved out-of-state shipments of dioxin.
Nuclear Engineering Company 9200 Shelbyville Road Louisville, Kentucky 40207 (Site is located in Beatty, Nevada)	Vicki Lynn (502) 426-7160	State approval for acceptance of dioxin-contaminated material is not forthcoming because of political ramifications. Therefore, the facility will not accept the waste.
Rollins Environmental Services, Inc. 2027 Battleground Road View Park, Texas 77536	Rolen Cains (713) 479-6001	Will not handle dioxin or dioxin-contaminated wastes.
Browning Ferris Industries, Inc. (BFI) 1020 Holcombe Road Houston, Texas 77030	(713) 790-1611	Does not handle dioxin-contaminated waste.
Kansas Industrial Environmental Services Wichita, Kansas 67201		Does not dispose of dioxin-contaminated materials; however, it has experience in transportation of materials.

Although deep well injection is widely practiced, its use for disposing of such a toxic material as TCDD is questionable. Currently there are no facilities specifically permitted for handling dioxins. As a result, this method cannot be considered for the waste at Denny Farm Site 1.

Controlled disposal by in-situ containment of waste must prevent the waste or any constituent thereof from entering the groundwater, surface water, and air (2,3). Such a concept involves surface runoff control, capping or surface sealing, and impermeable barriers. Surface runoff control may be implemented via proper engineering design of dikes, berms, ditches, channels, culverts, surface stabilization, subsurface interceptor drains and/or any combination of the above. This control seeks to minimize surface infiltration into the disposal trench by diverting water away from the trench.

Capping and sealing of the disposal trench surface eliminate airborne contamination and minimize infiltration caused by precipitation (2). Proper grading also enhances surface runoff. This seal and/or cap may consist of any one or combination of the following: synthetic liner material, fly ash, oils, soil-cement, lime stabilized soil, bituminous concrete and asphalt/tar materials.

Impermeable barriers constructed of bentonite, slurry, cement or chemical grouts, or sheet piling can be installed vertically to prevent off-site migration of leachate and contaminated groundwater and to divert non-contaminated groundwater around or away from the disposal trench. Construction involves drilling, boring, pressure injection, pile driving and excavation. These methods are applied to those sites which have an impermeable layer whether it be low porosity soils such as clay or continuous bedrock.

In-situ containment was not considered feasible for the following reasons:

- Lack of data on the subsurface condition below the trench floor, as well as the possibility for disturbance of the geological structure and stability of the bedrock below the trench. Concerns for fractures, piping, and increasing contaminant migration have been raised.

- o The quantity and type of sealant needed to isolate the trench was deemed highly speculative because of the karst conditions and the effects of the organic wastes may have on the sealants. Although it is realized that sealant selection is contingent upon waste identification, that identification has not been completed to date.

Therefore, in-situ containment is not considered further due to time limits and problems with the feasibility of applying the technology.

Treatment

Although removal of the material from the enviroment is the short-term objective of the project, treatment must be considered at some time so that indefinite storage is not required. The following treatment technologies have been investigated in relation the their applicability to Denny Farm Site 1.

A. Chemical Treatment

Ultraviolet photolysis of TCDD is a potentially promising method of treatment. Three conditions are required for significant TCDD breakdown: dissolution in a light-transmitting (307 nanometers) liquid film, the presence of an organic hydrogen donor such as a solvent, and irradiation with ultraviolet light (4,5).

This process is currently under development by three firms: Syntex Agribusiness, Inc., Westgate Research, and Vertac, Inc. The Syntex process has received U.S. EPA approval as a treatment method for dioxin and is presently undergoing testing at the Syntex facility in Verona, Missouri (6,7,8,9). TCDD is not totally eliminated by this process. Residual concentrations approximating 500,000 ppt, in addition to other waste products, are generated by this process.

Vertac, Inc., of Jacksonville, Arkansas, has developed a process for treating and/or destroying dioxin. Vertac, Inc., has indicated that Vertac has filed a patent application for the process, which has been successfully demonstrated to the State of Arkansas and the EPA (10). Commercial availability is anticipated by Vertac.

A treatment process that uses ultraviolet irradiation in conjunction with ozonization has been developed by Westgate Research (11) for the detoxification of chlorinated organics. Westgate furnishes a portable treatment system, thus enabling wastes to be treated on site. For treatment in the Westgate process, the liquid waste does not have to be clear; it may contain some color or sediment. Further, it may be feasible to extract the dioxin from contaminated sludge waste with a solvent such as methanol prior to treatment. As with the Syntex process, the Westgate process operates at low temperature and pressure; thus the potential for release to the environment is minimized.

The Westgate process is presently being tested for the decontamination of PCB-containing oils for the General Electric Resistors facility at Hudson Falls, New York. Tests to date have been successful, with 99 percent removal achieved. The system was also tested successfully for the detoxification of bottom sediments contaminated with kepone in Hopewell, Virginia. These tests were done for an EPA task force investigating alternative mitigative measures (12).

Ultraviolet photolysis appears to be a feasible, environmentally sound, and safe means of treating the TCDD content of at least the liquid portion of the waste at the Denny Farm Site 1. The possibility of treating the sludges and soils after extraction is not viable at this time. Although photolysis of chlorodioxins has appeared in research articles and is known within the scientific community, its acceptance as a proven technology is limited. As previously mentioned, there are at least three commercial firms developing this treatment method. In all cases the methods are classified as proprietary and therefore not available to the authors of this report. As a result, treatment efficiencies, byproducts, and disposal and/or storage of these byproducts could not be evaluated in this report. However, this is not to preclude future considerations of this alternative.

The chemical solidification of waste involves a chemical reaction between the waste and the solidifying agent. The proper selection of a solidification agent is dependent upon a thorough chemical analysis of the waste in question. In each case, one must consider short-term and long-term stability of the matrix and the propensity towards leaching into the environment. Cement-based solidification techniques cannot be used with particular organic matter because of interference with set, cure, and permanence of the cement-waste matrix. Lime-based applications cannot be considered because the porosity of the final material would inevitably allow the TCDD-contaminated material to leach. Thermoplastics solidification was also considered, but available literature indicates that this procedure should not be used for solidifying materials containing organic solvents or wastes which may break down when heated (13). Organic polymer techniques, although applicable to a broader range of compounds, involve the mixing of waste material with the organics followed by a chemical reaction between the various resins, catalysts, and waste. The waste must be properly dried prior to the process since the resultant solidified matrix has a tendency to weep or release any uncombined water. This water is often laden with pollutants.

Biological treatment through commercially available mutant microorganisms is an established and proven technology for certain applications--food processing, waste treatment, and limited subsurface hydrocarbon spills (14). In each case the basic requirement for the existence of the microorganism in the environment has been predetermined. The commercially available organism mixture known as Phenobac has been demonstrated to effectively biodegrade 2,3,5,-trichlorophenol and 1,2,4,5-tetrachlorobenzene, which are known to be present in the wastes at Denny Farm Site 1. However, the other components of the waste at the site may be toxic to Phenobac. In addition, the demonstrated destruction efficiencies of 100% for 2,3,5-trichlorophenol and 80% for 1,2,4,5-tetrachlorobenzene were based on experiments in a controlled environment in concrete pits (15). Data indicating positive results and reinforcing a proven technology for application to uncontrolled hazardous waste sites have not been produced. The material at Denny Farm Site 1 cannot be left in the ground to await the development of a mixture of organisms specific to the waste at this site. However, testing of the microorganism for applicability to the waste is recommended and can be accomplished during removal and sampling the drums.

B. Physical Treatment

Physical treatment methods are also available for dealing with hazardous wastes. Incineration is a process in which organic materials are degraded via the application of controlled heat. This degradation occurs through the thermal oxidation of the organic molecule. Inorganic constituents may not be affected. The proper method of incineration must be selected based upon certain considerations: waste components, physical characteristics, residence time, temperature requirements and destruction efficiencies (16).

The TCDD-contaminated material at the Denny Farm Site 1 consists of liquid waste, tarry still bottoms, and soil. Incineration of dioxin requires a temperature of 2,300°F to 2,600°F and a residence time of 5 seconds (16).

Land-based incineration provides the feasibility of on-site treatment through the possible use of a mobile unit currently under construction for the EPA by NB Associates of San Remon, California, and was scheduled for completion by August 1980. Any on-site application will be subject to initial testing and permitting (17).

A thorough investigation of incineration facilities throughout the United States reveals that none are willing to burn dioxin and the associated contaminated materials at this time (2). Currently, there are no permits issued for the specific purpose of incinerating dioxin and the dioxin-contaminated material. Such a permitting program, similiar in scope to the PCB program, would provide the criteria upon which private industry could develop facilities to handle the incineration as a land-based operation. Although a modular unit is under construction for the EPA, test burns have yet to be conducted. The two byproducts of this process, scrubber residue and ash, must be dealt with. In summary, the lack of land-based facilities eliminates this particular method for consideration this time.

The only documented burn of dioxin-contaminated material is that of Herbicide Orange incinerated in the Pacific Ocean west of Johnston Atoll from July to September 1977. The burns were performed on board the M/T Vulcanus, an incinerator ship chartered by Ocean Combustion Services, B.V., of the Netherlands (19). The wastes were burned in two identical refractory-lined incinerators with a calculated residence time of approximately 1 second at a flame temperature between 2,372 ^{o}F and 2,732 ^{o} F (2). Results of EPA calculations from the test burns were promising since they indicated a minimum destruction efficiency of 99.96% (2). However, the destruction efficiency during actual incineration could not be determined because no traceable amounts of TCDD were detected in the stack samples.

The potential problems with incineration at sea are based upon the fact that traces of TCDD and related compounds were found in incinerator residues and within stack residues despite the undetectable levels in the stack emissions. Also, the M/T Vulcanus incinerators are not equipped with scrubbers on the premise that many of the materials that would be pollutants if emitted from land-based incineration are greatly diluted by the ocean where they are natural constituents.

Ocean-based incineration costs are much lower than land-based operations--$80 to $90 per metric ton. However, transportation and storage costs must be added to obtain the total costs, and time must be considered. The EPA has proposed the possibility of employing the M/T Vulcanus for the incineration of dioxin-contaminated herbicides during the spring of 1981 (2). This is an option for the liquid phase contaminants but not for the contaminated soils or other debris.

Encapsulation is the process by which hazardous wastes are physically enclosed by a synthetic encasement to facilitate environmentally sound transport, storage and disposal. As a remedial action, encapsulation may be used to seal particularly toxic or corrosive hazardous wastes which have been removed from disposal sites.

Theoretically, encapsulation appears to be a viable answer for dealing with the waste once it has been excavated and removed from the disposal trench. However, the major disadvantage is that the process has yet to be applied on a commercial scale under actual field conditions. Additionally, the binding resins required for this process are expensive and the process requires large expenditures for energy and capital equipment costs. For these reasons, this approach is not being considered further.

Carbon treatment utilizes the physical phenomena of absorption and adsorption. This technology was developed for water purification and chemical processes, but recent applications have emerged for response to chemical spills in surface water and groundwater. However, application of carbon is dependent upon the physical and chemical characteristics of the waste in question. Carbon treatment may not be appropriate for the viscous, tarry, still bottoms at Denny Farm Site 1. The waste at the site would coat the carbon material and reduce the efficiency of the system to the point where it would not be feasible to use. In theory, this particular treatment would remove the TCDD from a quantity of waste and concentrate the TCDD in the carbon. Although this may reduce the bulk volume of the waste containing TCDD, the TCDD component must still be dealt with. The time constraints with respect to removal of the material from the ground prohibit consideration of this approach to the waste itself. It may be possible to use it to process wastewater for decontamination of personnel and equipment during the handling of the contaminated material.

Physical solidification involves a number of techniques designed to seal the wastes in a hard, stable, immobile mass. High costs are associated with this process, and a thorough chemical identification of the waste is necessary. These waste-specific processes are not applicable to all liquid wastes and must be thoroughly evaluated for each waste.

This application involves physically surrounding the waste particles with a solidifying agent. Short-term fixation is achievable in some cases; however, long-term projections for the stability of the material must be made via ageing and other tests (20). Consideration must also be given to the potential future release of waste material before this method is chosen. Common methods include use of cement, lime, thermoplastics or organic polymers; self-cementation; and glassification.

Solidification of a hazardous waste is primarily used to insure the safe handling and transport of the waste. The application of this technology for some hazardous wastes has been proven. In this case, however, there is concern about the interaction of the organic content of the waste with the solidifying agent(s). Although the technology has been in existence for some time, its application to hazardous waste is a recent innovation and therefore may require additional research (21).

Storage

Storage involves the holding of the properly containerized material over a period of time in such a manner as to remove the material from the environment. This method may have both on- and off-site applications.

Operators of designated storage/disposal facilities were contacted initially to determine their storage capabilities and willingness to accept the TCDD-contaminated waste and soils. Existing facilities would certainly eliminate the need for construction of an on-site structure, thus saving time and decreasing capital investment.

Naturally, prerequisites to storage at commercial facilites are excavation, temporary storage, and transportation. The first two areas are dealt with in Section 8, while transportation via commercial permitted carriers would have to be investigated beyond the limits of this report. The waste and associated contaminated material would have to be properly containerized in Department of Transportation (DOT) approved hazardous waste drums. In addition to federal regulations, transporters would have to comply with applicable state regulations based upon the routes of transportation chosen. The commercial facilities which were contacted and their replies are given in Table 7-2. The replies obtained from the commercial facilities indicated that an on-site

storage structure would have to be considered in the conceptual design stages of the remedial approach (Table 7-2). Standard approaches such as tanks, buildings, etc., as well as innovative approaches, will be reviewed. At a minimum, a viable concept at this time would have to accommodate the anticipated volume of waste material to be stored, have structural integrity consistent with the potential hazards posed by the release of the materials, and meet the requirements of applicable codes and regulations.

SUMMARY OF POTENTIAL REMEDIAL ACTIONS

Application of the generic selection criteria (proven technology, time, cost, risk, legal constraints) and site-specific criteria (site and waste characteristics) have eliminated a substantial number of potential remedial action methods. Storage and treatment and/or a combination of both are the remaining viable means, and both of these require removal of the waste and associated contaminated material from the disposal trench.

A logical sequence of events would involve excavation of the material with immediate temporary storage until such time as treatment, disposal, or permanent storage are available. Section 8 of this report presents criteria for the excavation and storage methods proposed for Denny Farm Site 1. These two phases are prerequisite to the application of any treatment method. The most promising treatment methods are chemical treatment by ultraviolet photolysis and physical treatment by incineration. These are not yet available commercially and require full investigation at some future date.

REFERENCES FOR SECTION 7

1. Federal Register, Volume 45, No. 98, 33073-33067.

2. Ecology & Environment,Inc. Remedial Action for Denny Farm Site 1 Aurora, Missouri - A Working Paper. Washington, D.C., June 1980.

3. Ecology & Environment, Inc. Technical Study and Remedial Actions for Denny Farm Site 1, Aurora, Missouri. Washington, D.C., July 1980.

4. Crosby, D. G. and Wong, A. S. "Photodecomposition of Chlorinated Dibenzo-p-Dioxins," in Science, Volume 173, 748-749, 1971.

5. Crosby, D. G. and Wong A. S. "Environmental Degradation of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)," in Science, Volume 195, 1337-1338, 1977.

6. Personal communication with Howard Beard, Office of Solid Waste, U.S. EPA, Washington, D.C., June 12, 1980. (202) 755-9205.

7. Inside EPA, Inside Washington Publishers, Inc., Washington, D.C., May 30, 1980.

8. Personal communication with Scott Ritchey, Region VII, U.S. EPA, Kansas City, Missouri, June 13, 1980. (816) 374-6534.

9. Personal communication with Russ Wyer, Deputy Director of Oil and Specialty Materials, U.S. EPA, Washington, D.C., June 12, 1980. (202) 245-3048.

10. Wilcox, Jack, TATL, Region IX, memo to Jim Buchanan, FITL, Region VII, June 12, 1980.

11. Personal communication with Jack Zeff, President, Watergate Research, Inc., Santa Monica, California, June 16, 1980. (213) 473-4541.

12. Personal communication with Charles Terrel, U.S. EPA, Aquatic Protection, Washington, D.C. (202) 472-3400.

13. U.S. EPA. Survey of Solidification/Stabilization Technology for Hazardous Industrial Wastes, EPA-600, 2-79-056, Cincinnati, Ohio, 1979.

14. Personal communication with Michele Telepchak, Sybron/Biochemical Corporation of America, Technical Data Sheets, Farmingham, N.Y. 1979-1980.

15. Wilkinson, R. R., Kelso, G. L., and Hopkins, F. C. State-of-the-Art Report: Pesticide Disposal Research. EPA-600/2-78-183, August 1978.

16. U.S. EPA. Incineration in Hazardous Waste Management Publication. SW 141, Office of Solid Waste Management Programs, 1975.

17. Personal communication with E. Martin, U.S. EPA Oil & Special Materials Control Division, Washington, D.C., August 27, 1980. (202) 755-9203.

18. Personal communication with Steven Dorreler, U.S. EPA Emergency Response Team, Edison, New Jersey, June 25, 1980.

19. Stevens, J. J., Crumpler, E., and Shin, C. C. "Thermal Destruction of Chemical Waste," Presented at 71st annual meeting of AICE, November 14, 1978.

20. U.S. EPA. Survey of Solidification/Stabilization Technology for Hazardous Wastes. EPA-600/2-79-056. Cincinnati, Ohio, 1979.

21. Personal communication with Robert B. Pojasek, Ray F. Weston, Woburn, Massachusetts, June 1980.

SECTION 8

PROPOSED REMEDIAL ACTION: CONCEPTUAL DESIGN

This section discusses in detail the conceptual design recommended for cleanup of the Denny Farm Site 1. It provides the general concept for gaining control of the TCDD-contaminated waste and presents the basis for Ecology & Environment, Inc.'s (E & E's) recommendations. Each component of the remedial action is discussed and cost estimates are made for the elements. Preliminary drawings are provided which illustrate the sequence of events. Finally, the total cost and time associated with the completion of the components of the remedial action are presented.

E & E has concluded from the prior studies of options for gaining control of the TCDD-contaminated waste that, in the short term, the drums of waste and the contaminated soil must be removed from the disposal trench and placed in temporary storage. This recommendation is supported by:

- The human toxicity of TCDD.
- The confirmed presence of TCDD.
- Poor condition of the barrels in the trench.
- Geological and hydrological conditions of the area which contribute to significant uncertainty of the integrity of the trench bottom and suggest the possibility of vertical migration of contaminants into the subsurface formation and groundwater.
- Risk of human exposure by leaving material in the trench is significantly higher than removing.

Both the release of toxic material from uncontrolled hazardous waste sites and the remedial actions taken to deal with them pose certain risks to the environment and to the public. E & E performed an analysis of the risk of exposure in numerical terms for the public. This analysis compared the the risk of several alternative remedial actions to the option of taking no action.

A detailed discussion of the E & E risk model is contained in Appendix B. A review of Table B-1 indicates that a combined total human exposure of 121.6 occurs if absolutely nothing else is done to the Denny Farm Site 1 other than acknowledge its existence. The mere presence of monitoring wells reduces this figure to 53.7 exposures (predicated on monitoring wells which will intercept any release of contaminants). The importance of proper well location, if possible, in a karst geological setting cannot be over emphasized. A further reduction in exposures, and the lowest value, occurs from the implementation of the recommended remedial action of excavation and on-site storage. This value is 48.3 exposures and is primarily due to short-term worker exposure.

The off-site transportation of the waste to the Verona, Missouri, facility offers a slightly increased element of risk (48.7 exposures) because the population at risk increases with the inclusion of the transportation route and the population in Verona, as well as the production employees. This analysis lends credence to the decision for undertaking the recommended remedial action.

The temporary storage on site provides the flexibility of utilizing treatment technologies in the future such as ultraviolet photolysis.

The remedial action consists of four major components:

1. Temporary storage facility
2. Site setup and mobilization
3. Excavation
4. Site closure

As presented, each component is a product of a refinement process in which engineering and cost estimating techniques were applied in an effort to obtain the most practical and cost-effective option. The costs were developed for each individual component based on data obtained from a limited number of potential suppliers and contractors, estimating manuals, price lists, and knowledge of local costs for labor and materials (1) (See also List of Contacts following References). Where appropriate, these base costs were adjusted to reflect the hazardous nature of the project by adding a premium to the costs for labor and equipment usage.

The design concept will be discussed in the sequence in which the individual components must be executed. In many cases the component is a set of engineering procedures rather than an actual design element, thus making the remedial action an integrated process. Each component will have criteria defined, elements identified, and cost and activity time estimated.

COMPONENT 1. TEMPORARY STORAGE FACILITY

To establish control over the waste materials and to provide acceptable storage until final disposition is determined, a temporary storage structure must be constructed. On-site storage has been selected because there are no immediate facilities nationally that will handle dioxin-contaminated wastes. Thus, the risks of exposure through transport to a distant storage facility cannot be considered at this time. On-site storage is the most reasonable approach since it limits the handling and transportation to a minimum until the final disposition of the waste is determined.

The storage facility is comprised of two units: foundation and structure.

Foundation

Preliminary geotechnical investigations of the area indicate that sinkhole development could threaten the stability of a storage structure. Two alternative foundations were considered: a structural slab constructed on bedrock and a structural slab constructed on grade supported by a system of grade beams supported by caissons which extend into the bedrock. For estimating purposes, the structural slab on bedrock and the caisson-grade beam system were designed to span a sinkhole 40 feet in diameter. The caisson-grade beam alternative was chosen because it was more economical. The detailed design effort would include a geotechnical study for purposes of selecting a site where risk of sinkhole formation is low and determining the placement of the caissons.

For considering foundation requirements, the storage facility should be located near the disposal trench on the Denny Farm. This would minimize the risks associated with transportation. The cost for a foundation is somewhat proportional to the amount of overburden on the bedrock; therefore, an area with minimal overburden should be selected. For this analysis, the assumption was made that a location with only 12 feet of overburden above the bedrock would be used. The proposed location should not be subject to flooding.

Structure

Two structural systems were considered: a reinforced concrete system and a steel system. The steel system is similar to the systems employed for standpipe water storage tanks. Both systems can be designed to resist natural phenomena, have an expected life in excess of 20 years, and are resistant to fire and unauthorized entry.

