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Hazardous Waste Ground-Water Task Force

Evaluation of Texaco Inc. Refinery Casper, Wyoming



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

UPDATE TO THE GROUNDWATER TASK FORCE REPORT
FOR
TEXACO, INC. REFINERY
EVANSVILLE, WYOMING

The Task Force report discusses conditions that were present at the time of the August 1986 inspection. Listed below are selected items pertaining to events which transpired after the inspection during the period August 1986 to September 1988.

- o During October 1986, Texaco began an aquifer recharge and flushing program in an attempt to correct contamination caused by the Chemical Evaporation Pond (CEP). The program consisted of building a dike across the southern third of the CEP and pumping North Platte River water into the southern portion of the CEP for infiltration into the aquifer below. Attached to this report is an analysis titled "Effects of Chemical Evaporation Pond Recharge" which is an analysis of the aquifer recharge activities performed since October 1986. Recommendations of the analysis will be addressed in the 3008(h) corrective action order issued on September 30, 1988, and which is discussed later in this update.
- o On May 6, 1987, EPA issued a Land Treatment Demonstration Permit to the Texaco Casper Refinery pursuant to the requirements of 40 CFR §264.272.
- o On June 15, 1987, Texaco submitted to EPA the "Casper Plant North Landfarm Reconnaissance Investigation Report" pursuant to Condition I. H. 2 of the Land Treatment Demonstration Permit. The Report provided soil analyses of landfarm soils which showed parts of the landfarm to have elevated metal and oil levels.
- o On December 1, 1987, Texaco submitted a letter to EPA stating that pursuant to Condition III. D. 7. of the Land Treatment Demonstration Permit they were reporting a finding of contamination below the treatment zone in their land treatment demonstration test plot.
- o Further soil core investigations and analyses of the landfarm were requested of Texaco by EPA on April 15, 1988 and May 9, 1988. These investigations were to determine extent and rate of migration of hazardous constituents in the landfarm soils. Texaco never conducted the requested investigations.

- o Texaco was notified of EPA's intent to deny an operating RCRA permit on August 2, 1988. The action was taken due to Texaco's failure to provide:
1) requested information, 2) permit application information, and 3) a demonstrated ability to manage a land treatment area in an environmentally safe manner.
- o On September 29, 1988, EPA issued a unilateral RCRA Section 3008(h) corrective action order to Texaco for facility wide site investigations, corrective measure studies, and corrective measure implementation at the Texaco Casper refinery.
- o On September 30, 1988, EPA issued a final determination on Texaco's application for a RCRA permit. Texaco's application was denied and the facility was ordered to cease receiving wastes.

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I EXECUTIVE SUMMARY

A. INTRODUCTION

1. Task Force Effort

Operations at hazardous waste treatment, storage and disposal (TSD) facilities are regulated by the Resource Conservation and Recovery Act (RCRA, P.L. 94-850). Regulations promulgated pursuant to RCRA (40 CFR Parts 260 through 265, effective on November 19, 1980 and subsequently modified) address hazardous waste site operations including monitoring of ground water to ensure that hazardous constituents are not released to the environment. The regulations for TSD facilities are implemented (for EPA-administered programs) through the hazardous waste permit program outline in 40 CFR Part 270.

The Administrator of the U.S. Environmental Protection Agency (U.S. EPA) established a Hazardous Waste Ground-Water Task Force (Task Force) to evaluate off-site and selected on-site TSD facilities and address the causes of non-compliance. The Task Force is generally comprised of personnel from EPA headquarters core team, regional offices, and the states.

2. Task Force Objectives

The principal objectives of the investigation at the Texaco Refinery in Casper, Wyoming were to determine the following:

- a) Compliance with the requirements of 40 CFR 265 Subpart F - Ground-Water Monitoring
- b) Evaluate the existing information on the ground-water protection program for potential compliance with 40 CFR Part 270
- c) Evaluate the existing and proposed ground-water protection program for potential compliance with 40 CFR Part 264
- d) Verify the quality of the facility's ground-water monitoring data
- e) Evaluate the sampling and analytical procedures employed by the facility
- f) Collect ground-water samples using the Task Force Protocol in order to evaluate and compare analytical results with those collected by Texaco in addition to determining the presence of hazardous waste constituents.