However, the steel plate structure offers several additional advantages over and above the reinforced concrete systems. First, the structure itself is a containment vessel, thereby providing secondary protection against contaminant escape. Secondly, since this type of structure is a standard commercial item, it can be procured, fabricated, and erected quickly and economically. Thirdly, the structure can withstand high wind loads, extremes in temperature, and certain types of stress better than a reinforced concrete structure. Finally, the structure has a salvage value either as a containment structure or as scrap metal. The size of the structure was determined by the following:

- o Anticipated maximum storage of 5,000 drums.
- o Access for inspection and removal of individual drums.
- o Ventilation.

A commercially available unit meeting estimated volume and dimensional requirements was selected.

The major elements of the temporary storage component are:

- o Select a number of potential sites on the Denny Farm for subsurface investigation. Perform detail geotechnical investigations to determine the depth to bedrock and the competency of the rock and to evaluate the factors which would indicate potential sinkhole development.

- Prepare the necessary engineering designs for the foundations and the structure.

- Prepare permit applications as required--state and federal regulations.

- Prepare site for storage facility.

- Construct storage facility.

The total estimated cost for completion of Component 1 is $360,000. The detailed cost estimate is presented in Table E-1 of Appendix E. Figure 8-1 provides a conceptual layout of the foundation and section view of the storage facility.

The anticipated construction time for this component is four months from execution of the geotechnical investigation to completion of the facility. The time requirement for obtaining permits was not included in this time projection.

COMPONENT 2. SITE SETUP AND MOBILIZATION

Site setup and mobilization include preparing the site for the excavation and providing the necessary support facilities. The major elements of this component are:

- Clear additional land to provide space for support facilities and for the excavation area.

- Move on site and install utility systems; provide trailers for the command post, equipment storage, and crew facilities

- Establish the necessary sanitary and water supply systems.

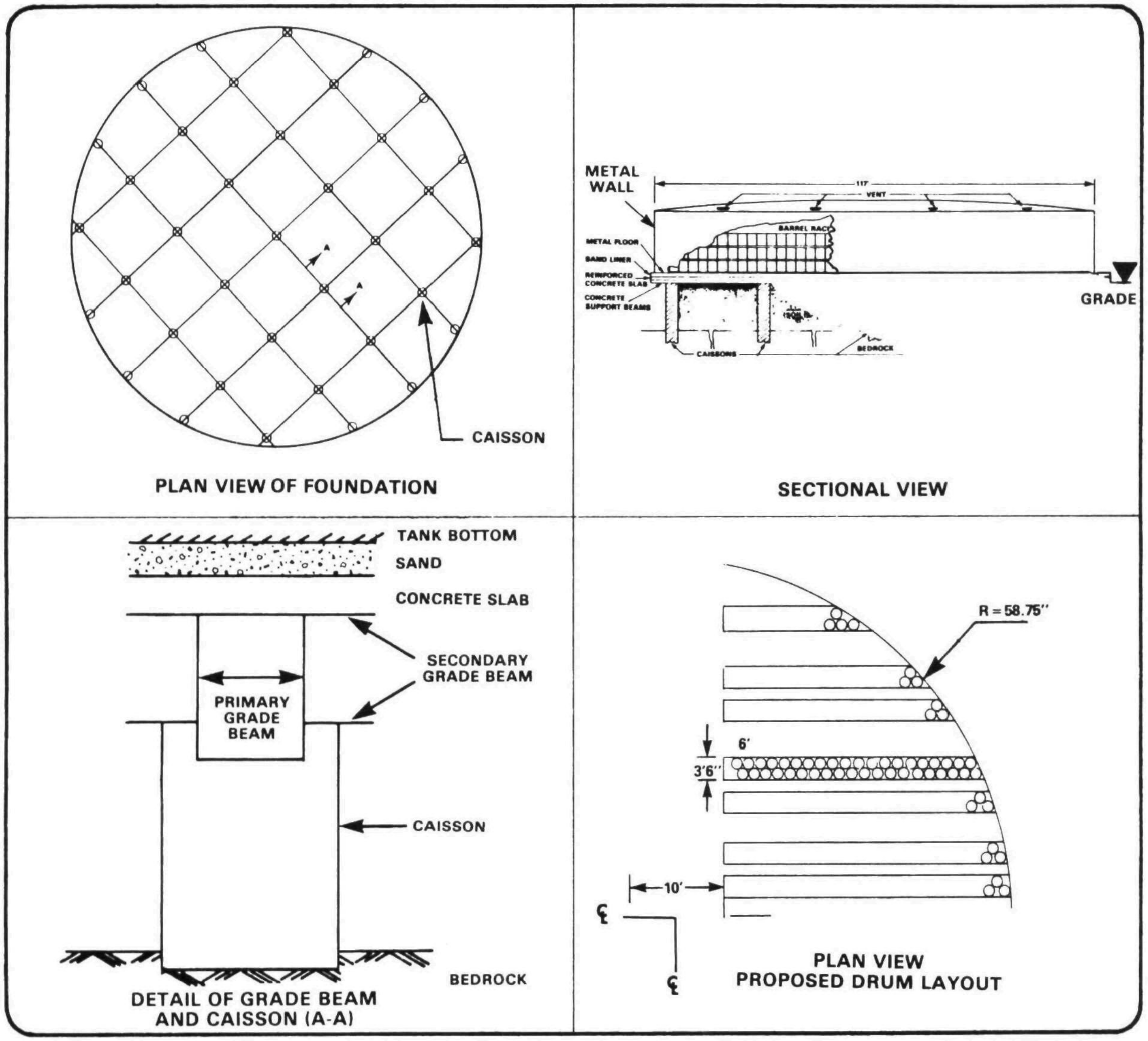

Figure 8-1. Temporary Storage Facility

- o Procure and provide on site all personnel protection equipment.

- o Conduct a worker training session once all systems are in place and ready for use.

- o Expand the fenced area to provide sufficient area for equipment operation and material handling.

- o Set up the drum and personnel decontamination facilities, install air supply systems for the totally encapsulated suits; and install construction lighting systems.

- o Construct runoff control system.

- o Remove the existing impervious cap and place the canvas tarp system in place.

The total cost for Component 2 is $358,670, which includes moving equipment onto the site, mobilizing labor and materials, and doing initial site preparation prior to commencing the excavation. In addition, all personnel protective equipment are procured and personnel properly trained for its use. Detailed cost estimates are provided in Table E-2 of Appendix E. Figure 8-2 shows a plan view of this proposed site setup. Component 2 will require about 10 days and will run concurrently with portions of Component 1 so that the excavation phase can start at completion of Component 1.

COMPONENT 3. EXCAVATION

Component 3 deals specifically with the excavation of a predetermined volume of soil (for purposes of cost estimates) and the removal of the drums and their contents. Since the extent of vertical migration has not been determined, this component has been divided into two subcomponents. Component 3A involves excavation of the trench area as defined by the previous E & E geotechnical study--perimeter 150 feet,

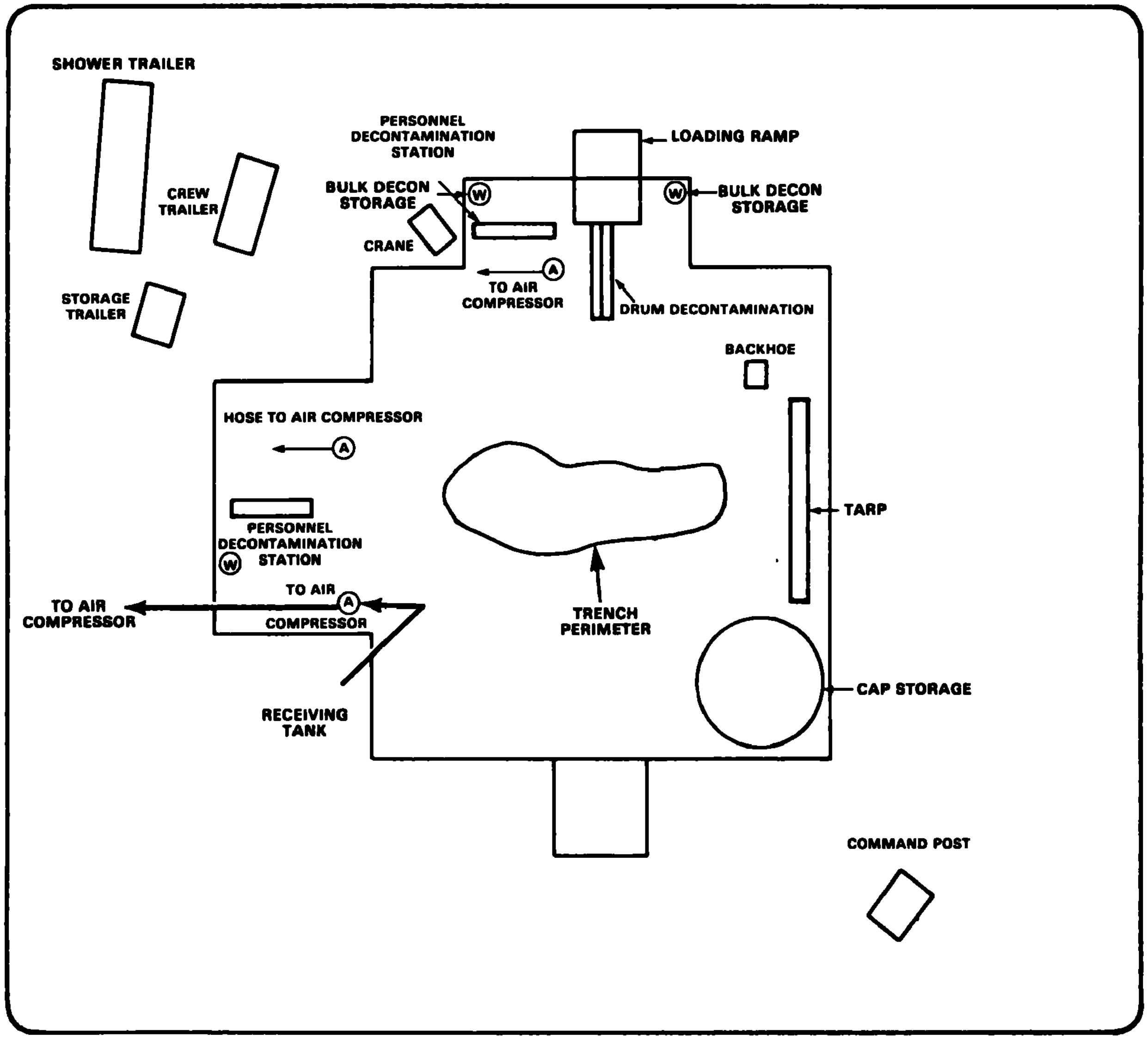

Figure 8-2. Plan View of Site Setup

depth 8 feet, total surface area 1,000 square feet, and 1:1 side slopes. An assumption is made that contamination has not migrated laterallv from the trench. Component 3B involves excavation of additional volumes of contaminated soil. Soil volume is based upon contamination reaching 4 feet below the anticipated trench floor, 8 feet below grade for a total of 12 feet below grade. This volume is calculated for the entire length of the trench with additional material for sideslopes based upon 1:1 slopes. Since volumes have been used, more excavation may occur in one area of the trench than others and not affect cost estimates.

The proposed excavation and storage plan which formed the basis of the cost estimates for Component 3A are:

- o Removal of the contents of the drums and the drums from the trench.
- o Removal of contaminated soil to an acceptable limit to prevent any residual material from being transported into the groundwater by precipitation/percolation.
- o Minimizing excavation time to reduce potential off-site environmental contamination.
- o Removal of the TCDD-contaminated waste from the trench without spreading contaminants into presently uncontaminated material.
- o Utilizing excavation methods which present the lowest risk of rupturing a drum.
- o Decontaminating containers and personnel on exit from the site.
- o Isolating the workmen and all other personnel on site from the contaminated material. The level of protection provided

would be dependent on the task being performed, i.e., those people who are in direct contact with the waste will have the highest level of protection.

- o Reducing the physical stress on the workers created by the protective gear and the environment (rotating shifts).
- o Using dust control to minimize the spread of loosened contaminated soil by wind action.
- o Using runoff control to minimize the spread of contamination by a precipitation event and subsequent surface runoff.
- o Using weather protection for the open trench to keep precipitation from entering the trench and transporting the material into the groundwater.

Excavation

Test boring and soil analysis during geophysical surveys indicate no lateral migration of waste outside the limits of the trench as defined by ground penetrating radar and metal detectors (2).

The objectives of 3A are to uncover the drums without rupturing them and to remove the contents of the original drums while removing the minimum amount of soil. The cost estimate is based on utilizing a small tractor-mounted backhoe, in conjunction with hand labor, to place soil into 55-gallon drums. The volume of soil to be removed during 3A of the excavation process should be viewed as an upper limit. It is anticipated that the 1:1 side slopes used for the purpose of the estimate could be reduced. The soil contains chert and clay and should provide a safe side slope at a steeper angle, thereby reducing the volume of the 3A excavation. A portion of the excavated soil could be stored on the floor and be removed as part of the 3B excavation.

Drum Decontamination

The exterior of all containers leaving the trench area would have to be thoroughly decontaminated. This would be accomplished by washing the drums with decontamination solution to remove any contaminated soil particles or liquid. To facilitate drum decontamination, roller or idler bar conveyors would be used. An assembly line approach for drum decontamination would then be possible. A small ramp would be excavated at the end of this conveyor to allow the trucks to back up level with the conveyor. Drums will be moved by use of hand trucks. A collection trough and pumping system would be placed beneath the conveyor to collect the water used to wash the drums. Once the trough becomes full, the pumping system would drain the trough to a bulk storage tank. At this time, it is not known if the water used to decontaminate the drums and personnel will contain levels of contamination above the allowable limits for discharge. All decontamination water could be sampled and analyzed from the bulk storage tank.

If the decontamination water does not contain levels of contamination above the allowable limit, water would be discharged or reused. Should contamination be found, the water would be placed in storage. The volume and cost estimates are based on the above procedure.

Waste and Drum Removal

After nine years it is reasonable to assume the drums in the trench are corroded, and this has been partially confirmed. It has been assumed that it is unsafe to lift any full or partially full drums directly out of the trench. The procedure developed for removal of the waste from the trench consists of pumping the contents from the original drum into the 55-gallon closed drums located on the side of the trench. An air-operated positive displacement pumping system would be utilized because it will help prevent the possibility of an explosion and has the ability to pump viscous liquids. Once the liquid contents are removed, the old drum would be placed into an overpack (85-gallon drum) and lifted out of the trench. A crane would be used to lift all material from the trench.

The chemical properties of the waste would have to be determined prior to drumming so that proper materials can be selected for the wetted surfaces of the pumping system and the drums. Samples of waste may be obtained from EPA-Region VII.

Worker Safety

Providing for the health and safety of personnel requires isolating the workmen and other personnel on site from the contaminated material.

As discussed in a previous section, the exposure routes for TCDD include skin absorption, ingestion, and inhalation. Therefore, it is E & E's recommendation that all on-site personnel be completely protected when in contact with any potentially contaminated material. The personnel protective equipment for the different operations is defined in Appendix D. The possibility of a spill, accident, and potential IDLH (immediately dangerous to life and health) atmosphere precludes the use of a lesser degree of protection. Totally encapsulated suits should be adequate for personnel within the fenced area. Once the drums are sealed and decontaminated, the level of protection can be reduced. Disposable coveralls with hood, gloves, boots, and full face respirators should be adequate for the off-site personnel, including the personnel at the storage facility.

A metal grate walkway instead of a conveyor will be used for personnel decontamination prior to leaving the fenced area. A collection trough and water handling system similar to that used for drum decontamination would be used. Separate personnel exits have been provided to limit movement across the excavated area. The work will always progress from low to high contamination (See Figure 8-3).

Worker Training

The use of safety equipment presents specific problems for workers, such as communications, visibility, dexterity, and psychological changes. A training period has been included to provide experience in equipment and procedures on order to acclimate the worker to the restricted working environment.

Excavation Time

In order to reduce the risk of spreading contaminated material, two eight-hour shifts are used. The third shift would be used to replenish

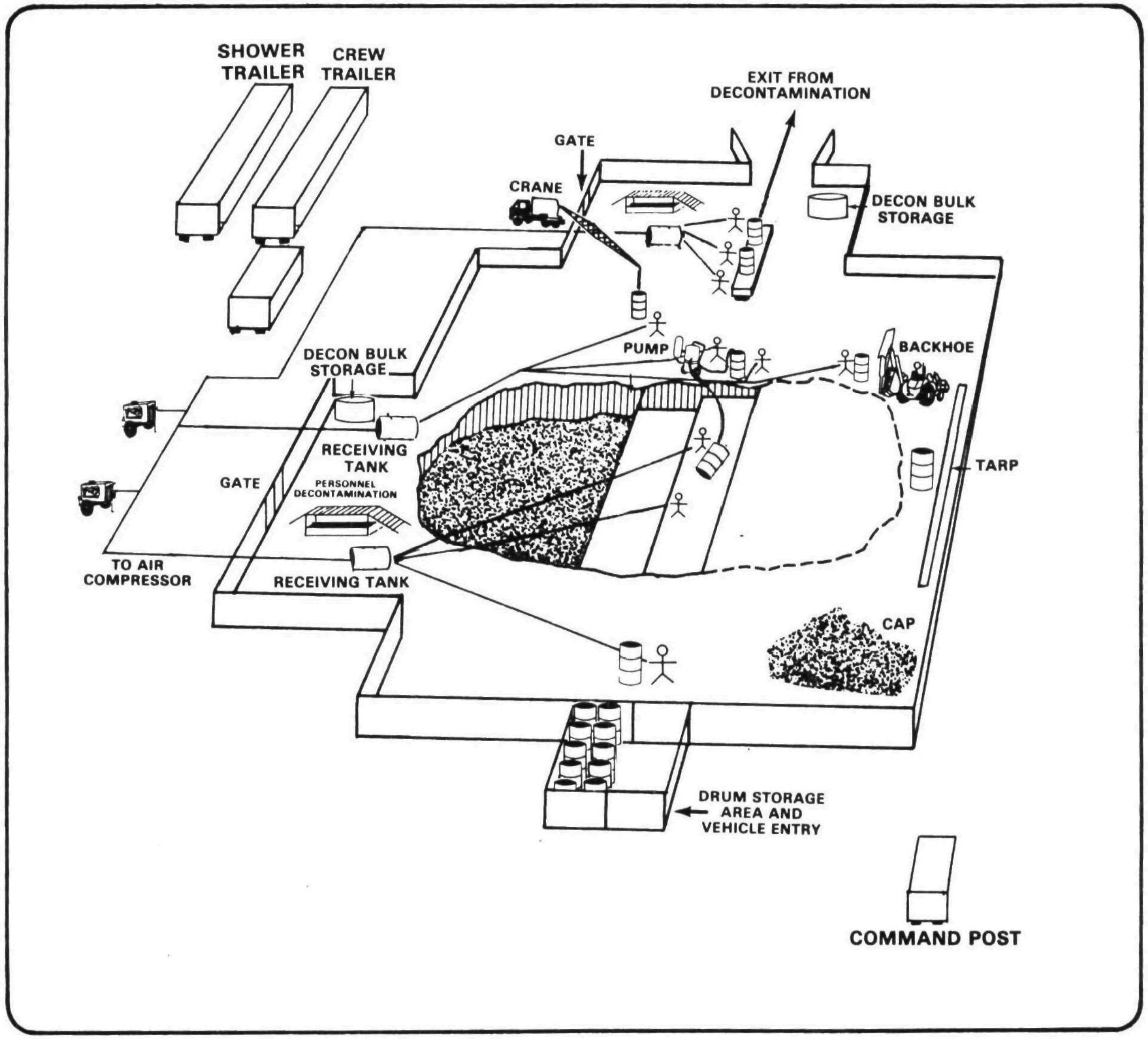

Figure 8-3. Site Excavation

supplies and service equipment. The shifts would be arranged to minimize work activity during adverse temperature periods of the day. A five-day workweek was used as the basis of the cost and time estimate.

Six- and seven-day workweeks were also evaluated. The seven-day workweek was not cost effective, while there did not appear to be a significant cost difference between the five- and six-day workweeks. The five-day workweek was selected, however, to minimize any cumulative worker fatigue.

Worker Fatigue

Performing physical work in the encapsulated suit will increase fatigue and decrease productivity. An analysis of the workmen per shift was made to develop cost estimates for the labor component of the various work elements. For Component 3A, approximately 42 people per shift would be required on site until all the drums were removed from the trench. Approximately 20 people would be required for 3B on site, and the work would be reduced to one shift, since the majority of the contamination would have already been removed.

Only 19 of the 42 workmen required for the 3A excavation would be on the site at any one time. The proposed distribution of the 19 workmen is as follows:

- Six will be in the trench digging, filling drums, and removing the contaminated material.

- Six will be at trench side assisting in the removal of the material and handling of drums as required.

- Six will be in the drum decontamination area.

- One would operate the backhoe. With the exception of the workmen in the trench, the on-site personnel would rotate to other areas at any time to provide temporary assistance.

The remaining personnel are distributed as follows:

- Six workmen would be utilized for personnel decontamination; two stations with three workmen each were used as the basis of the estimate.

- Four workmen would be utilized to load, unload, and transport the drums from the decontamination area to the storage facility.

- One person would be required to operate the crane to lift materials in and out of the trench.

- One safety officer, one foreman, and one engineer would also be required.

Nine personnel, who would be located off site at a rest station, would relieve personnel doing the work to reduce worker fatigue. A rotation system has been considered which would provide for a one-hour rest after two hours of work. The rotation system would also provide for the workmen rotating among the hand excavation assignments, the material handling assignments, and the drum decontamination assignment. The equipment operators, decontamination personnel, and personnel used to load, unload, and transport the material to storage could rotate jobs on a daily basis to help minimize any cumulative fatigue.

The major elements of Component 3A are:

- Begin excavation at either the west or east end of the trench by digging down and uncovering the drums for the full width of the trench. This excavation would be accomplished by using a backhoe in conjunction with hand excavation. Place all the soil in drums and move to the decontamination area and then to the storage facility.