3. Evaluation Procedures

To meet the objectives of the task Force evaluation for the Texaco facility in Casper, Wyoming, the following activities occurred:

- a) Compilation and analysis of all relevant data, reports and correspondence from U.S. EPA Region VIII files and files present in the offices of Wyoming DEQ in Cheyenne, Wyoming

- b) Sampling audit of facility's ground-water sampling procedures conducted from June 18 to June 20, 1986
- c) Collection and subsequent analysis of ground-water, surface water, hydrocarbon and pond liquid samples obtained from August 11 to August 15, 1986
- d) Site inspection and interviews with facility personnel and contractors from September 29 to September 30, 1987.

Some of the information obtained from Texaco was acquired well after the Task Force site visit in August 1986. These data have been utilized in this report where required to support the Task Force's evaluation of the current ground-water monitoring program.

B. SUMMARY OF FINDINGS AND CONCLUSIONS

The following summary of findings and conclusions is based on Task Force interpretations of existing data, observations and findings from the sampling event at the site on August 11-15, 1986, and the requirements of 40 CFR 264 and 265 Subpart F.

For simplicity, the Task Force's findings and conclusions below have been subdivided into sections corresponding to those of the technical report (Part II).

1. Hydrogeology

Two aquifers of concern exist in the North Area. The uppermost aquifer is composed of unconsolidated eolian sands and alluvial deposits, and the consolidated Teapot Sandstone, subcropping in the eastern portion of the facility. The second aquifer consists of unconsolidated alluvial deposits located within the North Platte River floodplain. The second aquifer is lower than the uppermost aquifer, but this difference is topographic, not stratigraphic. Even though the two aquifers are not connected in a geologic or hydrostratigraphic sense, the uppermost aquifer recharges the alluvial aquifer by means of seepage along an intervening bluff. The only aquifer of concern in the South Area is the unconsolidated alluvial aquifer. Except where the bedrock outcrops, the alluvial aquifer is present throughout the South Area.

North Area

The major potential contaminant pathways include the North Platte River and its associated alluvium, and possibly the Teapot Sandstone. All the above are used for water supply east of the site. The potential for contamination of the Teapot aquifer is undefined at the present time. Testing of downgradient Teapot wells for contamination is recommended.

South Area

The major impacts from the contaminants would probably be to the North Platte River. Escape of contaminants to the east, around the bedrock high and through permeable lenses in the unnamed middle member of the Mesaverde Formation are possible pathways to the river. While no bedrock aquifers underlie the South Area, migration of contaminants to the northeast may impact the Teapot aquifer. This pathway is presently undefined and conjectural. To reach the subcrop of this

aquifer, migration off-site to the northeast must take place. The distance to the subcrop of the Teapot Sandstone from the eastern boundary is not defined. In addition, the ground-water flow in the southeastern corner of the site is not fully understood a limited number of data points (wells and/or piezometers) exist in this area.

2. Ground-water Monitoring System

a. North Area Ground-water Monitoring Systems

The ground-water monitoring system in the North Area is currently regulated under interim status. Two RCRA-regulated units, the North Land Farm and the Chemical Evaporation Pond (CEP), are located in this area. The land farm is currently accepting and disposing waste under interim status. A Part B Permit Application for this unit was submitted to EPA in 1985. According to Texaco, the CEP ceased to accept wastes after June 1982, and was closed under interim status in 1986. Texaco states that degraded ground water in the North Area is emanating from the CEP. Due to this contamination, Texaco initiated an assessment monitoring program to delineate the rate and extent of migration and concentration of contaminants in the ground water. Texaco originally considered the two regulated units as one hazardous waste management unit. Currently, as part of the Part B Permit Application, the North Land Farm is separated from the CEP. At no time has Texaco designated monitoring wells as part of a detection monitoring program under interim status for the North Land Farm, even though they maintain that contamination is from the CEP. Because a detection system has not been designated, baseline and statistical data are not available. This information must be presented as Texaco intends to proceed into detection monitoring under 40 CFR 264 upon permit approval. The findings and conclusions discussed below are further subdivided into the following headings: Interim Status Ground-Water Monitoring (40 CFR 265), Proposed Ground-Water Monitoring System (40 CFR 264), Corrective Action for SWMUs (40 CFR 264.101), and the South Area Ground-Water Monitoring System.

Interim Status Ground-Water Monitoring (40 CFR 265)

- The present assessment monitoring program for the North Area as interpreted by the Task Force has several technical deficiencies that may not allow for an evaluation of the rate and extent of contamination in the ground water. Texaco is required by 40 CFR 265.93(d) to evaluate the extent of light and/or dense phase immiscibles that may be associated with the existing contaminant plume emanating from the CEP. A thorough evaluation of the adequacy of the existing monitoring wells to detect such phases should be initiated. Based on the Task Force evaluation, numerous wells in the North Area may not be capable of monitoring for light and/or dense phases. These data are needed for a complete evaluation of the extent and migration of contaminants in the uppermost aquifer as required by 40 CFR 265.93(d)(4)(i).
- As previously mentioned under hydrogeology, the full extent of the uppermost aquifer and the possible extent of the CEP contaminant plume may not be completely evaluated. This is due to the potential

for hydraulic communication between the Teapot Sandstone, a potential contaminant pathway, and the alluvium. The subcrop of the Teapot lies to the east of the CEP.

- Texaco must determine the rate and extent of migration and concentration of hazardous waste in the ground water (40 CFR 265.93(d)(4)). Currently, Texaco has made the above determination on only four parameters (TOC, phenol, sulfide and ammonia). The rate and extent of migration and concentration of all Appendix VII wastes must be established.
- As part of defining the rate and extent of contaminant migration under 40 CFR 265.93(d), Texaco should evaluate the effects of dilution, attenuation, hydrogeochemical and hydrobiological phenomena which may be affecting the extent of the CEP plume. This is important under assessment monitoring as the dimensions of the plume are bound to be affected by the recharge of the CEP as part of Texaco's remedial action plan for this ground-water contamination. Texaco has not proposed, as part of their interim status assessment program, data evaluation techniques which will fully address plume migration. This is a very important point in that when a corrective action program is initiated under 40 CFR 264.101 for the CEP plume, these data evaluation techniques will aid in determining the effectiveness of the remediation program, and will aid in tracking the rate and extent of contaminant migration. A number of possible analytic procedures could be applied to existing data to further assess the effects of recharge of river water on the attenuation of contaminant concentrations in ground water in the CEP area. These could include, but not necessarily be limited to, the following kinds of analyses:
 - o Trend analyses of contaminant concentrations versus time in monitoring wells, in an effort to isolate the effects of river water recharge from attenuation effects occurring prior to recharge. Monitoring wells might be grouped according to their distances downgradient from the recharge pond in an effort to eliminate some variability in the data.
 - o Reassessment of trends of maximum quarterly contaminant concentrations, to determine whether the data more probably suggest a stabilization of maximum concentrations, rather than a continuing decline. In addition, the wells at which maximum quarterly concentrations are detected should be identified, and an assessment made as to whether or not there is an identifiable trend of distance of maximum concentration from the CEP versus time.
 - o Since Texaco has suggested that changes in sulfide and sulfate concentrations may correlate with aerobic or anaerobic biodegradation, an examination of temporal or spatial trends in variations of sulfide/sulfate ratios might provide useful information. Similar geochemical studies might be possible using other chemical species.