- Hand excavate around the exposed drums to gain access to the bung or high point in the drum. Place soil removed into drums which will be lifted from the trench to the decontamination area and then transported to the storage facility.

- o Withdraw the contents of the drum by placing the suction hose through the bung or opening by special equipment and pump the contents to a drum located on the edge of the excavation. When the drum has been emptied, the new drum will be sealed and moved to the decontamination area.

- o Remove the original drum from the excavation after all the liquid has been removed and place in an overpack. Seal the overpack and lift it from the trench to the drum decontamination area.

- o Decontaminate drums.

- o Remove the decontaminated drums to the storage facility in truckload lots.

- o Continue the above sequence of excavation to uncover the drums, remove the liquid fraction of their contents, decontaminate the drum, and remove the decontaminated drums to the storage facility until all the drums are removed from the trench.

The anticipated activity time for this component is approximately 23 days. The estimated cost for Component 3A is $467,930. Table E-3 of Appendix E contains the detailed cost estimates and supporting data on materials and volumes of water required.

Component 3B Excavation

Excavation in 3B includes all the work required to determine the extent of contaminated soil and its removal. The soil will be removed and placed in 55-gallon drums. Layout of the 3B excavation is shown on Figure 8-4.

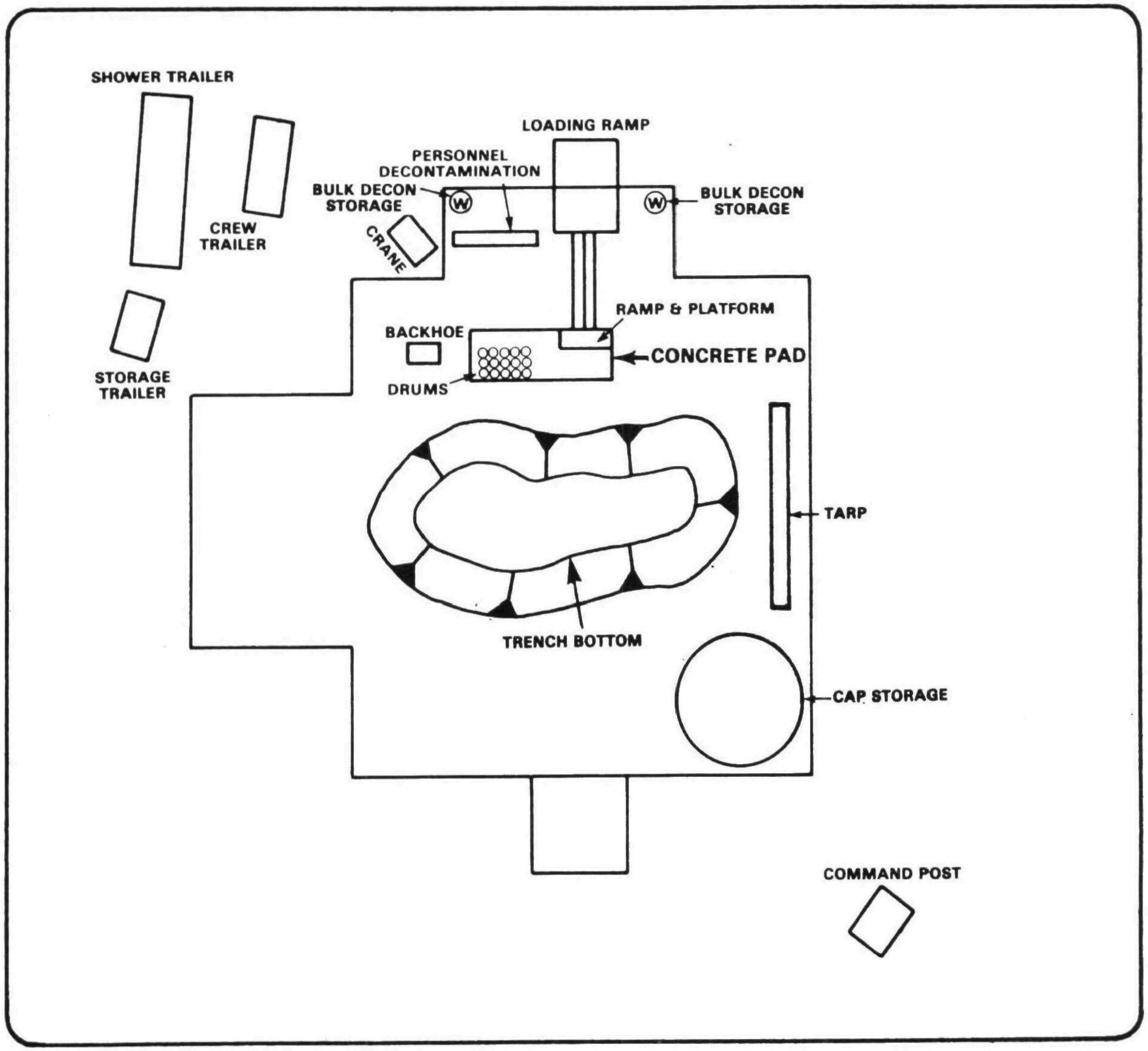

Figure 8-4. Plan View of Component 3B Excavation

The major elements of this component are as follows:

- o Sample the trench bottom and side to determine compliance with acceptable cleanup level.

- o Based on the results of the sampling and analysis, determine the location and volume of contaminated soil to be removed. If none, close out site as defined in Component 4.

- o Set up drum loading area.

- o Excavate the contaminated soil and place the soil in drums. Remove the drums to the decontamination area, decontaminate, and then move to the temporary storage structure.

- o Sample the trench bottom and other areas inside the fenced area to determine compliance with acceptable cleanup levels.

The activity time, which is based on the capacity of the storage structure, is 10.5 days of soil excavation. There are two costs associated with the Component 3B. The initial sampling ($44,000) of the trench to confirm levels of TCDD and TCP contamination will be a fixed cost. If there is a positive analysis, an additional fixed cost of $3,110 will be incurred for construction of the loading platforms. Variable costs, which include labor, equipment rental, and materials, amount to $11,340 per day or $380 per cubic yard of soil removed. An estimated detailed cost for Component 3B is found in Table E-4 of Appendix E.

COMPONENT 4. SITE CLOSURE

Site closure consists of removing all equipment, tools, and materials used to do the work, and backfilling and grading of the site.

The major elements of this component are:

- o Decontamination of all equipment and reusable tools.

- Removal to the temporary storage facility of all contaminated tools, equipment, and supplies which are expendable or are unable to be decontaminated, and all the decontamination water.

- Backfilling the trench with virgin material and regrading the area inside and outside of the fence.

- Removal of all trailers and support facilities (note the fence will remain).

The estimated activity time for this component is 10 days, and the estimated cost is $23,810. A detailed cost estimate is included in Table E-5 of Appendix E.

Summary of Component Costs

As shown on Table 8-1, the direct cost to complete the excavation and storage of drums and contaminated soil around the drums is estimated at $1,219,000. An estimated total project cost has been developed by adding to the sum of the component costs an allowance for contractors' overhead and profit and a contingency to account for unforeseen problems. The value of 70% of the direct cost was used to compute the contractors' overhead and profit.

Overhead is estimated at 45% while profit has been assigned 25%. These values appear to be reasonable because they are within the range used by contractors who are engaged in this type of cleanup work. A value of 20% of the direct costs was used to compute the contingency, but the contingency can be reduced once the plans and specifications are defined. Normal engineering projects estimate contingency at 10% at the conceptual design level; however, the 20% contingency factor is reasonable due to the nature of the work and safety requirements.

The total estimated project cost without the Component 3B is $2,486,000 (Table 8-1). (Component 3B considers only the requirements for further excavation. Storage through 3B is accommodated in the orginal structure.) The maximum costs, which include Component 3B and

TABLE 8-1

REMEDIAL ACTION

COMPONENT COST SUMMARY

COMPONENT	DESCRIPTION	AMOUNT
1	Storage Facility	$360,000
2	Site Setup and Mobilization	367,000
3A	Excavation	468,000
4	Site Closure	24,000
	Subtotal	$1,219,000
	Overhead and Profit (70%)	853,000
	Subtotal	2,072,000
	Contingency (20%)	414,000
	TOTAL PROJECT COST	$2,486,000

provide for excavation of the trench to an equivalent of 12 feet in depth, is $2,915,000 (Table 8-2). Not including permit preparation, the estimated duration of the effort is six months.

PLANNING CONSIDERATIONS FOR IMPLEMENTING PROPOSED REMEDIAL ACTION

A number of controls should be instituted for storage of the waste material. These controls are necessary to protect workers on-site and to prevent off-site migration of contaminants.

Site Control

A site control plan should be developed implemented which will address the following areas:

- o Designated hazard areas.
- o Access control points.
- o Establishment of on-site vehicle and personnel travel routes.
- o Establishment of administrative command post area.
- o Possible subdivision of the site for predetermined storage areas, rest area, and other miscellaneous areas as needed.

Storage Controls

Storage control involves a complete plan to organize and maintain proper records of all material placed within the storage structure. The storage structure must meet certain basic requirements:

- o The facility should be able to accommodate the anticipated volume required for stored material.
- o Ample room should be provided for the operation of storage equipment such as forklifts.

TABLE 8-2

REMEDIAL ACTION

COST SUMMARY

WITH ADDITIONAL EXCAVATION

Cost Summary for Trench Excavation/Storage		$1,219,000
Excavation* Fixed: $91,000 Variable Total: $119,000		210,000
	Subtotal	1,429,000
	Overhead and Profit (70%)	1,000,000
	Subtotal	2,429,000
	Contingency (20%)	486,000
	TOTAL	$2,915,000

*Based on 10.5 days of work with an additional 405 drums being stored. "Excavation will lower trench to 12 feet."

- o Ample room is needed for the inspection and removal of selected containers.
- o The structure should meet applicable codes and be able to withstand local weather and geologic conditions.
- o Security must be provided for possible vandalism and accidental entry.
- o The structure should provide for containing a spill.
- o Utilities must be provided.
- o Venting should be provided
- o Fire extinguishers, alarms, vapor detectors, and other safety equipment should be provided.

A comprehensive storage site control plan should be formulated including:

- o Spill prevention, control, and countermeasures plans.
- o Periodic inspections of storage structure and waste containers.
- o Proper record-keeping to document all inspections, material, movement, regulatory requirements, etc.
- o Additional security requirements such as barriers, warning signs emergency numbers, etc.
- o Area drainage.

REFERENCES FOR SECTION 8

1. Godfrey, R.S. (ed.), Building Construction Cost Data, R.S. Means Company, Inc., Kingston, Mass., 1980.

2. TECHNOS, Inc., Report of Geologic and Geophysical Investigation: Denny Farm Hazardous Material Site, Barry County, Missouri. Miami, Florida, 1980.

LIST OF CONTACTS MADE IN PREPARING MATERIALS AND LABOR COST ESTIMATES FOR SECTION 8

EQUIPMENT

Contractors Supply Company, Kansas City, Mo.	(816) 221-7788
Halco Equipment Company, Kansas City, Ks.	(913) 281-5700
Donco Equipment Company, Kansas City, Mo.	(816) 229-3422
Potter Equipment Company, Springfield, Mo.	(417) 852-9275

UNION LABOR RATES

Builder's Association of Kansas City	(816) 531-4741

ACTIVATED CARBON SYSTEMS FOR DIOXIN REMOVAL

John Bellinger/Calgon Carbon Service, St. Louis, Mo.	(314) 863-3200
Dr. Dave Stallins, Columbia National Fisheries Research Lab, Columbia, Mo.	(314) 442-2271

STRUCTURES FOR WEATHER PROTECTION

Rockhill Building Company, Kansas City, Mo.	(816) 761-4993
Munlake Construction Company, Kansas City, Mo.	(816) 254-5444
Sutherland Lumber Company, Kansas City, Mo.	(816) 587-9200
Payless Cashways, Kansas City, Mo.	(816) 474-4950
Roth Farm Supply, Kansas City, Mo.	(816) 737-3650
Kansas City Tent & Awning, Kansas City, Mo.	(816) 924-1883

ANALYSIS OF TCDD AND TCP IN AQUEOUS SOLUTIONS

Dr. Mike Taylor, Brehm Laboratory, Wright State University, Dayton, Ohio	(513) 873-2202

LIST OF CONTACTS
MADE IN PREPARING SECTION 8 (CONT'D)

WELL DRILLING and PUMPING EQUIPMENT	
Gerald Sill Drilling, Springfield, Mo.	(417) 866-7341
Boyles Brothers' Drilling, Springfield, Mo.	(417) 869-1298
Action Rotary Drilling, Wheatland, Mo.	(417) 282-5270
Layne-Western Company, Kansas City, Mo.	(816) 931-2353
CONTAINERS	
Cortland Container Company, Kansas City, Ks.	(913) 321-1212
U.S. Steel, Kansas City, Mo.	(816) 221-8311
PROTECTIVE EQUIPMENT AND DECONTAMINATION FACILITIES	
Mine Safety Appliances, Lenexa	(913) 888-2628
Arrowhead Grating Company, Kansas City, Mo.	(816) 471-3121
Donahower and Associates, Kansas City, Mo.	(816) 432-9306

SECTION 9

CONCLUSIONS AND RECOMMENDATIONS

Based on the geological, hydrological, and toxicological studies carried out by Ecology and Environment, Inc. (E & E), and the geophysical reconnaissance and risk analysis that have been conducted, E & E presents to EPA the following conclusions and recommendations concerning Denny Farm Site 1.

CONCLUSIONS

The geotechnical data, the toxicity of the waste, and the environmental factors require the following actions:

- Removal of the waste and associated contaminated materials from Denny Farm Site 1
- Storage of the waste and associated contaminated materials in a structure to be erected at Denny Farm Site 1

To achieve the required storage, the following excavation procedures are recommended:

- Consideration of weather protection
- Commitment to personnel safety
- Commitment to minimize time spent in the excavated disposal trench
- Ensurance that no contaminants leave the disposal site other than in containment vessels, i.e., drums
- Provision of sufficient storage to accommodate the removal of contaminated soil and material from the disposal site

To accomplish the recommended work, the cost estimate is $2,486,000.00.

RECOMMENDATIONS

In addition to the conclusions of this report noted above, E & E makes the following recommendations:

- That EPA proceed immediately to acquire the permits needed to excavate and store the hazardous waste materials at Denny Farm Site 1

- That EPA select a design engineering firm to prepare a final design and also select an execution contractor to carry out the required work at Denny Farm Site 1

- That EPA execute the recommended excavation and storage at Denny Farm Site 1

- That EPA continue with a long-term investigation of treatment and ultimate dispoal methods for the hazardous waste and associated contaminated materials at Denny Farm Site 1 that may meet the proven technology criterion before the expiration of the short-term storage solution presented in this report

APPENDIX A

SAMPLING DATA

TABLE A-1

GROUNDWATER MONITORING DATA

Sample No.	Well No.	Date	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3412	13	4-03-80	Phenolics	17,000	5,000	False positive
			TCDD	None	2	*ppt
AN3413	5	4-03-80	Phenolics	None	5,000	
			TCDD	None	2	
AN3438	4	4-03-80	Phenolics	None	5,000	
			TCDD	None	2	
AN3502	1	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3503	2	6-03-80	Phenolics	None	5,000	
			TCP	30	3	
			TCDD	None	20	
AN3504	3	6-03-80	Phenolics	8,000	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3505	4	6-03-80	Phenolics	14,000	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3506	5	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3507	6	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3508	7	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3509	8	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3510	9	6-03-90	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	

TABLE A-1 cont.

GROUNDWATER MONITORING DATA

Sample No.	Well No.	Date	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3511	Spring	6-03-80	Phenolics	None	5,000	*ppt
			TCP	None	3	
			TCDD	None	20	
AN3512	10	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3513	11	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3514	12	6-03-80	Phenolics	None	5,000	
			TCP	None	3	
			TCDD	None	20	
AN3515	13	6-05-80	TCP	None	3	
			TCDD	None	20	
AN3516	1	6-11-80	TCP	None	3	
AN3517	2	6-11-80	TCP	None	3	
AN3518	4	6-11-80	TCP	None	3	
AN3519	13	6-11-80	TCP	None	3	
AN3520	5	6-11-80	TCP	None	3	
AN3521	6	6-11-80	TCP	None	3	
AN3522	7	6-11-80	TCP	None	3	
AN3523	8	6-11-80	TCP	None	3	
AN3524	9	6-11-80	TCP	None	3	
AN3525	Spring	6-11-80	TCP	None	3	
AN3526	10	6-11-80	TCP	None	3	
AN3527	11	6-11-80	TCP	None	3	
AN3528	12	6-11-80	TCP	None	3	
AN3553	13	6-07-80	TCP	None	3	

TABLE A-1 cont.

GROUNDWATER MONITORING DATA

Sample No.	Well No.	Date	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3554	5	6-07-80	TCP	None	3	*ppt
AN3555	4	6-07-80	TCP	None	3	
AN3557	1	6-08-80	TCP	None	3	
AN3558	2	6-08-80	TCP	None	3	
AN3559	6	6-08-80	TCP	None	3	
AN3560	7	6-08-80	TCP	None	3	
AN3561	8	6-08-80	TCP	None	3	
AN3562	9	6-08-80	TCP	None	3	
AN3563	14	6-08-80	TCP	None	3	
AN3564	Spring	6-08-80	TCP	None	3	
AN3565	10	6-08-80	TCP	None	3	
AN3566	11	6-08-80	TCP	None	3	
AN3567	12	6-08-80	TCP	None	3	
AN3544	1	6-26-80	TCP	None	10	
AN3545	2	6-26-80	TCP	None	10	
AN3546	4	6-26-80	TCP	None	10	
AN3547	13	6-26-80	TCP	None	10	
AN3548	5	6-26-80	TCP	None	10	
AN3549	6	6-26-80	TCP	None	10	
AN3550	7	6-26-80	TCP	None	10	
AN3551	8	6-26-80	TCP	None	10	
AN3552	9	6-26-80	TCP	None	10	
AN3573			No data available			

TABLE A-1 cont.

GROUNDWATER MONITORING DATA

Sample No.	Well No.	Date	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3574	Spring	6-26-80	TCP	None	10	*ppt
AN3575	14	6-26-80	TCP	None	10	
AN3576	10	6-26-80	TCP	None	10	
AN3577	11	6-26-80	TCP	None	10	
AN3578	12	6-26-80	TCP	None	10	
AN3579	1	6-30-80	TCP	None	10	
AN3580	2	6-30-80	TCP	None	10	
AN3581	4	6-30-80	TCP	None	10	
AN3582	13	6-30-80	TCP	None	10	
AN3583	5	6-30-80	TCP	None	10	
AN3584	6	6-30-80	TCP	None	10	
AN3585	7	6-30-80	TCP	None	10	
AN3586	8	6-30-80	TCP	None	10	
AN3587	9	6-30-80	TCP	None	10	
AN3588	Spring	6-30-80	TCP	None	10	
AN3589	14	6-30-80	TCP	None	10	
AN3590	10	6-30-80	TCP	None	10	
AN3591	11	6-30-80	TCP	None	10	
AN3592	12	6-30-80	TCP	None	10	
AN3593	1	7-07-80	TCP	None	10	

TABLE A-1 cont.

GROUNDWATER MONITORING DATA

Sample No.	Well No.	Date	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3594	2	7-07-80	TCP	None	10	*ppt
AN3595	4	7-07-80	TCP	None	10	
AN3596	13	7-07-80	TCP	None	10	
AN3597	5	7-07-80	TCP	None	10	
AN3598	6	7-07-80	TCP	None	10	
AN3599	7	7-07-80	TCP	None	10	
AN5002	8	7-07-80	TCP	None	10	
AN5003	9	7-07-80	TCP	None	10	
AN5004	Spring	7-07-80	TCP	None	10	
AN5005	14	7-07-80	TCP	None	10	
AN5006	10	7-07-80	TCP	None	10	
AN5007	11	7-07-80	TCP	None	10	
AN5008	12	7-07-80	TCP	None	10	
AN5009	Melvin Marion	7-07-80	TCP	None	10	
AN5010	1	7-14-80	TCP	None	10	
AN5011	2	7-14-80	TCP	None	10	
AN5012	4	7-14-80	TCP	None	10	
AN5013	13	7-14-80	TCP	None	10	
AN5014	5	7-14-80	TCP	None	10	
AN5015	6	7-14-80	TCP	None	10	
AN5016	7	7-14-80	TCP	None	10	
AN5017	8	7-14-80	TCP	None	10	

TABLE A-1 cont.

GROUNDWATER MONITORING DATA

Sample No.	Well No.	Date	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN5018	9	7-14-80	TCP	None	10	*ppt
AN5019	Spring	7-14-80	TCP	None	10	
AN5020	14	7-14-80	TCP	None	10	
AN5021	10	7-14-80	TCP	None	10	
AN5022	11	7-14-80	TCP	None	10	
AN5023	12	7-14-80	TCP	None	10	
AN5024	Billy Edwards	7-14-80	TCP	None	10	
AN5025	1	7-21-80	TCP	None	10	
AN5026	2	7-21-80	TCP	None	10	
AN5027	4	7-21-80	TCP	None	10	
AN5028	13	7-21-80	TCP	None	10	
AN5030	6	7-21-80	TCP	None	10	
AN5031	7	7-21-80	TCP	None	10	
AN5032	8	7-21-80	TCP	None	10	
AN5033	9	7-21-80	TCP	None	10	
AN5034	Spring	7-21-80	TCP	None	10	
AN5035	14	7-21-80	TCP	None	10	
AN5036	10	7-21-80	TCP	None	10	
AN5037	11	7-21-80	TCP	None	10	
AN5038	12	7-21-80	TCP	None	10	

TABLE A-2

SOIL SAMPLING DATA

Sample No.	Description	Date	Sample Type	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3400	Borehole #1	4-22-80	Soil/composite	TCP TCDD	63,000,000 4,000	200,000 3,000	*ppt
AN3401	Borehole #2	4-24-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3402	Borehole #3	4-24-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3403	Borehole #4	4-24-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3404	Borehole #5	4-23-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3405	Borehole #6	4-26-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3406	Borehole #7	4-26-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3407	Borehole #8	4-26-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3408	Borehole #9	4-26-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3409	Borehole #10	4-25-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3410	Borehole #11	4-25-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3411	Borehole #12	4-24-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3421	Borehole #22	4-22-80	Soil/composite	TCP TCDD	None None	3,000 3,000	
AN3446	Trench soil sample	4-29-80	Composite	TCDD	42,000	1,000	WSU Analysis
AN8001	Boring #13	6-15-80	Composite 11 1/2-13 ft.	TCP TCDD	None None	20,000 70	EPA Analysis

TABLE A-2 cont.

SOIL SAMPLING DATA

Sample No.	Description	Date	Sample Type	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN8002	Boring #13	6-15-80	Composite 13-14 1/2 ft.	TCP TCDD	None None	2,000 70	EPA Analysis
AN8004	Boring #15	6-15-80	Composite 16-17 1/2 ft.	TCP TCDD	None None	2,000 70	EPA Analysis
AN8007	Boring #15	6-15-80	Composite 5-6 1/2 ft.	TCP TCDD	None None	2,000 70	EPA Analysis
AN8008	Boring #15	6-15-80	Composite 6 1/2-8 ft.	TCP TCDD	None None	2,000 70	EPA Analysis
AN8009	Boring #15	6-15-80	Composite 8-9 1/2 ft.	TCP TCDD	None None	2,000 70	EPA Analysis
AN8016	Boring #16	6-15-80	Composite 14-15 ft.	TCP TCDD	None None	1,000 70	EPA Analysis
AN8024	Boring #21	6-16-80	Composite 10-14 ft.	TCP TCDD	None None	1,000 70	EPA Analysis
AN8034	Boring #28	6-16-80	Composite 8-9 1/2 ft.	TCP TCDD	None None	1,000 70	EPA Analysis
AN8036	Boring #28	6-16-80	Composite 19-20 1/2 ft.	TCP TCDD	None None	1,000 70	EPA Analysis

TABLE A-3

SURFACE WATER MONITORING DATA

Sample No.	Description	Date	Sample Type	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3556	Pond west of Farm Site	6-8-80	Water (grab)	TCP TCDD	None None	3 20	
AN3568	Pond near Well #2	6-9-80	Water (grab)	TCP	None	3	
AN3569	Calton Creek	6-11-80	Resin Column water	TCP Extractable Priority pollutants	None None	1	
AN3570	Calton Creek	6-11-80	Resin column water	TCP Extractable priority pollutants Extractable organics	None None None	1	
VR5301	Spring River Highway 166	6-17-80	Sediment	TCP TCDD	None None	5,000	
VR5302	Spring River Highway 96	6-17-80	Sediment	TCP TCDD	None None	5,000	
VR5303	Spring River Highway 37	6-17-80	Sediment	TCP TCDD	None None	20,000	
VR5304	Spring River County Road P	6-17-80	Sediment	TCP TCDD	None None	5,000	
VR5305	Spring River U.S. U6	6-17-80	Sediment	TCP TCDD	None None	1,000	
VR5306	Calton Creek County Road VV	6-17-80	Sediment	TCP TCDD	None None	5,000	
VR5307	Little Flat Creek County Road C	6-17-80	Sediment	TCP TCDD	None None	5,000	
VR5308	Flat Creek County Road U	6-17-80	Sediment	TCP TCDD	None None	5,000 5,000	
VR5309	Flat Creek McDowell Mill Dam	6-17-80	Sediment	TCP TCDD	None None	5,000 5,000	

TABLE A-3 cont.

SURFACE WATER MONITORING DATA

Sample No.	Description	Date	Sample Type	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
VR5310	James River Nelson Mill Bridge	6-17-80	Sediment	TCP TCDD	None None	5,000 5,000	
VR5311	James River Frazier Bridge	6-17-80	Sediment	TCP TCDD	None None	5,000 5,000	
VR5312	Table Rock Lake Highway 76	6-18-80	Sediment	TCP TCDD	None None	5,000 5,000	
VR5313	Table Rock Lake Highway 76	6-18-80	Fish Samples 18 total 6 diff. species	TCP TCDD	None None	1,000 2,000	
VR5314	Table Rock Lake Highway 86	6-18-80	Sediment	TCP TCDD	None None	5,000	
VR5315	Table Rock Lake Highway 86	6-18-80	Fish 15 total 7 diff. species	TCP TCDD	None None	1,000 3,000	

TABLE A-4

DRUM (SOURCE) SAMPLE DATA

Sample No.	Description	Date	Sample Type	Parameter(s) Analyzed	*Quantity Detected	*Detection Limit	Comments
AN3440	Drum Sample Rusty Colored Liquid.	4-28-80	Single	Not analyzed, see composite sample information below.			Analysis by EPA. Each drum sample is actually a composite of the various liquid layers within the drum.
AN3441	Drum Sample Black residue.	4-28-80	Single	TCP, others TCDD	Identified-no 110,000,000	quantity spec. 20,000,000	
AN3443	Drum sample, black granular residue.	4-28-80	Single	TCP, others TCDD	Identified-no None	quantity spec. 29,000,000	
AN3444	Drum sample, black residue.	4-28-80	Single	TCP, others TCDD	Identified-no 65,000,000	quantity spec. 29,000,000	
AN3445	Drum sample, black residue.	4-28-80	Single	TCP, others TCDD	Identified-no 87,000,000	quantity spec. 29,000,000	
AN3441 AN3443 AN3444 AN3455	Drum samples, EPA Weighted average.	4-28-80	Volumetric Composite	TCDD	Weighted average is 81,000,000		
AN3440 AN3448 AN3449 AN3450	Drum samples.	4-28-80	Volumetric Composite	TCP Identified	19,000,000 Tetrachlorobenzene toluene, others	Not specified No quantity specified	No single analysis conducted on these samples.
AN3441 AN3443 AN3444 AN3445	26% 6% 32% 36% Drum samples.	4-28-80	Volumetric Composite	TCDD	319,000,000	1,300,000	Wright State Universtiy analysis
AN3440 AN3448 AN3449 AN3450	35% 10% 40% 15% Drum samples.	4-28-80	Volumetric Composite	TCDD	1,390	100	Wright State University analysis

APPENDIX B

RISK ANALYSIS

APPENDIX B

RISK ANALYSIS

INTRODUCTION: GENERAL APPROACH

The risks to human health posed by several alternative remedial actions for Denny Farm Site 1 can be quantitatively estimated by making a number of simplifying assumptions. This section defines what is meant by the terms "risk" and "exposure" and describes the general philosophy and methodology used to estimate the risks. The second section summarizes the risk results, the third section describes in detail the exposure scenarios and assumptions that were used to arrive at these results, while the last section presents details of the methods of calculation.

The major hazard to human health due to the wastes at the site is assumed to be the toxicity of dioxin (TCDD); for simplicity, only this hazard is considered. An "exposure" is considered to occur whenever a person comes directly in contact with TCDD in high enough concentrations that the dose of TCDD to his body exceeds an assumed safe level, which is taken to be 1 part per trillion (ppt) of body weight. The level of effect, that is, severity of health impairment, produced in the exposed person by this dose of TCDD cannot easily be predicted, and therefore the person is counted as potentially subject to some adverse health effect. Depending on the actual magnitude of the dose, which in turn depends on time duration of the contact and other pharmacological factors, the actual level of effect suffered may range from a mild and probably reversible case of chloracne to cancer of the liver.

In order for exposure to TCDD from the trench at the site to occur, a certain amount of TCDD must escape from the trench, spread from the site via some physical environmental pathway and ultimately enter the human body directly. An effort has been made to systematically consider all possible pathways and to identify those exposure scenarios which are most credible for four alternative actions.

In general, TCDD can enter the human body through several routes: oral, respiratory, and dermal. In this case, the route of body entry affecting the greatest number of people is oral ingestion of drinking water contaminated with dangerous concentrations of TCDD after environmental spread off site through groundwater ("Dangerous" concentrations are those above the safe level of 1 ppt). This type of pathway leads to the greatest contamination spread to the public off site. By comparison, the only other possible exposure routes occur via relatively short-range physical pathways and can potentially affect only a few workers on site. These other routes are direct skin contact or inhalation of TCDD-laden particulates or direct skin contact with liquid wastes.

Once the credible types of release and spread of TCDD from the trench are identified, the extent of the resulting exposure of people can be quantitatively estimated. By making simplifying assumptions about the physical mechanisms of the release and environmental spread and by taking into account known physical properties and principles, simple model calculations can be used to predict conservative distances of spread of the contaminant away from the site. In particular, one can compute the maximum distance around the site within which any sources of drinking water such as wells would be subject to dangerous concentrations of TCDD. Using a circular zone of influence around the site, the total number of people within this zone can be calculated. This number is the total exposures for the assumed release scenario.

In addition to the maximum extent of exposure, the probability of occurrence of such a release scenario must be considered. The probabilities of the various scenarios can also be quantitatively estimated by using historical data where available (e.g., for the probability of a tornado strike) and by making reasonable assumptions where numerical values are unavailable (e.g., the probability for the sudden formation of a sinkhole under the trench). The "risk" of a given exposure scenario is then defined as the mathematical product of the number of exposed people and the probability of occurrence of this scenario. Therefore, the risk of a given alternative action is the sum of the risks calculated for each of the credible release scenarios identified for that alternative. The risks of several alternative actions computed in this way can be compared quantitatively as an aid in deciding which action to take.

The most difficult part of this methodology is the initial stage of defining the credible exposure scenarios. The greatest problem is to combine the available bits of information, sometimes inconsistent, about physical properties of the contaminant TCDD, the geologic conditions around the trench, and known physical fluid flow principles to arrive at a plausible, yet consistent set of assumptions which can be used to describe the spread of TCDD away from the trench in groundwater. Quantitative calculations of extent of spread of TCDD away from the trench were carried out only for this groundwater pathway. It was credible to assume that successful mitigation methods such as dust control would be used to cut off the only other possible environmental pathway, i.e., wind-borne spread of TCDD-contaminated dust particles generated during trench excavation.

Although the resulting combinations of methods used are necessarily simplified, this analysis demonstrates that it is possible to arrive at quantitative answers for the risks by making credible assumptions. These answers, which are presented in the next section, should not be considered absolute. They are initial guidelines for further refinements but can be used in the meantime for discussing and comparing the several alternative actions.

SUMMARY OF ESTIMATED RISKS

Table B-1 presents the maximum and average numbers of people estimated to be exposed to dangerous concentrations of TCDD for each of several alternative remedial actions. Here, "dangerous" is taken to mean high enough to lead to a dose of 1 part per trillion (ppt) or greater in the average human body. For drinking water, this threshold concentration of TCDD is 0.035 parts per billion (ppb) (see Numerical Calculations section). The 1 ppt dose in the body is considered here as the allowable safe human dose of TCDD for either oral or dermal exposures.

The exposures in Table B-1 are categorized into workers on site and public off site, and also into short term and long term. "Short term"

TABLE B-1

SUMMARY OF ESTIMATED RISKS

MAXIMUM AND AVERAGE NUMBERS OF PEOPLE

EXPOSED TO DANGEROUS CONCENTRATIONS OF TCDD

Alternative Remedial Action	DURING SHORT TERM Workers on site	DURING SHORT TERM Public off site	DURING LONG TERM Workers on site	DURING LONG TERM Public off site	Total on site	Total off site	Combined Total exposures
1. Leave buried	0	1446 max 14.46 ave	0	119 max 107.10 ave	0	121.6 ave	121.6 ave
2. Install & maintain a groundwater monitoring system	0	379 max 0.13 ave	0	119 max 53.55 ave	0	53.7 ave	53.7 ave
3. Excavate & store material on site	43 max 20.6 ave	170 max 25 ave	0	67 max 2.7 ave	20 ave	27.7 ave	48.3 ave
4. Excavate + transport drums via truck to Syntex facility in Verona, Mo.	45 max 21.0 ave	180 max 25 ave	0	67 max 2.7 ave	21.0 ave	27.7 ave	48.7 ave

a "Average" is the maximum number multiplied by the estimated probability of occurrence; see Table B-2

b "Dangerous" means high enough to lead to a dose of 1 ppt or greater in the average human body; in drinking water, this threshold concentration is 0.035 ppb.

c "Short term" means during excavation period, approximately 1 month.

d "Long term" means greater than 1 year (assumes no other future actions are taken which lead to increased worker exposures).

refers to a time of about 1 month (about the length of time the trench would be open during the excavation in Alternative 3). "Long term" means greater than a year; it is assumed that no further worker actions are taken in the future which would lead to increased opportunities for worker exposure.

In each case shown in Table B-1, the maximum number of exposures given is that calculated for a specific release scenario, as described in the following section. For example, for Alternative 1 (leave buried) the value 1,446 is the maximum number of people estimated to be exposed to concentrations of TCDD in drinking water greater than 0.035 ppb. In the event of a hypothetical catastrophic geologic collapse or sinkhole beneath the trench, the groundwater and ultimately the drinking water wells from which these people are supplied would be rapidly contaminated. This particular scenario might be called the worst case for this alternative.

In addition to the maximum value shown in Table B-1, an average value for exposures is also given in each case. This average is the maximum number of exposures above multiplied by the estimated probability of its occurrence. The following section details how this probability of occurrence is estimated for each scenario, and Table B-2 summarizes the estimated probabilities. For example, for the sinkhole scenario described above for Alternative 1, the probability of occurrence was estimated to be 1 percent, or 14.46 exposures.

For each alternative, the total average exposure value is found by adding the average values for short term and long term. This is done separately for on-site and off-site classifications, and finally the sum of these two averages is the combined average risk (see far-right column in Table B-1).

Several general conclusions can be drawn from the results in Table B-1:

- Alternative 1 (leaving the trench as is) has the highest risk (121.6) of any of the alternatives, while Alternative 3 (excavate and store on site) has the lowest (48.3)

TABLE B-2

SUMMARY OF CREDIBLE EXPOSURE SCENARIOS

Alternative Remedial Action	Exposure Scenarios Considered	Estimated Probability of Occurrence	Estimated Max. No. of People Exposed to TCDD
1. Leave buried	(a) Catastrophic sinkhole leads to rapid release of contents of all 150 drums to water table below trench; subsequent horizontal flow of contaminants in "underground river" straight toward nearest private drinking water wells; people drink contaminated water from these wells (worst case).	1 chance in 100 (i.e., 1 percent)	1,446 (total Barry County population within 4.29 miles of site)
	(b) No sinkhole; instead, drums gradually leak maximum concentration at an assumed rate; waste leaches down conduit to water table, where dilution occurs because of greater water flow rate horizontally; again, "river" flows straight toward wells; people drink contaminated water from wells (most likely case).	90 chances in 100 (i.e., 90 percent)	119 (total Barry County population within 1.23 miles of site)
2. Install & maintain a groundwater monitoring system	(a) Monitoring well system is successful in warning nearby residents in time not to drink water in the event contamination of wells does occur (via either of scenarios above).	(0.01) (1/30) + (0.90) (0.50) $= 5.94 \times 10^{-4}$	0

TABLE B-2

SUMMARY OF CREDIBLE EXPOSURE SCENARIOS

Alternative Remedial Action	Exposure Scenarios Considered	Estimated Probability of Occurrence	Estimated Max. No. of People Exposed to TCDD
2. Cont'd.	(b) Catastrophic sinkhole occurs right after a well sampling time, with rapid contamination reaching water table and wells as above, and monitoring system does not warn residents in time; as a result, a certain limited number of people do drink contaminated water before a warning is issued (Maximum warning delay time of almost a sampling interval, say 29 days.) (worst case).	(0.01) x (1/30) $=3.3 \times 10^{-4}$	379
	(c) Gradual release of wastes to the water table occurs, and monitoring system does not warn residents in time; as a result, a limited number of people do drink contaminated water before warning is issued (On average, assume "safe time" before contamination of wells occurs is about half the well sampling interval, so there is a 50 percent chance that detection and warning will occur in time, and 50 percent that a delay of about a half sampling period, or 2 weeks, will occur.) (more likely case).	(0.90) x (0.50) =0.45	119

TABLE B-2

SUMMARY OF CREDIBLE EXPOSURE SCENARIOS

Alternative Remedial Action	Exposure Scenarios Considered	Estimated Probability of Occurrence	Estimated Max. No. of People Exposed to TCDD
3. Excavate and store material on site	(a) Workers on site are exposed directly to high concentration of TCDD because of a common accidnet during excavation (either by getting liquid or dust on skin, or in a wound, or inhaling contaminated dust).	0.20 over short term	2-3 workers
	(b) Tornado strikes site during excavation of drums, when trench is open, thereby spreading contaminated soil and perhaps liquids over a 2 square mile damage area around the site; people within this area are thereby exposed to contamination.	3.2×10^{-5} for short term	50
	(c) After excavation is complete, trench closed, and all excavated waste is stored in secure building nearby, gradual leaching of residual contamination remaining around the trench occurs, with ultimate contamination of wells; people drink low concentrations of TCDD in drinking water	0.95 over long term	0

TABLE B-2

SUMMARY OF CREDIBLE EXPOSURE SCENARIOS

Alternative Remedial Action	Exposure Scenarios Considered	Estimated Probability of Occurrence	Estimated Max. No. of People Exposed to TCDD
3. Cont'd.	(d) After excavation is complete, trench closed, and excavated waste stored securely, a sudden sinkhole occurs releasing all residual contamination around trench to water table; wells are quickly contaminated and people exposed through drinking water.	0.04 during long term	67
	(e) Workers in full suits are imperfectly decontaminated and leave site with amounts of TCDD on their bodies high enough to spread to other people off site.	0.1 x 0.25 = 0.025 probability of escape for each worker	40 workers 120 off site
4. Excavate and transport liquids and residues via truck to Verona, MO (Syntex facility) for treatment	(a) All 5 scenarios for Alternative 3 above apply, so risk contribution due to these is same as overall risk for Alternative 3. Additional possible scenarios are discussed below.		

TABLE B-2

SUMMARY OF CREDIBLE EXPOSURE SCENARIOS

Alternative Remedial Action	Exposure Scenarios Considered	Estimated Probability of Occurrence	Estimated Max. No. of People Exposed to TCDD
4. Cont'd.	(b) Truck accident occurs during transport to Verona, leading to release (spill) of liquid waste, which runs into Calton Creek because accident occurs just as truck passes over Calton Creek; despite spill contingency planning, 1 or 2 workers are exposed; no members of the public are exposed.	$(2.5 \times 10^{-6}) \times (0.5) \times (14 \text{ miles}) \times (0.02)^* = 3.5 \times 10^{-7}$ *coincidence factor for accident to occur right near Calton Creek	1-2 workers
	(c) Truck arrives safely at Verona, but an accident occurs at or near the Syntex facility, releasing some liquid wastes which run into nearby surface stream and ponds despite spill contingency measures; no workers are exposed, but about 10 members of public drink contaminated water or get contaminated dust on their skin (blown by wind after spilled liquid evaporates).	same as above	10

- The second lowest risk is associated with Alternative 4, which considers an additional component, transport via truck to Verona. The increase in risk of this alternative over that of Alternative 3 is small (48.3 to 48.7) and is due to the additional possibilities for exposures occurring during the truck transport and when the truck arrives at the more highly populated area of Verona.

- Installing a monitoring well system (Alternative 2) could be expected to reduce the risk to the public from drinking water to less than half its value without the monitoring system (Alternative 1) (53.7 compared to 121.6), by providing adequate warning in the event groundwater contamination did occur.

- For Alternative 1, even through the catastrophic sinkhole scenario leads to the largest number of exposures (1,446), the gradual leaching scenario contributes more to the risk, since its probability of occurrence is much greater (107.10 average compared with 14.46 average).

CREDIBLE EXPOSURE SCENARIOS CONSIDERED FOR EACH ALTERNATIVE

This section describes the credible scenarios which were considered for each alternative and the simplifying assumptions necessary to describe the consequences of the hypothesized environmental release of TCDD in each case. This will provide the maximum exposure numbers in Table B-1. The major parameters whose values were unknown and for which values had to be assumed are identified. Table B-2 summarizes the scenarios and gives as separate factors the estimated probability of occurrence and maximum number of exposures in each case. These are the factors which are used to develop the average risk number shown in Table B-1.

Alternative 1: Leave Buried

The first scenario considered is a catastrophic geologic collapse or sinkhole formation leading to a rapid release of the contents of all 150 drums from the trench. Even though a sinkhole would be only about 40 feet deep (1), it is hypothesized that a large amount of the liquid waste from the trench could still make its way rapidly down through the intervening clay layers to the water table about 120 feet below the trench. The contaminant is assumed to reach the water table in the form of a curtain 1 foot wide. The aquifer flows horizontally in a channel assumed to be 100 feet wide and 1 foot deep. An initial section of this aquifer assumed to be 50 feet in downstream length is taken as the known volume of water which is instantly contaminated with TCDD to the highest possible concentration of 0.2 μg TCDD/liter of water, or 200 ppt. The total mass of TCDD which actually dissolves in this volume of water is limited by the known solubility of TCDD in water, which is extremely low. This mass is 2.83×10^{-5} kg of TCDD (see Numerical Calculation section).

The contaminated water then flows horizontally in an underground river assumed to be 100 feet wide and 1 foot deep, in a straight line toward the nearest drinking wells. Ultimately, people are exposed to TCDD by drinking well water which has concentrations of TCDD greater than 0.035 ppb.

A mathematical model must be used to calculate how great a distance away in any one direction concentrations this high will occur. It is recognized that prediction of groundwater flow using standard approaches is impossible for the particular geologic setting of Denny Farm Site 1 (1,2). Such a prediction will nevertheless be necessary if a quantitative estimate of the risk is to be made.

The basic law of fluid flow through a porous medium is known as Darcy's Law (3). This principle has been used to make practical predictions of groundwater flow rates in assessing leachate production from landfills (3, 4, 5) and in analysis of the impact of groundwater pollution on human health (6). By assuming reasonable values for the porosity and hydraulic conductivity of the karst limestone through which the aquifer flows (1, 3), the estimated 3% hydraulic gradient away from the trench area can be used in Darcy's Law to calculate a steady seepage or pore velocity of 401 feet/day.