- o Mathematical modeling of the hydraulic effects of river water recharge could provide useful information regarding relative rates of recharge versus ground-water underflow, rates of transport of recharged water within the uppermost aquifer, and the areal and temporal extent of the effects of river water recharge. Furthermore, by treating the recharged water as an ideal tracer within an appropriate mass-transport model, it should be possible to estimate the attenuation due solely to dilution and dispersion effects, and thus provide estimates of the attenuation due to chemical and biological degradation phenomena.
- Texaco should expand the sampling and analysis of indicator parameters (e.g., TOC, phenols, sulfate and ammonia) during assessment monitoring to include organic constituents unique to the contaminated ground water. These data can be used not only to correlate with the indicator parameters, but to evaluate the effectiveness of corrective action in attenuating concentrations of organic constituents in the future. Under 40 CFR 265.93(d)(4)(ii), Texaco is required to determine the concentrations of the hazardous waste or hazardous waste constituents in the ground water. Once Texaco determined that waste constituents had entered the ground water, they were required to continue monitoring these constituents on a quarterly basis (40 CFR 265.93(d)(7)). At this time some wells are sampled quarterly, but then only for indicator parameters and not the waste constituents of concern.
- Construction and integrity of the existing wells are questionable due to a lack of detailed information, the use of natural gravel pack and/or filter pack extending far above the top of screen, and the lack of annular seals in numerous wells (40 CFR 265.91(c)).

These construction defects may not allow for the collection of discrete ground-water samples. Turbidity values collected by the Task Force (up to 750 N.T.U.) seem to indicate that some of the wells may not be adequately developed and/or constructed, and thus not performing properly.

Table 8 in the technical report points out that all of the wells in the North Area have one or more construction deficiencies (EPA, 1986a) which may impact their ability to provide representative, unbiased ground-water samples from the uppermost aquifer. The use of PVC construction material in this area may not be appropriate due to the presence of aqueous organic constituents which may degrade and cause adsorption, absorption or other phenomena which may bias analytical results.
- The land farm should have a detection monitoring system which will allow for the immediate detection of releases from this unit (40 CFR 265.90) at the same time as the rate and extent of contamination emanating from the CEP is being evaluated [40 CFR 265.93(d)]. Data collected from this interim status program, which Texaco had not yet implemented, could be used as baseline data in evaluating the

proposed detection system under 40 CFR 264.98 in Texaco's Part B Permit Application. For example, baseline statistical data for an upgradient background well do not exist for the North Land Farm. It is clear that once Texaco determined that contamination was emanating from the CEP and not the North Land Farm, the two units should have been separated [i.e. originally the two units were treated as one management area (40 CFR 265.91(b)(1))] and a detection monitoring program should have been initiated.

Proposed Ground-Water Monitoring System (40 CFR 264)

As previously discussed, Texaco has proposed in their Part B Permit Application, a detection monitoring program for the North Land Farm for compliance with 40 CFR 264.98. Four wells were proposed. The Task Force has the following comments on Texaco's proposal:

- Data collected and evaluated by the Task Force indicates that something unusual is happening at well M-36 as indicated by potentiometric maps and contaminant concentrations. This well should be replaced as the upgradient well for the proposed system. A new well(s) should be installed or other existing wells evaluated to determine the suitability of the well(s) as upgradient monitoring wells (40 CFR 264.97(a)).
- Texaco must designate monitoring wells at the point of compliance which will detect an immediate release of hazardous waste constituents to the ground water (40 CFR 264.98). Based on several factors, existing well M-10m and proposed wells M-38 and M-39 located at the point of compliance may not be sufficient to monitor the North Land Farm for a release. An insufficient number of wells exist directly south of the North Land Farm. In addition, of the three point of compliance wells, only the existing well (M-10m) would detect a dense phase immiscible. The two proposed wells (M-38 and M-39) are presently designed so as to monitor the ground-water surface only.
- The Task Force recommends that the construction and design of the wells be re-evaluated. Construction deficiencies noted in wells M-10m and M-36 may influence the quality of samples, and may provide a downward potential migration pathway for contaminants (40 CFR 264.97(c)). Again, the use of PVC well construction material is questionable.
- Because the proposed indicator parameters/waste constituents (benzene, toluene, lead, phenol and chromium) have been detected in the ground water emanating from the CEP, it is recommended that a thorough evaluation or waste analysis be performed for the land farm so that key indicator parameters can be established. If this is not possible, Texaco should propose a sensitive statistical test which will allow the detection of contaminants migrating from the land farm above and beyond the concentrations of existing contamination from the CEP [40 CFR 264.98(a) and 270.14(c)(6)(i)].