This steady flow velocity can then be used with a one-dimensional mass transport convection-diffusion equation (5) to calculate dilution of the initial spill mass. For simplicity, the aquifer is modeled as if it were a river, and standard dispersion equations applicable to a river are used (7, 8). Using the equation for an instantaneous spill of a mass of 2.83×10^{-5} kg of TCDD into the river flowing at the average velocity of 401 feet/day, it is calculated that a maximum concentration of 0.035 ppb will occur at a downstream distance of 4.29 miles.

Groundwater flow from the site is generally expected to be within the directional sector between northwest and southwest (1, 2), but this is not certain (1). Hence, it must be conservatively assumed that all drinking wells and hence all people who live within a radius of 4.29 miles from the trench may be exposed to concentrations of TCDD in water of 0.035 ppb or greater. Since the average population density of Barry County is known to be about 25 people per square mile (9), a circle with a radius of 4.29 miles includes about 1,446 people, which is therefore the maximum number of exposures for this scenario (Table B-2).

In the absence of better information (1, 2), the probability of occurrence of a sudden sinkhole and the ensuing instantaneous spill scenario described above is assumed to be 1 percent. Thus the average or mathematically, the expected value of exposures is 0.01 times 1446, or 14.46 persons, as shown in Table B-1.

The other scenario for groundwater contamination to occur and reach the public off site involves a gradual, continuous release of waste from the trench, with the liquid assumed to be dripping down a "hollow tube" of "piping" in the karst limestone to the water table below. This scenario considers the event to occur in the present without reference to the 9 years the drums have been buried. Even assuming there is a nominal drum leak rate of 5 gallons per hour and only 0.3% of the TCDD entering the clay layers at the top comes through in solution at the bottom, there is still enough TCDD reaching the water table to saturate the water. In other words, assuming the underground aquifer is the same river flowing with the seepage velocity of 401 feet/day as before, the effective rate of mass spill of TCDD into this river is limited only by the volume rate of river flow and the known maximum solubility of TCDD in water (0.2 µg TCDD/liter of water). The rate of solution is not controlled by the supply rate of TCDD in organic liquid wastes dripping down from the trench, and the effective rate of mass spill of TCDD into the water is thus computed to be 2.58×10^{-9} kg/sec. The concentration of TCDD in water at the first point of contact with the water table is limited to 200 ppt by solubility.

Using the equation for downstream dilution in a river from a continuous spill at this rate (7), it can be computed that a maximum concentration of 35 ppt of TCDD occurs in the water at a distance downstream of about 1.23 miles. Taking the distance to define a circular zone of influence as before, the maximum number of residents exposed is 119, assuming a population density of 25 people/square mile (Table B-2).

The probability of occurrence of this gradual leaking scenario is assumed to be quite high, say 90 percent. Hence, the average (or in mathematical terms, expected) number of exposures due to this gradual leaking case is 0.90 times 119, or 107.1 (Table B-1).

Note that during the remaining 9 percent of the time, it would be necessary to assume that no release of TCDD from the trench occurs which results in groundwater contamination. This is the case in which the clay layer beneath the trench actually does retain the waste and keeps TCDD from entering the water table (2). This case is not an exposure scenario since no exposures occur.

In summary, there are actually three mutually exclusive scenarios assumed possible for Alternative 1:

Scenario	Estimated percent probability	Max. no. of Exposures
o Gradual release to water table	90	119
o No release (clay retains TCDD)	9	0
o Catastrophic (instantaneous release to water table through sinkhole)	1	1,446

No spread of TCDD away from the site via atmospheric transport is considered possible in Alternative 1 since the trench remains closed. Even if a tornado strikes the area, it is assumed that the waste will not be disturbed since the trench is covered with a plastic cover and 2 feet of clean soil.

Altenative 2: Leave Trench as is, But Install Groundwater Monitoring System

Alternative 2 is geologically the same as Alternative 1, with the addition of a warning system. Thus, the possible scenarios for contamination of drinking water are the same as for Alternative 1, i.e., rapid release through a sinkhole or gradual continuous leaking of the drums. The probabilities that these two types of release will occur are also the same as they were for Alternative 1, namely 1 percent and 90 percent, respectively. However, there is now the possibility that the sampling of the monitoring wells may provide adequate warning to some of the residents not to drink the well water if water contamination occurs. As a result, the probability of exposures occurring, the maximum number of possible exposures, and therefore the risk (average number of exposures), are all less than those for Alternative 1.

To estimate the probability that the well monitoring system will warn the residents in the event of a rapid release, it is assumed that well sampling is done once a month. If the time between the release and the arrival of contamination at the wells is about 1 day, sufficient warning can be given only if the release occurs within 1 day just before a well sampling time (neglecting for simplicity the time required to analyze the well sample). Thus, about 1/30 of the time a warning will be issued in time and no exposures will occur. On the other hand, the worst case would occur if the sinkhole formed within 1 day after a sampling time. This occurrence would potentially lead to the maximum time elapsed between time of well water contamination and its detection (29 days), and hence the greatest number of people would be potentially exposed to this drinking water before a warning is issued. This worst case warning delay also has a chance of roughly 1/30 of occurring, if the time of occurrence of the sinkhole is random. Since the geologic occurrence of the sinkhole and the well sampling are independent events, the probability of the joint occurrence just described is 0.01 times 1/30, or about 3.3×10^{-4} (Table B-2).

Since it has already been assumed that the groundwater flows at the seepage velocity of about 400 feet/day, the leading edge of contaminated water from the assumed instantaneous spill would reach a downstream distance of about 2.2 miles after 29 days. The maximum number of persons exposed to concentrations of TCDD greater than 35 ppt in well drinking water can be no more than the total population within this distance from the site in any direction. Using the known average density of population in Barry County, 25 people/square mile (9), this total population is about 379 people (Table B-2).

The other possibility for well water to become contaminated is through the gradual release of wastes from the leaking drums, resulting in a continuous spill into the underground river (probability assumed to be 90 percent). In this case, the average warning delay would be about half the well sampling interval, or 2 weeks. Thus, there is roughly a 50 percent chance that detection and warning will prevent exposures, while the other 50 percent of the time, a delay of about 2 weeks will occur before residents are warned. At the constant flow velocity assumed (400 feet/day), the front of the pollutant will reach a distance of about 1.23 miles downstream from the site. Therefore, the maximum number of exposures in this event will be no greater than the total population within the distance, which is about 119 people. This is the same maximum number of exposures as would occur if no warning were provided (see Alternative 1); however, the probability of this case occurring is now only 0.90 times 0.50, or 0.45 (Table B-2).

For Alternative 2, there are no possibilities for worker exposure or for any above-ground spread of contaminant.

<u>Alternative 3: Excavate and Store Contaminated Material On Site</u>

For Alternative 3, there are more possibilities for exposures of humans to TCDD to occur than for either of the previous two alternatives.

Because of the excavation, the workers could be exposed directly to high concentrations of TCDD as a result of an accident during the excavation operations. Workers could get liquid waste or contaminated soil directly on their skin or inhale contaminated fine soil particulates. Types of possible accidents envisioned include one worker inadvertently striking a co-worker with a pick or shovel, thereby penetrating his protective suit, or a worker losing a glove. Workers would be trained to follow procedures to minimize chances for such accidents, and communications with and between workers in full encapsulated suits would be provided.

The total number of workers on site at any one shift is estimated to be about 42 (see Section 7), with 19 of these in full protection suits inside the fenced area. The workers farthest from the trench, outside the fence (about 17), will have at least coveralls and face-mask respirators with filters, which are efficient enough to remove any respirable clay particles which might be contaminated with TCDD.

It is assumed that some form of dust control such as calcium chloride will be used during excavation to keep the amount of airborne contaminated soil particles to a minimum. Most of the excavation of the highly contaminated soil intermingled with the drums will be done by hand, which will not have as great a potential for generating airborne clouds of contaminated dust as would the excavation of larger amounts of soil by heavy machinery. This machine excavation phase would begin only after the drums themselves and highly contaminated soil were removed by hand, and the soil remaining would therefore not be as highly contaminated. Even if the dust-control measures were to fail, the site is located in a wooded area, and the trees surrounding the clearing would effectively prevent long-range transport of a dust cloud off site, so that off-site exposures to airborne contamination are prevented.

Nevertheless, there might be a 20 percent chance that 2 or 3 workers might be involved in accidents (not necessarily the same accident) which result in their direct exposure. That is, it is not credible that, for instance, 10 or more workers could be exposed.

Another possible scenario is that a tornado could strike the site during the exact time when the trench is open, thereby spreading contamination over a wide area. The probability of such a tornado strike can be estimated using available historical data (11) on occurrences of tornadoes at about 3.2×10^{-5} (See Numerical Calculation section). The consequences of a tornado strike would actually be limited in area to the average tornado damage zone, which is known from historical data to be about 2 square miles (11). The number of people off site who might conceivably be exposed directly to high concentrations of TCDD in the event of such a strike would be approximated by the resident population within a circular area this size (about 0.8 mile radius) centered on the site, or about 50 people. (Storm casualties are not considered.)

Even if no exposures occur during the 1 to 1.5 month excavation period, residual TCDD contamination remaining in the soil around the excavation may still reach groundwater and thereby contaminate wells. A rapid release may occur following the formation of a sinkhole, or there may be a gradual release fed by leaking drums in the trench. These two types of release are somewhat more likely to occur than in Alternative 1 because of the geologic disturbance created by the excavation (2). Therefore, the probabilities of occurrence are now taken as 95 percent (compared to 90 percent) for the sudden sinkhole, and 4 percent (as compared to 1 percent) for the continuous release case (Table B-2).

To estimate the extent of the exposures that could occur through the drinking of TCDD-contaminated well water for either of these cases of residual release, the residual source strength of TCDD remaining around the trench after the excavation must be estimated. This residual amount will depend on both the cleanup level that is decided upon as a stopping point for soil excavation and on the extent of spread of TCDD in the soil in lower concentrations beyond this level.

However, a representative calculation can be made if it is assumed that the source strength is now effectively weakened to the extent that the residual amount of TCDD which actually dissolves in the groundwater is conservatively 1/10 of that originally assumed. Thus, for the case of the sinkhole formation and subsequent instantaneous spill, the total spill mass is now taken to be only 2.83×10^{-6} kg of TCDD (compared to 2.83×10^{-5} kg TCDD in the calculations for previous alternatives). Assuming a spill of this amount into the same river as before (average seepage velocity of 400 feet/day), the greatest downstream distance at which a concentration of 0.035 ppb of TCDD in drinking water occurs is about 0.93 miles. At an average population density of 25 persons/square mile, this distance potentially includes about 67 residents (Table B-2).

For the other scenario of gradual release, the effective continuous mass spill rate of TCDD into the water table is taken to be 1/10 of its value previously, or 2.58 x 10^{-10} kg TCDD/sec. The corresponding downstream distance at which the maximum concentration of 0.035 ppb of TCDD in water occurs is 1/10 of the previous distance, or 649 feet. There are essentially no drinking wells within this distance of the site, and therefore, there are no exposures for this scenario (Table B-2).

Alternative 4: Excavate and Transport Both Liquids and Residues Via Truck to Verona, Mo.

Alternative 4 includes the same possibilities for exposure to TCDD as Alternative 3, and the contribution to the overall risk of this alternative due to all these scenarios is the same as the total risk computed for Alternative 3. However, there is now an additional contribution to risk because of the opportunities for exposure of workers and members of the public. A truck accident resulting in a release of some of the liquid wastes from the bulk tank carrying them may occur either on the highway during the trip to Verona or at the Verona facility.

The probability of a truck accident is known from historical data to be about 2.5 accidents per million truck-miles, or 2.5 x 10^{-6} accidents per truck mile (12). Further, the chance of such an accident resulting in a release or spill of hazardous material, if the truck was carrying such a cargo, is about 0.5, given the occurrence of the accident (12). The length of the highway route from Denny Farm Site 1 to Verona is about 14 miles (north on Highway VV, west on Highway Z to U.S. 60, and back east to Verona). Hence the probability of a truck accident resulting in a spill somewhere over this route can be calculated as the product of the above factors. The worst case would be that in which the accident occurred just as the truck was crossing a stream. The only such crossing on the route to Verona is that of Highway VV at Calton Creek just north of the site. It is assumed that Calton Creek could be contaminated if the accident occurred within an eighth of a mile of the crossing. The chance that the accident, if it occurs at all over the 14-mile route, will occur within this quarter of a mile, is roughly 0.25 mile/14 miles, or 0.02. This coincidence factor would further reduce the probability of this scenario (See Table B-2).

Even if a truck accident were to occur, however, it is assumed that mitigating measures would be applied to minimize exposures resulting from the spill. Contingency measures could include having properly trained and equipped workers travelling with the trucks or stationed near the Calton Creek bridge before the transport of the waste begins. As a result, it could be assumed that no members of the public could be exposed; however, as with the possibility of accidents in the trench during excavation, it is possible that 1 or 2 workers could be exposed (Table B-2).

The other possibility remaining is that the truck arrives without incident at Verona, but an accident occurs after arrival. The probability of occurrence of this would be the same as for the accident on the highway. However, because of the proximity of the greater numbers of people to the accident (the Southwest Local Government Advisory Council projects a 1980 population of 680 for Verona), it is credible that despite spill contingency measures, a liquid spill could reach surface streams or ponds in the area. As many as 10 members of the public could thereby be exposed. Exposures could be either by drinking water or by direct skin contact with contaminated water or wind-borne dust after the liquid spill evaporates.

Additional Risk Due to Decontamination Accidents

Alternatives 3 and 4 involve trench excavation and necessitate decontamination of the trench workers wearing full protection suits following each working interval. There is thus the possibility that the personnel decontamination procedures may be less that completely effective, and some workers may be directly exposed to TCDD. If such exposure is not observed by the supervisor, such a worker could then leave the site with high concentrations of residual TCDD contamination still on his body or clothes and could subsequently spread this contamination by direct contact with other members of the public off site (e.g., his family). This scenario, which might be called "decon accidents," could lead to a significant number of exposures of both workers and public and therefore increases the risk of Alternatives 3 and 4. The following paragraphs describe how this risk can be estimated by making several reasonable simplifying assumptions.

Decontamination of workers in full protection suits may not be completely effective because of both (1) human error in following the prescribed decon procedures and (2) the purely physical limitations of reducing the amount of TCDD contamination remaining on the outside of the suits and equipment, even when the procedures are carried out without obvious accident due to human error. Human error is especially likely to occur during the early stages of work, before extensive experience at carrying out the decon procedures is gained. Workers could be exposed directly to liquid wastes by skin contact or could inhale contaminated particulates, if, for example, they rush through procedures because of panic or if the contamination is not visually obvious. It is also possible that the supervisory personnel observing the decon procedure may not always adhere strictly to the specified safety procedures or may not notice an opportunity for inadvertent worker contamination in the event the worker has a minor accident such as mentioned above. It is less likely that a worker might inadvertently take off site with him some piece of his external suit or equipment (e.g., a camera) which was not fully decontaminated and which should have been left in the decon area.

In order for worker exposure occurring during decontamination to ultimately lead to off-site exposure of other people, three successive events must happen: (1) the worker must become accidentally contaminated himself, as a result of an accident or incomplete washing of his suit, and this must further go unnoticed or unchecked by the supervisor; (2) the level of residual contamination of the escapee's body must be great enough and in such a physical form that contamination can be spread readily to another person off site via direct contact; and (3) the worker must come into direct contact with one or more other people off site. The likelihood of each of these events, as well as the average number of exposed people involved at each step, can be estimated as follows.

First, consider the likelihood of a worker escaping decon with undetected contamination. Taking account of the possibilities discussed above, it is reasonable to assume that there is as high a chance as 50 percent that a given worker, especially an inexperienced one, might encounter some difficulty or accident during the decontamination operation and become contaminated to some degree. However, most of these will be of minor consequence, and most incidents will be obvious enough to be noticed by the observer, so that more intensive efforts can be immediately applied to counter the accident (e.g., washing off a minor splash onto skin). Assume that only 10 percent of the workers entering the decon procedure will both suffer such an accident and go unnoticed by the observer and hence leave the site with some level of residual TCDD still on their bodies.

However, in most of these cases of "escape", the worker may still not be highly enough contaminated to cause additional exposures of the people he comes in contact with off site. The great affinity of TCDD for soil particles and human skin, as compared to other substrates or water, is a factor limiting the ease of further spread of TCDD from the contaminated escapee. For concreteness, suppose that only 1 in 4, or 25 percent, of the escapees are so contaminated that they are able to spread contamination to another person upon contact.

Finally, suppose that as he leaves the site each worker has a certain definite chance of coming into direct contact with 0, 1, 2, or 3 people off site. (For simplicity, assume that the chance of contacting more than 3 people is negligible.) Assume further that each such contact leads to the other person being exposed to residual TCDD. Suppose a 5 percent chance of not contacting anybody, a 70 percent chance of contacting 1 person, a 20 percent chance of contacting 2 people, and a 5 percent chance of contacting 3 other people. Therefore, the average number of secondary off-site exposures caused by each highly contaminated worker who has escaped decon is about 1.25 persons.

To estimate the numbers of exposed people corresponding to these assumed probabilities, consider that at any one shift there will be approximately 20 workers in full protection suits who will have to undergo the decontamination procedure. On average, about 10 percent of these, or 2 workers per shift (4 workers per day), escape decon and leave the site with some residual contamination. However, only 1 of these 4 workers is actally highly contaminated enough to be capable of causing secondary exposures off site. On average, this 1 worker per day causes 1.25 secondary exposures per day. Assuming a rough duration of the intensive hand excavation phase of about 20 days, this means that over this short term an average of 20 workers have become exposed to this high level, have escaped decon, and have caused 20 times 1.25 or 25 secondary off-site exposures, for a total of 45 exposures.

The worst possible case could be envisioned as follows: On the first shift, all 20 suited workers become contaminated and yet escape decon; all 20 are highly enough contaminated to cause secondary exposures; and finally, each of these 20 thereby exposes the maximum number of 3 other people off site. Thus, 20 workers are exposed and 60 secondary off-site exposures occur, for a total of 80 exposures during the one shift. If this worst case persists and also happens during the second shift, then during the whole day, a maximum of 40 workers and 120 off-site people have been exposed, for a total of 160 exposures (Table B-2).

Repetitions of this worst possible event over shifts on successive days would not really lead to new exposures. The same 2 crews of 20 fully suited workers would be assumed to return for the 2 shifts the next day, and the set of secondary contacts of a given worker would likely not change greatly from day to day.

For any individual worker, the probability of the worst case assumed above would be 0.1 times 0.25 times 0.05 or 1.25×10^{-4}. These factors are, respectively, the probability of escaping decon, the probability of being highly contaminated, and the probability of contacting 3 secondary people. Thus, the probability of the worst case, where every one of the 20 crew members is assumed to cause 3 off-site exposures, is the above value raised to the 20th power, assuming that thhe workers are independent. This probability is very small, since the worst case assumes a multiple coincidence of individual worst cases.

Total Exposures Shown in Table B-1 for All Scenarios

The average numbers of exposures of both workers (20) and of secondary off-site members of the public (25) estimated above for the 20-day duration of the excavation period must be added to the average numbers of exposures in each category (on site and off site) due to other possible exposure scenarios, described earlier. For example, for Alternative 3, the average number of workers exposed during the short term will be 0.6 (average from accidents occurring while working in the trench) plus 20 (from decon accidents described above), or 20.6. The average number of public or off-site exposures is similarly 1.6×10^{-3} (from the tornado strike scenario) plus 25 (secondary contact due to escaped contaminated workers as above), or still essentially 25 (Table B-1). Similar average values apply for Alternative 4, except that an average of 1.0 replaces the value 0.6 above.

The maximum possible numbers of exposures shown in each category in Table B-1 are similarly the sums of the maximum numbers estimated to occur for each of the several exposure scenarios. For example, for Alternative 3, the maximum number of workers exposed during the short term is shown as 3 (due to accidents during work in the trench) plus 40 (the maximum due to decon accidents), or 43 workers. The maximum number of off-site public exposures is 50 (from the tornado scenario) plus 120 (secondary exposures due to escaped contaminated workers), or 170 maximum total.

Similar additions are performed and shown in Table B-1 for Alternative 4: For on-site exposures there is a maximum of 5 (estimated for accidents during working--3 during work in trench, another 2 due to the truck accident scenario) plus 40 (maximum due to decon accidents), or 45 total. For off-site exposures, the maximum shown is: 50 (from tornado scenario during open trench phase), plus 10 (due to a truck accident occurring near the populated area of Verona), plus 120 (maximum secondary contacts of the 40 escaped contaminated workers above), for a total of 180.

NUMERICAL CALCULATIONS

This section presents some of the calculations made and methods used in the course of the risk analysis.

Formulas Used to Compute Maximum Concentrations in River Flow

Table B-3 summarizes the formulas for non-tidal river flow used to make the calculations of concentrations of TCDD downstream of the assumed spill into the water table (7, 8). The diffusion coefficients used in these formulas are those given in Reference 7.

Instantaneous Release (Sinkhole Scenario) Spill Source Strength

The total mass of TCDD released from the trench in organic liquids is 26.4 lb = 12.0 kg = total amount in all drums (see separate calculation). However, because of the limited solubility of TCDD in water, only a small fraction of this amount can actually dissolve in the water when it reaches the water table.

Assume that the initial volume of water in the aquifer beneath the trench into which the spill falls is 100 feet wide, 1 foot deep, and 50 feet long.

$$100 \text{ ft} \times 50 \text{ ft} \times 1 \text{ ft} = 5000 \text{ ft}^3 = 141.6 \text{ m}^3 = 1.42 \times 10^5 \text{ l of water}$$

Since the maximum solubility of TCDD in water is only 0.2 ug TCDD per liter of water, the amount of TCDD dissolving in the above volume of water is

$$\begin{aligned} M &= (1.42 \times 10^5 \text{ l water}) \times (0.2\,\mu\text{g TCDD per l of water}) \\ &= 2.83 \times 10^4\,\mu\text{g TCDD} \\ &= 2.83 \times 10^{-5} \text{ kg TCDD} \end{aligned}$$

This is then taken as the total mass of an instantaneous spill in the formulas in Table B-3.