- The detection monitoring system proposed for the North Land Farm should be capable at all times of monitoring up- and downgradient of the land farm. With the recent initiation of recharge to the CEP, the effects of ground-water mounding on ground water flow should be continually monitored. This type of water level measurement program and schedule should be proposed as part of the detection program to ensure that up- and downgradient wells will be monitored at all times (40 CFR 264.97 and .98).

Corrective Action for SWMUs (40 CFR 264.101)

Because of the regulatory status of the CEP (i.e. ceased receiving wastes in June, 1982), it is apparent that the corrective action program which was recently instigated will be monitored under 40 CFR 264.101. At this time, Texaco has not proposed such a program. The Task Force recommends that the following conditions be included in this corrective action program. In addition, deficiencies in the ability of the current ground-water monitoring system to address releases from SWMUs are discussed.

- Texaco must implement a corrective action program which mitigates ground-water contamination from the CEP and other SWMUs in the North Area (40 CFR 264.101). Because 40 CFR 264.101 lacks the specific regulatory requirements for corrective action, the Task Force feels the following conditions should be considered at a minimum:
 - o The number and locations of wells to be utilized, rationale for their selection and an evaluation of the construction details to evaluate the integrity of each well.
 - o Designate those indicator parameters and waste constituents to be used to compare to a background well which can provide data that can accurately represent the conditions at the site. This is essential in order to show that all waste constituent concentrations of concern, and not just some, are decreasing.
 - o Design a sampling and analysis collection program and complementary data evaluation techniques which can ultimately show the effectiveness of restoring the quality of ground water in the North Area.
 - o Data evaluation techniques should be outlined in specific detail, so that Texaco's evaluation of the corrective action efficiency can be monitored continuously. Data evaluation techniques were previously discussed.
- At this time, Texaco has not provided the data to evaluate the potential impacts of other solid waste management units in the North Area. Specifically, the Solid Waste Landfill adjacent to the CEP and the Asphalt Landfill should be investigated to evaluate whether or not these units have impacted ground water. This is important as source abatement is the first step in any ground-water corrective action program.

b. South Area Ground-Water Monitoring System

The ground-water monitoring system in the South Area addresses a substantial accumulation of floating hydrocarbon in the central portion of the site and a dissolved organic plume in the southeastern corner. A hydrocarbon recovery system (recovery wells, recharge wells and interceptor trenches) is currently removing and treating the floating hydrocarbons in the central portion. Because no regulated units exist in the South Area, the floating hydrocarbon is probably a result of past waste management practices, specifically releases from the numerous solid waste management units identified in this area. Corrective action currently underway in the South Area is subject to the regulatory requirements of 40 CFR 264.101, corrective action for SWMUs.

The Task Force review of the available data produced the following recommendations:

- The Task Force recommends the identification and abatement of all potential sources of ground-water contamination in this area which may continue to release contaminants into the ground water.
- In the past, Texaco has only evaluated the extent of floating hydrocarbon in the central portion of the facility. The Task Force recommends that evaluation for the presence of dissolved and/or dense phase immiscible organics be performed. The Task Force sampling identified the presence of both dissolved and dense phase immiscible organics in this area.
- Texaco should initiate a sampling and analysis program to evaluate the full extent of hydrocarbon contamination. These data will provide a baseline for future monitoring to evaluate the effectiveness of corrective action.
- It is recommended that a thorough evaluation of construction and design specifications be performed prior to designating wells needed for ground-water quality analysis. An evaluation by the Task Force has shown numerous wells to contain construction defects.
- Texaco should evaluate the existing wells located between the plume and the North Platte River to detect light, dense and dissolved organics in order to detect a release prior to discharge to the North Platte River, specifically in the area between the east end of the east interceptor trench and the west end of the reported clay barrier. Note that the Task Force identified contamination immediately adjacent to the river within this area.
- Texaco should implement a performance monitoring program to evaluate the efficiency of the interceptor trenches and recovery wells currently in operation.

A ground-water monitoring program used to evaluate the performance of oil recovery operations may include, but is not limited to the following recommendations:

- o Texaco should implement a performance monitoring program for the interceptor trenches, which at a minimum should include 1) an evaluation of grade control to ensure that ponding in the trenches is not occurring; 2) continued monitoring of water levels in wells adjacent to the east interceptor trench, and wells adjacent to the west interceptor trench and the North Platte River to ensure the trenches are continuing to act as ground-water sinks. This is important as it is probable that the oil recovery system (recovery and recharge wells) plus seasonal variations in water levels will alter the performance of the trenches. In order for the trenches to be effective, they must operate to account for these variations. Texaco should consider additional wells south and north of the trenches to evaluate gradients; 3) the implementation of a monitoring program of wells installed between the trenches and the North Platte River to ensure that contamination is not migrating past the trenches. The wells should be completed to monitor for floating hydrocarbons, dissolved organics and dense immiscible phases; 4) A maintenance and operation program to inspect the trenches to ensure proper operation. Inspections should include an evaluation of the drains for chemical clogging (biological slimes), excess siltation due to introduction of fines and other mechanical failures associated with the pumps and skimming devices in each sump.

In addition, it is apparent that the oil recovery system (recovery and recharge wells) may be increasing contamination of the aquifer by injecting untreated ground water back into the aquifer. As part of performance monitoring, Texaco should sample the water being recharged to the aquifer for organics. Based on these analyses, Texaco should present a treatment method (if required) such as air stripping to remove the dissolved hydrocarbons to an acceptable level. The use of the PCS coke settling pond and the service water ditch for discharge of skimmed water from RW-1 and the interceptor trenches, respectively, should be evaluated as they may also be re-introducing contaminants into the ground water through seepage. An enclosed treatment system as opposed to open ponds would be more appropriate. In conclusion, the treatment technologies currently in place should be re-evaluated to determine further impacts to the ground water and/or surface water bodies.

- The Task Force recommends that Texaco address the 950 feet of shoreline along the North Platte River which does not contain interceptor trenches or barriers, and does not appear to be within the influence of the recovery wells. This appears to be a prominent pathway for potential off-site contaminant migration. This is supported by the presence of contamination in wells SS-4 and SS-5 in the form of a floating and/or sinking phases. Based on the location of wells SS-4 and SS-5, it appears that discharge of contaminants to the North Platte River may be occurring, possibly on a seasonal basis.
- It is recommended that Texaco evaluate the potential for releases in this area to the North Platte River. This may include the installation of additional wells between SS-4 and recovery well RW-1. As part of this evaluation, the structural integrity of the clay barrier installed in 1957 should be investigated in order to determine the efficiency

of this structure to control contaminant migration (i.e. floating, dissolved and/or dense immiscibles). If the potential for migration is high, which it appears to be in this area, Texaco should consider the installation of an enhanced ground-water control system in this area which may include French drains or barrier walls, or possible expansion of the oil recovery system (recovery wells). As part of this monitoring and performance evaluation for the trenches, inspection for seeps along the south bank of the North Platte River (entire Texaco property) should be implemented so that immediate detection of releases can be made. The inspection schedule for seeps should take into account seasonal fluctuations in water levels, river stages, and operation and shutdown of the hydrocarbon recovery system.

- The Task Force recommends that Texaco evaluate the quality of ground water pumped from the recovery wells and discharged down recharge wells. The ground water is not treated for dissolved organics prior to recharge. It appears that this lack of treatment may further contribute to contamination of the uppermost aquifer.
- The Task Force recommends that Texaco install additional wells in the southeastern corner of the site to address the full extent of contamination in this area. Task Force data indicate that concentrations of organics were detected along the eastern property boundary. Migration of organics off-site to the east may be of concern. Concentration in these wells as detected by Texaco immediately following the Task Force Evaluation (October 1986) are as follows: benzene (21 to 10,000 ug/l); ethylbenzene (<10 to 3,500 ug/l); toluene (<10 to 5,000 ug/l); and xylene (<10 to 5,800 ug/l).