TABLE B-3

FORMULAS FOR MAXIMUM CONCENTRATION

IN RIVER DISPERSION*

	NEAR FIELD	FAR FIELD
INSTANTANEOUS SPILL	$C_{max} = \dfrac{2M}{(4\pi t_{max})^{3/2}\sqrt{e_x e_y e_z}}$	$C_{max} = \dfrac{M}{A\sqrt{4\pi E t_{max}}}$
CONTINUOUS SPILL	$C_{max} = \dfrac{M}{2\pi x\,(e_y e_z)^{1/2}}$	$C_{max} = \dfrac{M}{UA}$ for large t_{max}

MEANINGS OF SYMBOLS:

C_{max} = maximum concentration of pollutant at downstream distance x (at midstream, on water surface), in kg/m^3

x = downstream distance from spill, m

t_{max} = time after spill when maximum concentration occurs at x, t_{max} = X/U, in sec

U = average river flow velocity, m/sec

A = cross-sectional flow area = width x depth of river, m^2

M = total mass of pollutant in instantaneous spill, kg

M = constant mass spill rate of pollutant for continuous spill, kg/sec

E, e_x, e_y, e_z = turbulent diffusion coefficients appropriate for river, m^2/sec (values given in Reference 13)

*See Reference 13

Gradual Leaking (Continuous Release) Spill Source Strength

Assume the drum leak rate is 5 gal/hour of liquid organic wastes. Taking the density of the waste to be 1.2 g/l, this is

$$5 \text{ gal} \times 1.2 \text{ g/ml} \times 3.785 \times 10^3 \text{ ml/gal} = 2.27 \times 10^4 \text{ g}$$
$$= 50.07 \text{ lb organic liquid waste/hour}$$

(Incidentally, at this rate, the entire 8,250 gallons of liquid waste would be spilled after 1,650 hours, or about 2.3 months.)

Assuming a maximum concentration of TCDD in these waters of 319 ppm, the total amount of TCDD contained in this volume of water is

$$(2.27 \times 10^{-2} \text{ million g waste}) \times (319 \text{ g TCDD per million g waste})$$
$$= 7.24 \text{ g TCDD}$$
$$= 1.60 \times 10^{-2} \text{ lb TCDD}$$

Thus, the effective rate of TCDD leaving the trench in the liquids is

$$1.60 \times 10^{-2} \text{ lb/hr} = 7.26 \times 10^{-3} \text{ kg/hr} = 2.02 \times 10^{-6} \text{ kg TCDD/sec}$$

However, in this case, assume that both clay adsorption in the layers passed by the liquids as they seep vertically downward to the water table and the minimal solubility of TCDD in water reduce the effective rate of mass entering the water table as a spill, as follows:

First, assuming a 99.7% retention factor for adsorption of TCDD by the clay, the effective rate at which TCDD arrives at the water table is only 0.3% of the above, or 6.06×10^{-9} kg TCDD/sec.

Secondly, the solubility of TCDD limits the rate of dissolving: Effective mass spill rate M = (river water volume flow rate) x (Solubility of TCDD).

Assume river dimensions; contaminant arrives at water table in "rain" or "curtain" 100 feet wide:

$$\left.\begin{array}{r} \text{100 feet wide} = 30.48\ \text{m} \\ \text{1 foot deep} = 0.3\ \text{m} \end{array}\right\} \begin{array}{c} \text{cross-sectional flow area} \\ A = 9.14\ \text{m}^2 \end{array}$$

The average river velocity is the seepage velocity calculated using Darcy's Law (see separate calculation).

$$\begin{aligned} U &= 401.1 \text{ feet/day} \\ &= 4.64 \times 10^{-3} \text{ feet/sec} \\ &= 1.41 \times 10^{-3} \text{ m/s} \end{aligned}$$

Thus, volume flowrate of river is

$$\begin{aligned} Q &= UA \\ &= (1.41 \times 10^{-3} \text{ m/sec}) \times (9.14 \text{ m}^2) \\ &= 1.29 \times 10^{-2} \text{ m}^3 \text{ of water/sec} \end{aligned}$$

Hence

$$\begin{aligned} M &= (1.29 \times 10^{-2} \text{ m}^3 \text{ water/sec}) \times (10^3 \text{ l/m}^3) \times (0.2\ \mu\text{g TCDD/l water}) \\ &= 2.58\ \mu\text{g TCDD/sec} \\ &= 2.58 \times 10^{-9} \text{ kg TCDD/sec} \end{aligned}$$

This value was then used in the continuous spill river dilution equations in Table B-3 to calculate downstream concentrations of TCDD.

Calculations of Downstream Concentrations

The equations in Table B-3 yield mass concentrations of TCDD in kg/m^3 To express these as percent by weight of water, they are divided by the mass density of water (10^3 kg/m^3) and then the power of ten adjusted so as to express the result in ppm, ppb, or ppt, depending on the magnitude.

Calculation of Seepage Flow Velocity for Horizontal Movement

For karst limestone, assume

$$\text{porosity } n = 10\%$$
$$\text{hydraulic conductivity } K = 10^4 \text{ gal/day/ft}^2$$
$$= 4.72 \times 10^{-1} \text{ cm/sec}$$

These values are within the range of values given in the literature literature (3) for karst limestone and are likely to be reasonable for the area of Denny Farm Site 1 (1).

The hydraulic head gradient away from the site is about a 50-foot drop over a distance of a third of a mile (1760 feet), or

$$\Delta H/\Delta x = (-50 \text{ ft})/1760 \text{ ft} = -0.03 \text{ (about 3\% gradient)}$$

Hence, from Darcy's Law (3, 5), the velocity is

$$V = (-K) \times (\Delta H/\Delta x)$$
$$= -(10^4 \text{ gal/day/ft}^2) \times (1 \text{ ft}^3/7.48 \text{ gal}) \times (1 \text{ day/8}$$
$$= 4.64 \times 10^{-4} \text{ ft/sec} \quad \text{(Darcy velocity)}$$

Hence the seepage velocity is

$$V_s = V/n$$
$$= (4.64 \times 10^{-4} \text{ ft/sec})/0.1$$
$$= 4.64 \times 10^{-3} \text{ ft/sec}$$
$$= 1.41 \times 10^{-3} \text{ m/sec}$$
$$= 401.1 \text{ feet/day}$$

Calculation of Total Amount of TCDD at Denny Farm Site 1

A. Assumptions

1) 150 55-gallon drums, each full (known to be conservative)
2) Average density of organic liquid wastes in drums = 1.2 g/ml
3) All drums contain TCDD at the highest concentration measured, which is 319 ppm.

B. Calculation:

150 drums x 55 gal/drum x 1.2 g/ml x (3.785×10^3 ml)/gal
= 3.747×10^7 grams (total mass of liquid waste)
= 37.47 million grams

(37.47 million grams) x (319 grams of TCDD per million grams liquid)
= 11953 grams of TCDD

Dividing by 453.6 grams per pound, the total amount of TCDD is 26.4 lb.

Note: This is consistent with a recent report that the total amount of TCDD contained in the 4,300 gallons of waste at the Syntex plant in Verona, Mo. prior to photochemical oxidation was 13 pounds (14).

There is reason to believe that the density of the liquids stored in the drums at Farm Site 1 may be about the same as that in the Syntex bulk storage tank. In the above calculation, the assumption that all drums are full means a total liquid waste volume of 8,250 gallons. According to the above calculation, half of this volume of liquid, which is 4,125 gallons, or approximately the same volume as the Syntex storage tank (4,300 gal), would contain 13.2 pounds of TCDD. Therefore, the assumption of an average liquid density of 1.2 g/ml seems reasonable.

Calculation of the Safe Concentration of TCDD in Drinking Water

Once a given dose of TCDD is taken as a "threshold" or "no effect" level for the human body for oral exposure, the corresponding "safe" concentration level of TCDD in drinking water can be calculated. This is the concentration in water which, when ingested, will lead to the establishment of the given threshold dose within the human body. To do this, it is necessary to take into account three factors:

- The average ingestion rate of drinking water of a person assumed to be 2 liters per day;
- The average body weight of a person taken to be 70 kg;
- The average retention efficiency for TCDD ingested in drinking water taken for simplicity to be 100% (that is, 100% of all ingested TCDD in drinking water is assumed to be delivered to the body as dose).

For simplicity, the question of possible bioaccumulation of TCDD in the human body from drinking water is not considered here.

If 0.001 μg/kg/day (i.e., 1 ppt of body weight per day) is taken as the threshold concentration in the human body, C_b, and C_w denotes the corresponding concentration in drinking water averaged over a day, then:

$$C_b = (2 \text{ liters of water}) \times C_w \times 1.0 \times 10^6 / 70 \text{ kg}$$

C_b = threshold concentration in body, averaged over a day, in μg/kg
C_w = corresponding concentration in drinking water, g/l
270 kg = average body weight
liters = average amount of water drunk per day
1.0 = assumed retention efficiency factor

Solving the above for C_w yields $C_w = 3.5 \times 10^{-8}$ g/l, or $C_w = 3.5 \times 10^{-2}$ μg/kg of water, which is 0.035 ppb or 35 ppt in water, averaged over a day.

For comparison, it is worth noting that the maximum possible concentration of TCDD in water is 0.2 μg/kg = 0.2 ppb = 200 ppt, since the solubility of TCDD in water is 2×10^{-7} g/l.

The value of 0.001 μg/kg/day above is being considered as a possible practical drinking water standard and is considered by some to be a "no observed effect level" (NOEL) for oral exposure to TCDD based on feeding studies with rats (10).

To allow for uncertainty in the assumed threshold dose C_b above, a safety factor of 100 could have been introduced to extrapolate the animal data to humans, so that the threshold level in humans could instead be assumed to be 10^{-5} μg/kg/day. The corresponding safe concentration in drinking water sould then be 1/100 of that computed above, or only 0.35 ppt in water, daily average.

Calculation of Probability of a Tornado Striking the Site

1. Denny Farm Site 1 is located in a 2-degree quadrangle defined by 92° and 94°W meridians of longitude, and 36°N and 38°N parallels of latitude.

2. The area A of this 2-degree square is approximately

$$A = (109.5 \text{ miles longitude}) \times (138.8 \text{ miles latitude})$$
$$= 15{,}198.6 \text{ square miles}$$

3. The total number of tornadoes that have first touched ground within this 2-degree square has been tabulated historically (11):

T = 111 tornadoes
over N = 46 years (1916-1961)

See Figures 15A, 16A, or 16B in Reference 11. On average, T/N = 111/46 = 2.413 tornadoes per year have occurred within this 2-degree square.

4. The average area D damaged by a tornado is 2 square miles (11, p. 31)

5. The probability per year of a tornado striking any particular point within the 2-degree square (in particular, Denny Farm Site 1) is therefore (11, p.28):

$$p = (T/N) \times (D/A)$$
$$= (2.413 \text{ per year}) \times (2/15{,}198.6)$$
$$= 3.175 \times 10^{-4} \text{ per year}$$

This assumes that the Denny Farm Site 1 is effectively a point target, i.e., its area is small compared to that of the tornado damage zone (D = 2 square mi.).

6. Over an extended period, say 50 years, the probability of at least one tornado striking the site is therefore:

$$1 - (1 - p)^{50} = 50\ p$$
$$= 0.0158, \text{ or } 1.6 \text{ percent}$$

7. For the possibility of a tornado striking the site during the period when the trench is open for excavation (Alternative 3), assume the trench is open for about 1/10 of a year. Thus, the probability of this scenario is about:

$$p = (3.2 \times 10^{-4} \text{ per year}) \times (0.1 \text{ year})$$
$$= 3.2 \times 10^{-5}$$

REFERENCES FOR APPENDIX B

1. Personal Communication with Boyd Possin, E & E hydrologist, August 20, 1980

2. Williams, Dr. J. Hadley. Hydrologic Aspects of the Farm Dump Site Near Verona, McDowell Quadrangle, Barry County, Missouri. Geology & Land Survey, State of Missouri, June 4, 1980.

3. Freeze, R. Alan, and John A. Cherry. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, N.J., 1979.

4. Boyle, William C., and Robert K. Ham (University of Wisconsin). Assessment of Leaching Potential from Foundry Process Solid Wastes. pp. 129-147 in Proceedings of the 34th Industrial Waste Conference, May 8, 9, and 10, 1979, Purdue University, Lafayette, Indiana, J.M. Bell, Ed., Ann Arbor Science Publishers Inc., Ann Arbor, Michigan, 1980; see pp. 137-139.

5. Cleary, Robert W., David W. Miller, and George F. Pinder. Groundwater Pollution and Hydrology. Princeton University, Princeton, N.J., 1980 (course notes in 3-ring binder).

6. Del Pup, John, et al. (Ecological Analysts, Inc.), and Robert Stadelmaier (RFCRA Reasearch Inc.). An Assessment of the Potential Impact on Human Health from Operation of a Chemical Waste Management System. pp. 270-276 in Proceedings of 1980 National Conference on Control of Hazardous Material Spills, May 13-15, 1980, Louisville Kentucky, published by Vanderbilt University, 1980; see p. 273.

7. Department of Transportation, U.S. Coast Guard. Assessment Models in Support of the Hazard Assessment Handbook. CG-D-65-74, prepared by A.D. Little, Inc., January 1974 [NTIS AD-776 617]; see Chapter 4, "Mixing and Dilution".

8. Eisenberg, N.A., et al. A Critical Technical Review of Six Hazard Assessment Models. Prepared for U.S. Coast Guard by Enviro Control, Inc., CG-D-122-76, December 1975 [NTIS AD/A-035 599 See Chapter 3, "Mixing and Dilution Model."

9. State of Missouri, Division of Budgeting & Economic Planning; contacted by John Caoile, E & E, August, 1980.

10. The FIFRA Scientific Advisory Panel Evaluation of the Oncogenicity, Fetotoxicity, and Exposure Characteristics for 2,4,5-T, Silvex, and TCDD, Appendix I, p. 72325, in Final Determination Concerning the Rebuttable Presumption Against Registration for Certain Uses of Pesticide Products Containing 2,4,5-T..., Environmental Protection Agency, Federal Register, Vol. 44, Thursday, December 13, 1979, 72316-72328.

11. Court, Arnold. Tornado Incidence Maps. ESSA Technical Memorandum ERLTM-NSSL 49, U.S. Dept. of Commerce, Environmental Science Services Administration, National Severe Storms Laboratory, Norman, Oklahoma, August 1970.

12. Menzie, Charles A. (EG&G Environmental Consultants). An Approach to Estimating Probabilities of Transportation-Related Spills of Hazardous Materials. Environmental Science & Technology 13(2), February 1979, 224-228.

13. Department of Transportation, U.S. Coast Guard. Assessment Models in Support of the Hazard Assessment Handbook. CG-D-65-74, prepared by A. D. Little, Inc., January 1974 (NTIS AD-776-617), see Chapter 4, "Mixing and Dilution".

14. Hazardous Materials Intelligence Report. 15 August 1980, p. 8.

APPENDIX C

BORING LOGS

Field Boring Log

Project: Farm Site No. 1

Date: July 15, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 13

Assistant Driller: Tom Tillman

Surface Elevation: 100.2

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-10.0	PA	—	Reddish Brown Clay, silty, cherty, moist, stiff
10.0-11.5	* 2" SPT	—	Same, but more moist to very moist
11.5-13.0	* 2" SPT	—	Same
13.0-14.5	* 2" SPT	—	Same
14.5-16.0	* 2" SPT	—	Same
16.0-17.5	* 2" SPT	—	Same
17.5-19.0	2" SPT	105	Same
19.0-20.5	2" SPT	49	Same
20.5	Drilling Discontinued		

REMARKS:

* - 2" SPT were sampled by pushing spoon hydraulically into soil.

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

WB - Wash Bore

FT - Finger Tooth Bit

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1
Date: July 15, 1980
Drilling Company: Terracon Consultants
E & E Geologist: John Caoile
Driller: Jim Murphy
Boring No.: 14
Assistant Driller: Tom Tillman
Surface Elevation: 99.9
Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-3.0	PA	—	Reddish Gray cherty gravels & sands, some clay, dry, loose
3.0-5.0	PA	—	Same but becoming more clay-like
5.0-6.5	2" SPT	69	Red Clay, very cherty, slightly moist, very stiff
6.5-10.0	PA	—	Red Silty Clay, cherty, dry to slightly moist, stiff
10.0-11.5	2" SPT	50	Red Silty Clay, cherty, dry to slightly moist, stiff
11.5-15.0	PA	—	Red Silty Clay, cherty, dry to slightly moist, stiff
15.0-16.1	2" SPT	50/1"	Red Silty Clay, cherty, dry to slightly moist, stiff
16.1-20.0	PA	—	Red Silty Clay, cherty, dry to slightly moist, stiff
20.0-21.2	2" SPT	60/3"	Reddish Brown Silty Clay, cherty, slightly moist, stiff
21.2-27.0	PA	—	Reddish Brown Silty Clay, cherty, slightly moist, stiff
27.0	Auger Refusal		

REMARKS:

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
FT - Finger Tooth Bit
WB - Wash Bore
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 15, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 15

Assistant Driller: Tom Tillman

Surface Elevation: 100.8

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-5.0	PA	—	Reddish Brown Silty Clay, slightly moist to moist, stiff
5.0-6.5	2" SPT	80	Same
6.5-8.0	2" SPT	40	Same
8.0-9.5	2" SPT	39	Same
9.5	Drilling Discontinued		

REMARKS:

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

FT - Finger Tooth Bit

WB - Wash Bore

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 15, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 15A

Assistant Driller: Tom Tillman

Surface Elevation: 100.5

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-20.0	PA		Reddish Brown Silty Clay, some chert, moist, stiff
20.0	Drilling Discontinued		

REMARKS:

The purpose of B-15A was to characterize the anomaly area with respect to an HNU-Photoionizer prior to sampling at the other locations.

No meter response was observed during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
WB - Wash Bore
FT - Finger Tooth Bit
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 15, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 16

Assistant Driller: Tom Tillman

Surface Elevation: 99.2

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-2.0	PA	—	Buff Silt (Loessial Topsoil), dry, loose
2.0-3.5	2" SPT; low recovery	30	Red Cherty Clay, slightly moist, stiff
3.5-5.0	2" SPT	32	Red Cherty Clay, slightly moist, stiff
5.0-6.5	2" SPT	25	Reddish Brown Silt & Clay, slightly moist, stiff, some chert fragments
6.5-10.0	PA	—	Reddish Brown Silt & Clay, slightly moist, stiff, some chert fragments
10.0-14.0	PA	—	Same, less cherty
14.0-15.5	2" SPT	85/3"	Same, becoming more cherty
15.5-19.5	PA		Reddish Brown Silt & Clay, slightly moist, stiff, some chert fragments
19.5	Auger Refusal (Cherty Limestone)		

REMARKS:

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

WB - Wash Bore

FT - Finger Tooth Bit

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 15, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 17

Assistant Driller: Tom Tillman

Surface Elevation: 99.3

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-2.0	PA	--	Buff Silt, come clay, dry, loose
2.0-3.5	2" SPT	29	Red clay, silty, some chert fragments, slightly moist, stiff
3.5-5.0	2" SPT	30	Red clay, silty, some chert fragments, slightly moist, stiff
5.0-6.5	2" SPT	48	Red clay, silty, some chert fragments, slightly moist, stiff
6.5-14.0	PA	--	Same, but more clay & moisture at 8.5' - 10'
14.0-15.5	2" SPT; low recovery	34	Red clay, silty, some chert fragments, slightly moist, stiff
15.5-17.5	PA	--	Red silty clay, numerous
17.5-19.6	2" SPT	51	Same
19.6-24.0	PA		Same
24.0	Drilling Discontinued		

REMARKS:

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
WB - Wash Bore
FT - Finger Tooth Bit
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 20

Assistant Driller: Tom Tillman

Surface Elevation: 100.9

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-6.1	PA	—	Buff Silt (Loessial Topsoil), dry, loose
6.1-25.0	PA	—	Red Clay, Silty, Cherty, becoming very cherty below 20', moist, stiff
25.0-26.5	PA	—	Red Silty Clay and bedded chert, slightly moist, very stiff
26.5	Auger Refusal		

REMARKS:

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
WB - Wash Bore
FT - Finger Tooth Bit
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 21

Assistant Driller: Tom Tillman

Surface Elevation: 101.3

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-0.5	PA	—	Buff Silt (Loessial Topsoil), slightly moist to dry, loose
0.5-5.0	PA	—	Red Clay, silty, cherty, slightly moist, stiff
5.0-6.5	2" SPT	59	Same
6.5-8.0	2" SPT	33	Red Silty Clay, some chert fragments, moist, stiff
8.0-9.5	2" SPT	40	Red Silty Clay, cherty, slightly moist, stiff
9.5-14.0	Jar Sample taken 10'-14' auger cuttings	—	Red Clay, some silt & chert, moist, stiff
14.0-15.5	2" SPT		Same
15.5-19.0	PA	—	Red Clay with chert fragments, moist, stiff
19.0-19.1	2" SPT	25/1"	Red silty clay and chert, moist, hard
19.1	Auger Refusal		

REMARKS:

No HNU Photo-ionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

FT - Finger Tooth Bit

WB - Wash Bore

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 23

Assistant Driller: Tom Tillman

Surface Elevation: 100.2

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-1.5	PA	—	Buff silt (Loessial Topsoil), slightly moist, loose
1.5-5.0	PA	—	Red Clay, trace silt, cherty, dry to slightly moist, stiff
5.0-6.5	2" SPT	56	Same
6.5-8.3	PA	—	Same
8.3	Auger Refusal		

REMARKS:

No HNU-Photoionizer response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

WB - Wash Bore

FT - Finger Tooth Bit

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1
Date: July 16, 1980

Drilling Company: Terracon Consultants
E & E Geologist: John Caoile

Driller: Jim Murphy
Boring No.: 24

Assistant Driller: Tom Tillman
Surface Elevation: 100.5

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-3.2	PA		Buff Silt (Loessial Topsoil); very cherty at 2 - 3' deep, moist, loose.
3.2-5.0	PA		Red Silty Clay, cherty, slightly moist, stiff.
5.0-5.5	2" SPT (no recovery)	30/4"	Same
5.5-10.0	PA	—	Same
10.0-11.5	2" SPT	24	Same
11.5-14.0	PA	—	Red Silty Clay, Cherty, moist, stiff
14.0-14.5	PA	—	Numerous chert float rock, hard
14.5	Auger Refusal		

REMARKS:

Offset 5½ feet west of stake due to tree branches overhead.

No HNU-Photoionizer Response during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
FT - Finger Tooth Bit
WB - Wash Bore
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 25

Assistant Driller: Tom Tillman

Surface Elevation: 99.8

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-1.8	PA	—	Buff Silt, tr. clay (Loessial topsoil), dry, medium
1.8-2.0	PA	—	Red Clay, Silty, some chert frag- ments, moist, stiff
2.0-3.5	2" SPT low recovery	31	Same, very cherty, moist, stiff
3.5-5.0	2" SPT	33	Red Silty Clay, cherty, moist, stiff
5.0-6.5	2"SPT	52	Red Clay and chert fragments, moist, stiff
6.5-8.0	2" SPT	73	Same
8.0-14.0	PA	—	Same, but moist to very moist about 8.5'
14.0-15.5	2" SPT	52	Same
15.5-19.0	PA	—	Red Clay, some chert & silt, moist, stiff
19.0-20.5	2" SPT	53	Same
20.5-27.5	PA	—	Interbedded Red Cherty Clay, and chert float rock, hard.
27.5	Auger Refusal		

REMARKS:

No HNU-Photoionizer Response during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
WB - Wash Bore
FT - Finger Tooth Bit
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1 Date: July 16, 1980

Drilling Company: Terracon Consultants E & E Geologist: John Caoile

Driller: Jim Murphy Boring No.: 26

Assistant Driller: Tom Tillman Surface Elevation: 98.1

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-3.9	PA	—	Buff Silt, trace clay (loessial topsoil), moist, loose
3.9-34.0	PA	—	Red Silty Clay, some chert, moist to very moist, stiff
34.0	Drilling Discontinued		

REMARKS:

Penetrated chert float rock about 10.5', 5" thick

No HNU-Photoionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

WB - Wash Bore

FT - Finger Tooth Bit

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 27

Assistant Driller: Tom Tillman

Surface Elevation: 99.0

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-2.5	PA	—	Buff Silt & Clay (Loessial topsoil), moist, loose
2.5-6.0	PA	—	Red Silty Clay, some chert fragments, slightly moist, stiff
6.0-6.5	PA		Chert - float rock
6.5-32.7	PA		Red Silty Clay, trace chert fragments, plastic; moist, stiff
32.7-33.3	PA		Chert fragments, hard
33.3	Auger Refusal		

REMARKS:

No HNU-Photoionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

WB - Wash Bore

FT - Finger Tooth Bit

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 28

Assistant Driller: Tom Tillman

Surface Elevation: 99.9

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-2.1	PA	—	Buff Silt, trace clay (loessial topsoil), slightly moist, stiff
2.1-5.0	PA		Red Silty Clay, some chert, moist, stiff
5.0-6.5	2" SPT	45	Same
6.5-8.0	2" SPT	36	Same
8.0-9.5	2" SPT	64	Red Clay, moist to very moist, stiff
9.5-14.0	PA	—	Same
14.0-15.5	2" SPT	60/5"	Same, but becoming less moist
15.5-19.0	PA	—	Red Clay, some chert fragments, moist, stiff
19.0-20.5	2" SPT	35	Same
20.5-25.0	PA	—	Red Silty Clay, cherty, slightly moist, stiff
25.0-32.2	PA	—	Same, becoming more cherty
32.2-33.2	PA	—	Interbedded chert and Red Silty Clay
33.2	Auger Refusal		

REMARKS:

No HNU-Photoionizer Response during drilling.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

FT - Finger Tooth Bit

WB - Wash Bore

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 17, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 29

Assistant Driller: Tom Tillman

Surface Elevation: 100.3

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-2.5	PA	—	Buff Silt, some clay (loessial topsoil), slightly moist, loose
2.5-4.5	PA	—	Red Silty Clay, Cherty, moist, stiff
4.5-5.0	PA	—	Sandstone boulder
5.0	Auger Refusal		

REMARKS:

No HNU-Photoionizer Response during drilling.

Additional hole was drilled 5' south of B-29 and designated B-29A.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

FT - Finger Tooth Bit

WB - Wash Bore

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 17, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 29A

Assistant Driller: Tom Tillman

Surface Elevation: 100.3

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-2.3	PA	—	Buff Silt, trace clay (loessial topsoil), slightly moist, stiff
2.3-4.5	PA	—	Red Clay, some silt, cherty; moist, stiff
4.5-4.7	PA	—	Chert boulder or zone
4.7-34.0	PA	—	Red Clay, some silt & chert fragments, moist to very moist, very stiff
34.0	Drilling Discontinued		

REMARKS:

Offset 5 feet south of B-29 due to chert boulder.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
WB - Wash Bore
FT - Finger Tooth Bit
FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1 | Date: July 17 to 19, 1980

Drilling Company: Terracon Consultants | E & E Geologist: John Caoile

Driller: Jim Murphy | Boring No.: 30 (well hole)

Assistant Driller: Tom Tillman | Surface Elevation: 88.6

Water Table: Completion see remarks
24 hours ______

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-3.6	PA	--	Buff silt (loessial topsoil), slightly moist, stiff
3.6-11.8	PA	--	Red silty clay, some chert, slightly moist, stiff
11.8-17.0	PA	--	Olive gray silty clay (shaley), slightly moist to dry, stiff
17.0-25.2	PA	--	Olive silt, dry, stiff
25.2-27.5	PA	--	Cherty limestone, broken, hard
27.5-34.0	PA	--	Alternating red clay and chert, hard
34.0-35.0	RB		Chert, very hard
35.0-37.5	DC (NX-size) 24%recovery	Run#1	Chert, gray-white, dense crystalline, some fracture lines
37.5-39.4	DC - 80% recovery	Run # 2	Same
39.4-39.7	DC- 100% recovery	Run # 3	Same
39.7-10.9	RB		Same
40.9-41.9	DC- 100% recovery	Run # 4	Same
41.9-42.8	DC- 100% recovery	Run # 5	Same
42.8-47.4	RB		Same
47.4	Drilling Discontinued		

REMARKS: No HNU-Photoionizer Response during drilling.

Lost circulation at 44', continued with rock bit. After 1 hour of drilling, water was at 39.5'. Core water level dropped to 41' in 2½ hours, and was at 41' when the well pipe was installed.

KEY

PA - Power Auger

SPT- Standard Penetration Test (split-spoon sampling)

ST - Shelby Tube

DC - Diamond Coring

RB - Rock Bit

WB - Wash Bore

FT - Finger Tooth Bit

FH - Fish Tail Bit

Field Boring Log

Project: Farm Site No. 1

Date: July 16, 1980

Drilling Company: Terracon Consultants

E & E Geologist: John Caoile

Driller: Jim Murphy

Boring No.: 31

Assistant Driller: Tom Tillman

Surface Elevation: 101.0

Water Table: Completion dry
24 hours dry

Depth, ft.	Method of Advancement	N-value	Soil Description
0.0-0.8	PA	—	Buff Silt (Loessial topsoil), dry, loose
0.8-11.2	PA	—	Red Silt and Clay, some chert fragments, moist, stiff
11.2-12.5	PA	—	Same, but more chert fragments
12.5-15.5	PA	—	Gray-White Cherty Limestone, weathered, hard
15.5	Auger Refusal		

REMARKS:

No HNU-Photoionizer Response during drilling.

KEY

PA - Power Auger
SPT- Standard Penetration Test (split-spoon sampling)
ST - Shelby Tube
DC - Diamond Coring
RB - Rock Bit
FT - Finger Tooth Bit
WB - Wash Bore
FH - Fish Tail Bit

SOIL SAMPLES TAKEN

Sample No.	Boring No.	Depth
AN8000	13	10'-11'
AN8001	13	11½'-13'
AN8002	13	13'-14½'
AN8003	13	14½'-16'
AN8004	13	16'-17½'
AN8005	13	17½'-19'
AN8006	13	19'-20½'
AN8007	15	5'-6½'
AN8008	15	6½'-8'
AN8009	15	8'-9½'
AN8010	14	5'-6½'
AN8011	14	10'-11½'
AN8012	14	15'-16.1'
AN8013	14	20'-21'
AN8014	16	3½'-5'
AN8015	16	5'-6½'
AN8016	16	14'-15'
AN8017	17	2'-3½'
AN8018	17	3½'-5'
AN8019	17	5'-6½'
AN8020	17	17½'-19'
AN8021	21	5'-6½'

SOIL SAMPLES TAKEN
(cont.)

Sample No.	Boring No.	Depth
AN8022	21	6½'-8'
AN8023	21	8'-9½'
AN8024	21	10'-14'
AN8025	23	5'-6½'
AN8026	24	12'-14'
AN8027	25	3½'-5'
AN8028	25	5'-6½'
AN8029	25	6½'-8'
AN8030	25	14'-15½'
AN8031	25	20'-21½'
AN8032	28	5'-6½'
AN8033	28	6½'-8'
AN8034	28	8'-9½'
AN8035	28	14'-15½'
AN8036	28	19'-20½'

APPENDIX D

OCCUPATIONAL HEALTH AND SAFETY CONSIDERATIONS

APPENDIX D

OCCUPATIONAL HEALTH AND SAFETY CONSIDERATIONS

In developing remedial actions for the Denny Farm Site 1 cleanup, E & E examined carefully the safety requirements for contractor personnel. This appendix addresses the occupational health and safety considerations for excavation and cleanup of dioxin-contaminated materials.

Because of the extreme toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), the unknown airborne concentrations of other organic vapors, e.g., trichlorophenol, and the possibility of oxygen depletion in the trench, utmost concern must be given to the safety and health of the personnel performing the excavation. (For all intents, an IDLH--Immediately Dangerous to Life or Health--atmosphere must be assumed during the excavation phase.)

Personnel safety must take into consideration these hazards and provide maximum protection from exposure via skin or mucous membrane absorption and inhalation. It is evident that full body protective clothing and supplied air must be provided for the excavation crew and personnel working directly with contaminated material prior to decontamination. The personnel protective equipment (PPE) has been selected based on the need for worker safety, the nature of the required operation, and the duration of the operation. The specified PPE for different work crews affords the maximum protection and follows accepted guidelines (NIOSH). Since the degree of hazard, i.e., exposure to dioxin, is different for a number of operations necessary in the cleanup, different levels of protection are recommended as defined below:

<u>Excavation Team in and around Trench</u>--Possible IDLH conditions

Fully encapsulated suit with cooling apparatue (vortex tube and manifold)
Airline and self contained breathing apparatus (airline in pressure-demand mode)
Impermeable gloves
Impermeable boots with steel shank

Decontamination Crew--Contact with drums and equipment

Fully encapsulated suit with cooling apparatus (vortex tube and manifold)
Airline and self-contained breathing apparatus (airline in pressure-demand mode)
Impermeable gloves
Impremeable boots with steel shank

Personnel Decontamination Crew--Contact with personnel and equipment

Airline suits/helmets with cooling apparatus
Impermeable clothing
Impermeable gloves and boots

Depending upon the location of the decontamination area, the appropriate respiratory protection may be lowered to a full-face piece air purifying respirator.

Back Hoe Operator in and around Trench

Self-contained breathing apparatus
Impermeable clothes (vinyl or tyvek)
Impermeable gloves and boots

Because of the possibility of damage to the airline hose and the impracticability of attaching an airline to mobile equipment, SCBA is the only alternative. Stay time should be longer for the operator since activity is minimal. By rotating two operators there should be no loss of efficiency during the overburden removal.

Crane Operator

Coveralls
Gloves
Boots

The low level of protection assumes that an enclosed and powered air cab is available. If an open cab is used an air purifying respirator and impervious clothing will provide the proper protection for the operator. Vapor and dust levels may change the PPE assessment for the crane operator.

Off-site Personnel

Protective equipment will be dictated by vapor concentrations and the degree of airborne particulate (dust particles).

Upwind personnel will probably not need any PPE; however, in the event that the above conditions exist, an air purifying respirator along with coveralls will provide necessry protection.

Additional Safety Support Equipment

1. Decontamination Trailer

   For on-site personnel showers and laundry facilities to minimize transport of contaminated material from site.

2. Air Compressors

   To supply Grade 0 breathing air. The compressor must be equipped with either a high temperature alarm or carbon monoxide alarm or both.

3. Water

   It is necessary that water be available for decontamination, showering, and laundry purposes.

4. Steam Decontamination System

   For equipment.

5. Organic Vapor Monitor

   The possibility of organic and flammable vapor buildup within and around the trench excavation area must be considered for personnel safety. Regular monitoring for explosive vapor should occur during operations. Several types of explosion meters are available from suppliers.

6. Miscellaneous

   There are numerous other safety and personnel protection measures which should be considered during a hazardous operation of this nature, especially for the excavation contractor. These considerations may directly influence the total cost of the cleanup. They include:

   - Medical monitoring
   - Non-sparking tools
   - Explosion-proof equipment
   - Fire-extinguishing materials
   - Varying levels of personnel protection dependent on specific task within or without secured area of site
   - Providing for adequate rest, well-balanced meals, and other personal hygiene during operations
   - Daily safety briefings on site
   - Training of personnel in safety and work procedures

APPENDIX E

COST TABLES FOR PROPOSED REMEDIAL ACTION

TABLE E-1

COMPONENT 1

TEMPORARY STORAGE FACILITY

ASSUMPTIONS

- Site for storage facility is available near waste site
- Shallow soil overburden
- Total storage requirement is 5000 drums.

ESTIMATED COSTS FOR THE ELEMENTS OF THIS COMPONENT:

Geotechnical Investigations	$ 25,000
Land - 1 Acre @ $1,000/per acre (assuming purchase of land)	1,000
Engineering Design Lump sum @ $25,000 (design of pad, caissons)	25,000
Steel plate fabrication, transport, and erection	190,000
Site Preparation - 1 acre at $1,000/per acre	1,000
Foundations	
a. Excavation - 1200 C.Y. at $3/C.Y.	3,600
b. Caissons - 37 caissons X 12 V.F. @ $32/V.F.	14,200
c. Grade Beams - 95 C.Y. at $285 C.Y.	27,100
d. Slab - 200 C.Y. at $165 C.Y.	33,000
Drum Rack, Misc. Interior	25,000
Electrical, Ventilation & Vandal-proof Access	15,000
TOTAL FOR COMPONENT 1	$360,000

*Cost estimate for fabrication & erection by Pittsburgh - Des Moines Corporation

TABLE E-2

COMPONENT 2

SITE SETUP & MOBILIZATION

ASSUMPTIONS:

- o Protective Equipment will be used by all personnel
- o Offsite facilities to be available duration of project
- o Requires installation of complete utilities
- o Ten days for this component

ESTIMATED COSTS FOR ELEMENTS OF THIS COMPONENT:

SITE CLEARING		
expanding road, additional clearing		
2 acres, $4,000/acre		$ 8,000
UTILITIES		
<u>Telephone</u>		
$200 to connect phone		
$1,000/mth phone bill	$1,200	
<u>Sanitary Facilities</u>		
$200/mth. 1 month	200	
<u>Lighting System</u>		
2-30' lighting-towers		
$600/mth. each	1,200	
<u>Power System</u>		
7.5 KW Generator		
$300/mth. plus $30/day		
operating cost for 30 days	1,200	
	3,800	3,800
OFFSITE BUILDINGS (TEMP.)		
<u>Command Post 12' x 8' Trailer</u>		
$300/mth plus $100 delivery	400	
<u>Storage Area 12' x 8' Trailer</u>		
materials, equipment, suits, etc.		
$300/mth. plus $100 delivery	400	
<u>Crew Trailer 20' x 8</u>		
$500/mth x 1 month + $150 delivery	650	
<u>Shower Trailer</u>		
$350/day x 40	14,000	
	15,450	15,450

TABLE E-2 con't

SITE PREPARATION

Material		
Remove Portions of Existing Fence		
$3.00/linear ft. x 100 linear ft.	$300	
Relocate Old Fence		
$3.00/linear ft x 100 linear ft.	300	
Install New Fence		
$10.00/linear ft x 100 linear ft.	1,000	
Personnel Gates		
2 x $50.00	100	
Vehicle Gate		
1 x $120.00	120	
Canvas Trench Cover		
Canvas		
$1.05/S.F. x 60' x 100'	6,300	
Materials		
(anchors, ropes, springs)	2,000	
	10,120	10,120
Equipment		
Backhoe rental		
1 x $550/wk. x 2/wks	1,100	
Backhoe operating		
1 x 40 hrs/wk. x 2/wks. x $3.50/hr.	280	
	1,380	1,380
Labor		
Laborers		
6 x 8 hrs/day x 10 days x $13.93/hr.	6,690	
Foreman		
1 x 8 hrs/day x 10 days x $19.85/hr	1,590	
Supervisor		
1 x 8 hrs/day x 10 days x $40.00/hr	3,200	
Backhoe Operator		
1 x 8 hrs/day x 10 days x $16.85/hr	1,350	
Per Diem		
9 people x $45/day x 14 days	5,680	
	18,510	18,510
Training		
(84 people for 2, 8-hour training sessions)		
Assume average daily labor cost		
Labor		
2 days x $10,100/day (Daily Labor)	20,000	
Living expenses (per diem)		
3 days x $5,670/day	17,000	
	37,000	37,000

TABLE E-2 con't

DRUM DECONTAMINATION EQUIPMENT			
Idler Conveyors	2 x $ 500	$1,000	
Water Storage Tank	1 x $ 200	200	
Water Supply System for Drum Wash.	1 x $ 500	500	
Decontamination Water Collection System	2 x $ 700	1,400	
Bulk Storage Tanks installed	2 x $1000	2,000	
Sampling			
3 samples per Bulk Tank	9 x $ 700/sample	6,300	
		11,400	11,400
PERSONNEL DECONTAMINATION EQUIPMENT			
Water Storage & Supply Systems	2 x $700	1,400	
Metal Grate Walkways & Decon Line	2 x $650	1,300	
Water Collection Systems	2 x $700	1,400	
		4,100	4,100
PROTECTIVE EQUIPMENT			
Personnel for Set up and within Fence			
Fully Encapsulated Suits	2 shifts x 28 people x 2 per person + 20 x $800/unit	105,600	
Airline Mask with Escape Cylinder	27 people + 13 spares x $925		
Vortex Cooling Tubes	40 x $230	37,000	
Cooling Manifolds	40 x $50	9,200	
Disposable Splash Suits & Gloves		2,000	
Setup	9 people x $12/day x 10 days + 10%	1,190	
Excavation	2 shifts x 28 people/shift x $12 day x 23 days +10%	17,000	
Boots	2 shifts x 35 (7 spares) x $30.00	2,100	
Hardhats	35 (7 spares) x $3.50	125	
Full Face Respirators (when off-site)	32 (4 spares) x $70	2,240	
Respirator Cartridges			
Setup	9 x 8/day/person x $3.85 x 10 days + 10%	3,050	
Excavation	2 shifts x 32 people x 4/day/person x 23 x $3.85	22,670	
		202,180	202,180

TABLE E-2 con't

Equipment Operators			
Self Contained Breathing Appartus	2 x $680	$ 1,360	
Spare Tanks	4 x $220	880	
Cooling vests	4 x $600	2,400	
		4,640	4,640
Air Supply Equipment			
Air Hose: Excavation Personnel	20 hoses x 150 ft/hose x $1.70/ft.	$ 5,100	
Decontamination Personnel	12 hoses x 75 ft x $1.70	1,530	
Air Hose Manifolds	32 connect x $121/4 connect	970	
Air Compressor Systems			
Rental	250/wk for 5 wks. x 3 units	3,750	
Operating Costs	3 x $30/day x 23 days	2,070	
		13,420	13,420
Decontamination Personnel			
Full Face Respirators	8 (2 spares) x $70	560	
Boots	8 x $30 x 2 shifts	480	
Hardhats	8 x $3.50	30	
Disposable Splash Suits & Gloves	2 shifts x 6 people x $12/day x 23 days + 10% for spares	3,645	
Respirator Cartridges	2 shifts x 6 people x 8/day/ person x 23 days x $3.85 + 10%	9,350	
Robert Shaw Escape Masks	8 x $200	1,600	
		15,670	15,670
Personnel Outside Fenced Area			
Full Face Respirators	10 (8 + 2 spares) x $70 x 2 shifts	1,400	
Boots	10 (8 + 2 spares) x $30 x 2 shifts	600	
Hardhats	10 (8 + 2 spares) x $3.50 x 2 shifts	70	
Disposable Splash Suits & Gloves	2 shifts x 8 people x $12/day x 23 days + 10%	4,860	
Respirator Cartridges	2 shifts x 8 people x 8/day x 23 days x $3.85 + 10%	12,470	
Robert Shaw Escape Masks	8 people x $200 each	1,600	
		21,000	21,000
		TOTAL FOR COMPONENT 2	$366,670

TABLE E-3

COMPONENT 3A

EXCAVATION

ASSUMPTIONS:

- o Union Wage Rates for Barry County are used and include a $4.50 per/hour premium
- o Overall productivity is 70%
- o The Excavation is established by a perimeter of 150 feet with an area of 1000 S.F. and a trench depth of 8 feet.
- o 150 drums of contaminated waste material exists in trench

---

Estimated Costs for Elements of this Component:

EQUIPMENT*

Crane		
Rental		
$3,900/mo. + 1 week @ $900/wk.	$ 4,800	
Operating		
$5/hr. x 16/hr/day x 23 days + $400 Delivery	2,240	
Backhoe		
Rental		
$2,025/mo. + 1 week @ $470/wk.	2,495	
Operating		
$3.50/hr. x 16/hr/day x 23 days + $200 Delivery	1,488	
Forklift		
Rental		
$1,050/mo. + 1 week @ 245/wk. + $160 for drum handling attachment	1,455	
Operating		
$4/hr. x 16 x 23 days + $200 Delivery	1,672	
Flatbed Truck		
Rental		
$750/mo. + 1 week @ $173/wk. x 2 trucks	2,225	
Operating		
$1/hr. x 16 hr. x 23 days x 2 trucks	736	
Water Truck		
Rental		
$1,900/mo. + 1 week @ $439/wk. x 1 truck	2,470	
Operating		
$4/hr. x 2 hrs/day x 23 days	184	
	19,765	19,765