3. Task Force Sampling and Monitoring Data Analysis

During the Task Force inspection, 16 ground-water samples and three surface water samples were collected. The purpose of this sampling was to determine the concentrations of hazardous waste constituents in the ground water at Texaco, and to verify Texaco's past analytical performance. The Task Force review of these data produced the following findings and recommendations:

- The Task Force data from the North Area confirmed the presence of hazardous waste or hazardous waste constituents in the ground water. In general, the data indicate that the area near the CEP and North Land Farm are the most contaminated, with monitoring well M-36 showing the highest concentrations. Low levels of organic contaminants were detected in one of the alluvial aquifer wells (M-12S) during the evaluation. The data also indicate that surface water samples taken from the inlet of the Excess Service Water Effluent Ponds and the Alluvial Pond were not contaminated with any organic constituents. Inorganic constituents which exceeded applicable standards included arsenic and selenium at wells M-10s and M-36, and selenium and nitrate at the inlet pond of the Excess Service Water Effluent Pond. The secondary standards for sulfates, iron, manganese and other parameters were also exceeded at numerous wells.
- The Task Force data from the South Area (central portion) show the presence of several organic constituents in the four wells sampled (SS-19, SS-49, SS-34 and SS-4). Constituents and ranges include: benzene (38-6000

ug/l), ethylbenzene (ND-310 ug/l), toluene (ND-620 ug/l), and total xylenes (ND-3000 ug/l). The highest concentrations of the above mentioned organics were found in well SS-49. Several other base/neutral organics were detected in wells SS-19, SS-49 and SS-4, with SS-4 showing concentrations of organics (chrysene, fluorene, fluoranthene, etc.) ranging from 700 to 2800 ug/l. Organics were not detected in the upgradient well (M-41a) sampled by the Task Force. It is recommended that concentrations of dissolved organics and the presence of dense phase immiscible organics be evaluated by Texaco.

- Several deficiencies in Texaco's Sampling and Analysis Plan were noted. The Task Force recommends that the plan be updated to reflect current sampling procedures and methodologies, and include the detail required to assure the collection of quality data. In accordance with the TEGD (EPA, 1986), the following technical deficiencies of the written sampling and analysis plan were noted by the Task Force:
 - o The air in the well head should be and was not sampled for organic vapors using either a photoionization analyzer or an organic vapor analyzer.
 - o A discussion of how static water levels will be obtained was not included.
 - o The plan does not specify how light and/or dense phase immiscibles would be detected. A discussion on how Texaco will determine the thicknesses of such layers should also be included.
 - o A step-by-step procedure for well evacuation was not included in the plan. Specifically, the procedures used by the facility when an appropriate volume of water cannot be evacuated, should be discussed.
 - o Texaco should further discuss sample withdrawal procedures. The plan does state the choice of materials used during sampling withdrawal, but does not indicate how samples will be obtained for light and/or dense phase immiscibles.
 - o Texaco indicates in the addendum to the sampling and analysis plan that ground-water samples that are organically contaminated should be filtered. This is in direct opposition to current protocols.
 - o A detailed QA/QC program that will be used in the field and laboratory should be specified in the Sampling and Analysis Plan.
- The Task Force data for surface water from the PCS pond, which is used for effluent from recovery well RW-1, also showed the presence of numerous organics, thus indicating that this pond may be a continued source for ground-water contamination and that effluent from RW-1 may be contaminated.
- The Task Force data show concentrations of organics (benzene, toluene, ethylbenzene and naphthalene) detected in well SS-7 located along the

eastern property boundary. It is recommended that the source of this contamination be identified, along with its extent.

4. Compliance With Superfund Off-Site Policy

Under current EPA policy, if an off-site TSDF is to be used for land disposal of waste from a Superfund-financed cleanup of a CERCLA site, the TSDF must be in compliance with the applicable technical requirements of RCRA. The Texaco facility does not accept off-site Superfund cleanup wastes and therefore was not evaluated with regard to the offsite policy.

II TECHNICAL ASSESSMENT

A. INVESTIGATIVE METHODS

The Hazardous Waste Ground-Water Task Force (Task Force) investigation consisted of the following:

- o Reviewing and evaluating records and documents from U.S. EPA Region VIII files, Wyoming Department of Environmental Quality (DEQ) files, and Texaco Refinery files.
- o Conducting an on-site facility inspection during the week of August 11, 1986.
- o Sampling and analyzing data from 16 ground-water monitoring wells and three surface water locations.