* Includes 50% surcharge for two shift operation

TABLE E-3 con't

MATERIALS		
Drums		
Soil (from Tables E-3.1 & E-3.2)		
2,370 drums x $25/drum	$59,250	
Waste drums		
150 drums x $25/drum	3,750	
Waste Overpacks		
150 drums x $75/drum	11,250	
Decontamination Water (assuming positive sampling) 610 drums x $25/drum	15,250	
Water (from Table E-3.2)		
Drum Decontamination		
5,875/gal. x $0.05/gal	295	
Personnel Decontamination		
24,800/gal. x 0.05/gal	1,240	
Showers, Miscellaneous		
46,370/gal. x $0.05/gal	2,320	
Waste and Water Pumping System (purchase) (Air operated pumps with anti-corrosive coatings)	3,000	
Hand Truck for Drums	250	
Disposable Supplies, Trashbags, Etc.	1000	
Calcium Chloride for Dust Control	1000	
	98,610	98,610
LABOR		
Laborers		
36/shift x 23 days x 8 hrs/day x 2 shifts/day x $13.93/hr.	184,500	
Equipment Operators		
Crane		
1 x 23 days x 8 hrs/day x 2 shifts/day x 17.33/hr.	6,380	
Backhoe		
1 x 23/day x 8 hrs/day x 2 shifts/day x $16.85/hr.	6,200	
Forklift		
1 x 23/days x 8 hrs/day x 2 shifts/day x $16.25/hr.	5,980	
Foreman & Supervisors		
Project engineer		
1 x 23/days x 8 hrs/day x 2 shifts/day x $40.00	14,720	
Offsite foreman		
1 x 23/days x 8 x $19.85 x 2 shifts/day	7,300	

TABLE E-3 con't

<u>Safety officer</u> 1 x 23/day x 8 x $19.85 x 2 shifts/day x 19.85/hr.	7,300	
TOTAL LABOR	232,380	232,380
Living Allowance (per diem) 42 people x $45/day per x 32 days x 2 shifts	117,180	117,180
TOTAL COST FOR COMPONENT 3A		$467,930

TABLE E-3.1

COMPONENT 3A

SOIL & WATER VOLUMES

SOIL EXCAVATION			
Volume of Soil to be Excavated			
Trench			
1,000 S.F. x 8' deep	8,000 C.F.		
Sideslopes			
150 linear feet x 32 C.F./L.F.	4,800 C.F.		
	12,800 C.F.		
Volume Machine Excavated			
Trench			
1,000 S.F. x 2 feet	2,000 C.F.		
Sideslopes			
4,800 C.F x 50%	2,400 C.F.		
Volume Hand Excavated			
12,800 C.F. - 4,400 C.F.	8,400 C.F.		
WATER REQUIREMENTS		GALLONS	GALLONS
Drum Decontamination			
2670 drums x 2 gal/drum		5,875	5,875
Personnel Decontamination			
Inside Fence: 28 people/shift x 2 shifts x 15 gal/day/person x 23 days		19,320	
Outside Fence: 4 people/shift x 2 shifts x 5 gal/day/person x 23 days		3,220	
Contingency 10%		2,260	
		24,800	24,800
Personal Hygiene			
42 people x 2 shifts x 20 gal/peison/day x 23 days		38,640	
Contingency 20%		7,730	
		46,370	46,370
		TOTAL WATER	77,045

TABLE E-3.2

CONPONENT 3A

DRUM REQUIREMENTS

SOIL*		Drum	
Machine Excavated			
4,400 CF x 1.35/7.3 CF/Drum		815	
Hand Excavated			
8,400 CF x 1.35/7.3 CF/Drum		1,555	
	TOTAL	2,370	2,370
* Assumes 35% swell factor for soil			
DECONTAMINATION WATER			
Drum Decon			
5,875 gal/55 gal/drum		110	
Personnel Decon			
24,800 gal/55 gal/drum + 10%		500	
	TOTAL	610	610
WASTE MATERIALS			
Contents		150	
Waste Drums in Overpacks		150	300
	TOTAL DRUM REG.		3,280

TABLE E-3.3

COMPONENT 3A

LABOR REQUIREMENTS

ASSUMPTIONS

- Productivity of personnel in safety equipment at 100% is 15 CF/hr for hand excavation
- Productivity of backhoe operator in safety equipment at 100% is 50 C.F./hr.
- Productivity of personnel in safety equipment at 100% for handling drums is the following:

a.	Waste drums in trench	2 man-hrs/drum
b.	Excavated soil drums	1 man-hr/drum
c.	Machine excavated drum	1/2 man-hr/drum
d.	Drum decontamination	1/2 man-hr/drum

- Labor rates with $4.50/hr premium on Union rates for Barry County

a.	Laborer	$13.93/hr.
b.	Light, Fork Lift Equipment Operator	16.25/hr.
c.	Medium Backhoe Equipment Operator	16.85/hr.
d.	Heavy Crane Equipment Operator	17.33/hr.
e.	Foreman, Safety Officer	19.85/hr.
f.	Supervisor, Project Engineer	40.00/hr.

LABOR REQUIREMENTS (On site)

Hand excavation	Hours	
1. Soil excavation within trench 8,400 C.F. @ 15 C.F./manhour	560	
2. Removal of waste from drums & removal of empty drum in overpack 150 x 1 man hr./drum	150	
3. Removal of drums filled with hand excavated soil 1,555 x 1/2 man hr./drum	780	
TOTAL	1,490	1,490

TABLE E-3.3 con't

	Hours	Hours
Machine Excavation		
4,400 C.F./50 C.F./hr	88	88
Drum Handling		
1. New Drums with Waste & Overpacks		
150 drums x 1 man hour/drum	150	
2. Drums Containing Hand Excavated Soil		
1,553 x 1/2 man hour/drum	780	
3. Drums Containing Machine Excavated Soil		
815 drums x 1/2 man hour/drum	480	
	1,410	1,410
Drum Decontamination		
2,370 drums + 300 new drums & overpacks + 110 x 1/2 man hrs./drum	1,390	1,390
	TOTAL HOURS*	4,298

* Does not include offsite support and supervisory personnel

TOTAL PERSONNEL REQUIREMENTS PER SHIFT

	Outside Fence	Inside Fence	Shift
a. Trench excavation		6	6
b. Backhoe operation		1	1
c. Drum Decontamination		6	6
d. Drum handling, drum removal, transport to D-con		6	6
e. On-site backup personnel		9	9
f. Personnel decontamination	6		6
g. Crane operator	1		1
h. Off-site material handling	3		3
i. Forklift	1		1
j. Foreman	1		1
k. Safety officer	1		1
l. Project engineer	1		1
			42 per shift

TABLE E-4

COMPONENT 3B

EXCAVATION

ASSUMPTIONS

- o Drums and intermingled soil removed from trench
- o Sample trench floor and walls to determine concentration of TCP & TCDD are within acceptable limits
- o Only firm cost would be the first time sampling and, if positive results, the platform construction.
- o Single shift activity due to lower hazard

FIXED COST		
Sampling of Trench (WSU estimate on analysis of 40 samples)		$44,000
Drum platform and loading ramp construction Concrete pad 35' x 10' x 6" for 50 drums		
o Formwork and preparation	$ 200	
o Concrete, 1 C.Y. load, delivered	350	
o Backhoe 2 day @ $180/day	360	
o Labor		
a. Backhoe operator (1) 8 hr @ 16.85/hr	135	
b. Laborers (3) people $13.93 hr x 2 days x 8 hr/day	670	
c. Supervisor 1 person x 2 days x 8 hr/day x $40/hr	640	
d. Per Diem 10 man days @ $45/man	450	
o Wooden ramp & platform materials	300	
	$ 3,110	$ 3,110

VARIABLE COSTS

Storage (existing capacity for an additional 2,030 soil drums leaving 7% for decontamination materials)

TABLE E-4 con't

MATERIAL		
Drums (See Table E-4.1)		
204 drums/day x $25/drum	$5,100/day	
Water (See Table E-4.1)		
(Decontamination water)+(shower water)		
= 944/gal/day x $0.05/gal	50/day	
Personnel Protection Equipment		
1. Respirator cartridges		
16 people x 8 cart/day x $3.85 + 10%	550/day	
4 people x 4 cart/day x $3.85 + 10%	70/day	
2. Disposable splash suits		
20 people x $12/unit + 10%	270/day	
TOTAL	$6,040/day	$6,040/day

EQUIPMENT		
a. Crane with Clamshell		
Rental & operating	$ 340/day	
b. Backhoe Loader		
Rental & operating	$ 210/day	
c. Forklift		
Rental & operating	$ 130/day	
d. Flatbed Truck		
Rental & Operating	$ 85/day	
e. Water Truck		
Rental & Operating	$ 130/day	
f. Shower Truck		
Rental + operation	$ 350/day	
g. Miscellaneous equipment & utilities	$ 350/day	
TOTAL	$1,550/day	$1,550/day

TABLE E-4 con't

LABOR (see Table E-4.1)			
Laborers			
15 people x 8 hrs/day x $13.93/hr		$ 1,675/day	
Equipment operators			
1. Crane			
1 person x 8 hrs/day x $17.33/hr		140/day	
2. Backhoe			
1 person x 8 hrs/day x $16.85/hr		135/day	
3. Forklift			
1 person x 8 hrs/day x $16.25/hr		130/day	
Supervisors			
1. Project engineer			
1 person x 8 hrs/day x $40/hr		320/day	
2. Safety officer			
1 person x 8 hrs/day x 19.85/hr		160/day	
Per Diem			
20 people x $45/day		900/day	
	TOTAL	$3,460/day	$ 3,460/day
BACKFILL			
Virgin Soil: 38.5 C.F. x $7.5/C.F.			$ 290/day
	TOTAL VARIABLE COST FOR COMPONENT 3B		$11,340
	THE COST FOR REMOVING 1 CUBIC YARD IS		$ 380

TABLE E- 4.1

EXCAVATION DATA

Labor requirement: 20 personnel
12 on-site laborers (2 backup)
3 off-site laborers
1 crane operator
1 backhoe operator
1 forklift operator
1 supervisor
1 safety officer

SUPPORTING CALCULATIONS

SOIL

Volume of soil to be excavated	
6 people x 4 drums/hour x 8 hours	192 drums/day
192 drums x 7.3 C.F./drum x 1.35 (swell factor)	1040 C.F./day
1040 C.F./day/27 C.F./C.Y.	38.5 C.Y./day
Volume to be machine excavated	
38.5 C.Y./day	

WATER

Volume of decontamination water	
Drums	
192 drums x 2 gal/drum/day	384 gals/day
Personnel	
16 people x 10 gal/person/day	160 gals/day
	544 gals/day
Volume of shower water (not stored)	
20 people/day x 20 gal/person	400 gal/day

DRUM REQUIREMENTS

Drums	
192 drums contain soil	192 drums
Personnel & Drum Contamination	
544 gal/day/55 gal/drum	10 drums
Micellaneous	2 drums
	204 drums

TABLF E-5

COMPONENT 4

SITE CLOSURE

ASSUMPTIONS

- o Remove all materials from site
- o Close site and secure storage facility
- o All contaminated material placed in storage
- o No surcharge on equipment use

ESTIMATED COSTS FOR COMPLETION OF THIS COMPONENT:

EQUIPMENT		
Steam cleaner		
Rental + operating costs 2 wks @ $250/wk	$500	
Flatbed truck		
Rental		
2 wks x $150/wk	300	
Operating		
4 hrs/day x 10 days x $1/hr	40	
Water truck		
Rental		
2 wks @ $380/wk	760	
Operating		
4 hrs/day x 10 day x $1 hr	40	
	1,640	$1,640
PERSONNEL PROTECTION EQUIPMENT		
Disposable coveralls		
6 people x 1 unit/day x $12/unit x 10 days + 10%	790	
Respirator cartridges		
6 people x 8 cart/day x $3.85/cart + 10%	190	
	980	980
MATERIALS		
Drums		
Drums for disposables		
2 drums/day x 10 days x $25/drum	500	
Water		
Steam cleaning		
150 gal/day x 8 days x $0.05/gal	60	
Personnel		
6 people x 10 days x 5 gal/day x $0.05/gal	75	

TABLE E-5 con't

Disposable supplies		
Gloves, trashbags, etc.	$200	
	840	840
LABOR		
Laborers		
5 people x 8 hr/day x 10 days x $13.93/hr	5,575	
Supervisor		
1 person x 8 hr/day x 10 day x $40/hr	3,200	
Per diem		
60 man days x $45/man days	2,700	
	11,480	11,480
DEMOBILIZATION		
Remove all equipment		3,000
Trench Backfill		
(Based on Phase I Excavation)		
Virgin Soil		
640 C.Y. x 7.5/C.Y.	4,800	4,800
Bulldozer Rental		
1 wk. x $400/wk. + $200 Delivery	600	
Bulldozer Operating Cost		
3 days x 8 hrs/day x $4.00/hr.	100	
Bulldozer Operator		
3 days x $16.85/hr. x 8 hrs./day	405	
	1,110	1,100
	TOTAL COST OF COMPONENT 4	$23,840

APPENDIX F

CREDENTIALS

APPENDIX F

CREDENTIALS

The selection of the remedial action necessary for the Denny Farm Site 1 cleanup has necessarily been a multidisciplinary effort. Ecology and Environment's (E & E) Region VII FIT office has been developed to support the investigation requirements of the contract. In considering both the technical and time requirements for the completion of this present study, the E & E FIT National Project Management Office (NPMO) developed a Special Projects Team composed of specialists from throughout the country. Regional direction was maintained with technical and publications support provided by the NPMO.

The following persons were assigned to the Special Projects Team either through the duration of the study or for special support.

JAMES J. BUCHANAN

Discipline: Project Management

Team Assignment: Project Manager

Educational Credentials: Postgraduate Studies in Analytical Chemistry;
B.S., Aquatic Biology/Chemistry

Summary of Work Experience:

Mr. Buchanan has had extensive experience in the management of hazardous waste and pollution control projects. At the present time, he is the manager of Ecology and Environment's Field Investigation Team Regional Office in Kansas City (Region VII). Mr. Buchanan has also been an instructor in the control of hazardous materials for various groups, and he has been an Environmental Emergency Response Team Leader in the State of Ohio.

RUSSELL J. ENOS

Disciplines: Toxic and Hazardous Waste Identification; Solid Waste Management; Transportation of Hazardous Wastes

Team Assignment: Deputy Project Manager

Educational Credentials: B.S., Botany and Chemistry; Pharmacy

Summary of Work Experience:

Mr. Enos has over five years of project management experience in the investigation of solid waste and hazardous waste facilities including background information search; environmental monitoring (air, surface water, groundwater); short-term/long-term remedial measures; and alternate methods of disposal and treatment. In addition, Mr. Enos has served as a private consultant to those generating, transporting, or disposing of hazardous wastes.

ROBERT J. KING

Disciplines: Mechanical Engineering and Public Health

Team Assignment: Resource Coordinator

Educational Credentials: M.P.H., Public Health; United Nation's Graduate Program on the Human Environment; B.M.E., Mechanical Engineering

Summary of Work Experience:

Mr. King is the Assistant National Project Manager for Training and Safety for the Field Investigation of Uncontrolled Hazardous Waste Sites. Mr. King has also been responsible for environmental work on a $40 million technical support contract with the Department of Energy's Division of Fossil Fuel Processing coal conversion program.

JON R. BARKHURST

Discipline: Mathematics

Team Assignment: Risk Analyst

Educational Credentials: M.S., Mathematics

Summary of Work Experience:

Mr. Barkhurst works in Ecology and Environment's Risk and Hazards Management Group. He has evaluated leaks associated with petroleum transportation systems and has formulated mathematical models to predict expected damage from large pipe breaks. He applied probability theory, statistical methods, pipe fractional mechanics, and computer modeling for this study.

EDWARD M. BRIESCH

Discipline: Chemical Engineering

Team Assignment: Chemical Engineer

Educational Credentials: Professional Engineer

Summary of Work Experience:

Mr. Briesch has extensive experience in engineering investigations of industrial accidents (including fire and explosions), defective product designs, and accident preventions. He also has been responsible for the analysis of hazards connected with various chemical products and the installation of chemical facilities.

JOHN A. CAOILE

Discipline: Civil Engineering and Geology

Team Assignment: Geologist

Educational Credentials: B.S., Geology; Senior Undergrduate Standing in Civil Engineering (1980)

Summary of Work Experience:

Mr. Caoile's previous work experience has been in the geotechnical consulting field. His work included supervision and field logging of drill crews, laboratory testing of soil and rock, preparation of geologic maps and cross sections, and field inspections. Mr. Caoile's previous projects have included seepage studies for wastewater treatment plants, foundation soil investigations, sewage lagoon studies, development of criteria for compaction requirements using bentonite to control permeability, drainage of excavations, and settlement analysis.

GARY P. CLEMONS

Discipline: Biology

Team Assignment: Toxicologist/Public Health

Educational Credentials: Ph.D., Fungicide Toxicology; M.S., Insecticide Toxicology; B.S., Entomology

Summary of Work Experience:

Dr. Clemons has seven years of experience in laboratory research investigation dealing with the mode of action and animal metabolism of agricultural toxins and the purification and chemical nature of red-tide algae toxins. He has also had five years of experience with the U.S.

National Park Service and Ecology and Environment in the environmental management of natural areas.

FRANK COATES

Discipline: Biology

Team Assignment: Safety Officer

Educational Credentials: B.A., Biology

Summary of Work Experience:

Mr. Coates was hired by Ecology and Environment, Inc., in April 1980. Before joining E & E, he worked for a period of three years with OSHA in St. Louis, Missouri Mr. Coates has also had one year's experience at the Loyola (Chicago) University Medical Center.

RICHARD P. HARRINGTON

Discipline: Safety Management

Team Assignment: Safety Officer

Educational Credentials: M.S., Public Safety

Summary of Work Experience:

Mr. Harrington is experienced in handling emergency situations and has several years of experience in establishing and operating fire fighting programs at Air Force missile bases. He is knowledgeable in emergency response field organization and practices. Mr. Harrington has studied public safety, accident investigation, physical security, and law in recent graduate studies.

JOSEPH H. HOFFMAN

Disciplines: Mathematics and Physics

Team Assignment: Risk Analyst

Educational Credentials: M.A., Mathematics; B.S., Physics

Summary of Work Experience:

Mr. Hoffman is a member of Ecology and Environment's Risks and Hazards Management Group. As such, he analyzes the hazards to public safety associated with a number of E & E's projects, e.g., the transport and terminal transfer of liquefied natural gas and liquefied petroleum gas. In order to quantify these risks in an objective way, Mr. Hoffman applies the best available scientific knowledge and methodolopgy to develop mathematical models which can be used to predict the physical consequences of an accident. This requires an interdisciplinary approach to the description or modeling of several distinct types of problems.

BOYD N. POSSIN

Discipline: Hydrology/Geology

Team Assignment: Hydrologist/Geologist

Educational Credentials: B.S., Earth Science; M.S., Water Resources Management; M.S., Geology

Summary of Work Experience:

Mr. Possin has over seven years field and office experience in defining groundwater-surface water relationships in soil and bedrock regimes. He has conducted landfill hydrology and groundwater containment movement studies in residual soil, carbonate bedrock environments in Pennsylvania, and in glacial soil, multiple lithological bedrock environments in Wisconsin, Illinois, Minnesota, and Indiana.

JOHN B. SCHULTZ

Disciplines: Information/Documentation Management and Public Affairs

Team Assignment: Public Information/Documentation Officer

Educational Credentials: M.A., Education; M.A., Religion; B.A., Philosophy

Summary of Work Experience:

Mr. Schultz has nearly twenty years of experience in the gathering and dissemination of information and in writing and editing for publication. This experience has included work with highly technical data and with sensitive, secret, and top secret material. Since 1973, Mr. Schultz has been working mainly in the areas of medical education (particularly drug abuse), energy, and environmental studies.

JACK E. WILCOX

Discipline: Environmental Engineering

Team Assignment: Environmental Engineer

Educational Credentials: Professional Engineer in Training (EIT); B.S.E., Environmental Engineering

Summary of Work Experience:

As a member of Ecology and Environment's Technical Assistance Team in Region VI for EPA, Mr. Wilcox observed and monitored the cleanup of the Vertac waste site near Little Rock, Arkansas. He also organized the sample results and provided requested technical assistance for that job.

JOHN ZIRSCHKY

Disciplines: Environmental Civil Engineering

Team Assignment: Cost Estimating and Earthwork Evaluation

Educational Credentials: M.S., Environmental Engineering; B.S., Civil Engineering

Summary of Work Experience:

Mr. Zirschky has one year of research experience involving the construction and operation of land treatment systems. He has also worked with conventional treatment systems.

The following subcontractors were used for the study:

F.C. Hart Associates, Inc.

Subcontractor to E & E on the FIT program; provided resources and expertise on the evaluation of mitigative options.

Gross, Shuman, Brizdle, Laub & Gilfillan, P.C.

E & E corporate legal counsel; provided review of legal requirements of the Denny Farm Site 1 cleanup.

Dr. Raymond D. Harbison

Discipline: Pharmacology and Biochemistry

Team Assignment: Health Advisor

Educational Credentials: Ph.D., Pharmacology and Biochemistry

Summary of Work Experience:

Dr. Harbison directs the National Hazardous Materials Training Course which is sponsored by the Toxic Substance Control Institute. He has also worked as a consultant to E & E on the Oil and Hazardous Materials TAT program for EPA and on E & E's corporate Health and Safety Committee.

Dr. Robert C. James

Discipline: Toxicology

Team Assignment: Toxicologist

Educational Credentials: Ph.D., Pharmacology; B.S., Chemistry

Summary of Work Experience:

As a toxicologist for AWARE, Inc., Dr. James assisted in the assessing of the impact of toxic and organic materials on the environment from various hazardous waste treatment and disposal sites. Dr. James also has authored various publications on clinical pharmacology and toxicology.

LaBella Associates, P.C.

Engineering and management firm in the design of waste management systems; provided engineering expertise in the design and cost estimates for storage operation.

Technos, Inc.

Geophysical survey firm; provided field evaluation of geology and hydrology by use of remote geophysical sensing technology.

Terracon, Inc.

Well drilling firm; completed drilling for sampling program.