1. Records/Document Review

Records and documents obtained from EPA Region VIII, Wyoming DEQ and Texaco were compiled and reviewed prior to, and following, the on-site inspection. The purpose of this review was to obtain information regarding past and present facility operations, details of the waste management units and the facility's ground-water monitoring program.

The complete list of documents used during the evaluation is presented in Section F. Documents which were of significant importance included: Part B Permit Application (November 5, 1985), CEP Closure Plan (October 5, 1984), Casper Plant North Land Farm Reconnaissance Investigation Report (June 15, 1987) and the series of Annual Reports (1983-1987) of the Ground-Water Pollution Abatement Program.

2. On-Site Inspection

A facility inspection was performed at the Texaco Refinery during the week of August 11, 1986. The objective of this inspection was to determine compliance with federal regulations, in particular, those regarding the ground-water monitoring system.

3. Task Force Sampling Locations and Methods

A total of 16 ground-water monitoring wells and three surface water locations were sampled by the Task Force. A detailed discussion of the monitoring wells is presented in Section D of this report.

Each sample was analyzed for the 40 CFR 265.92(b)(1), (2) and (3) parameters, volatile organics and the base neutral/acid extractable organics. Field analyses included pH, temperature and specific conductance. Data from sample analyses were reviewed to further evaluate Texaco's ground-water monitoring program and to identify ground-water contamination. Summary tables of analytical results for the samples collected by the Task Force are presented and discussed in Section E of this report. The raw data are presented in Appendix A.

B. FACILITY HISTORY, OPERATIONS AND DESIGN

1. Background

Texaco owns and operates a crude oil refinery located in the municipality of Evansville, Natrona County, Wyoming. The refinery was operational from 1921 until August 1982, when it temporarily ceased production for economic reasons (A.T. Kearney, 1986). The facility currently remains inactive. During its operational life, the facility processed crude oil into gasoline, diesel and other fuels. Texaco owns property on both sides of the North Platte River (Figure 1). The property located north of the North Platte River (North Area) contains crude oil tankage areas and several waste management areas, including two RCRA-regulated hazardous waste management units. These are the Chemical Evaporation Pond (CEP) and the North Land Farm. The property south of the North Platte River (South Area) contains the process units, product tankage areas, several solid waste management units (SWMUs), and office buildings (Figure 2).

The primary surface water feature in the area is the North Platte River which flows through the Texaco site. The river is perennial and a prominent regional drainage feature which encompasses a wide area of influence. There are no naturally occurring perennial or intermittent streams on either the North or the South Areas.

On the North Area, runoff is controlled, for the most part, within the various facilities found there. The primary method is the retention and evaporation of the small quantities of precipitation which fall on the area. Locally, in the area around the Excess Service Water Effluent Ponds, runoff is directed through sheet flow into the ponds adding only minor amounts to their water inventory (A.T. Kearney, 1986).

The South Area is managed somewhat differently. A series of ponds adjacent to the river are designed to, among other things, collect runoff from the facility. In these ponds, runoff water from process areas is kept separate from that originating in non-process areas. During operation, much of the runoff eventually ends up in the facility's service water system and from there, is either discharged to the Excess Service Water Effluent Ponds (North Area) or used as process water in the refinery operations in the past. All runoff now is collected and allowed to evaporate within the ponds. If the runoff exceeds the pond's capacity, the water is pumped to the Excess Service Water Effluent Ponds (A.T. Kearney, 1986).

The facility is partially located in the 100-year flood plain. Figure 3 depicts the 50 and 100-year flood potential. As may be seen from Figure 3, the North Area waste management units all lie outside the 100-year flood plain. Approximately one-third of the South Area lies within the 100-year flood plain.

The climate of Casper, located approximately three miles west of the facility, is temperate and dry. The average temperatures range from a maximum of 83°F in the summer months to a minimum of 16°F in the winter months. Mean monthly temperatures exceed freezing in all months except December through March. The average date of the last freezing temperature is May 22 and of the first freezing temperature is September 22 (A.T. Kearney, 1986).

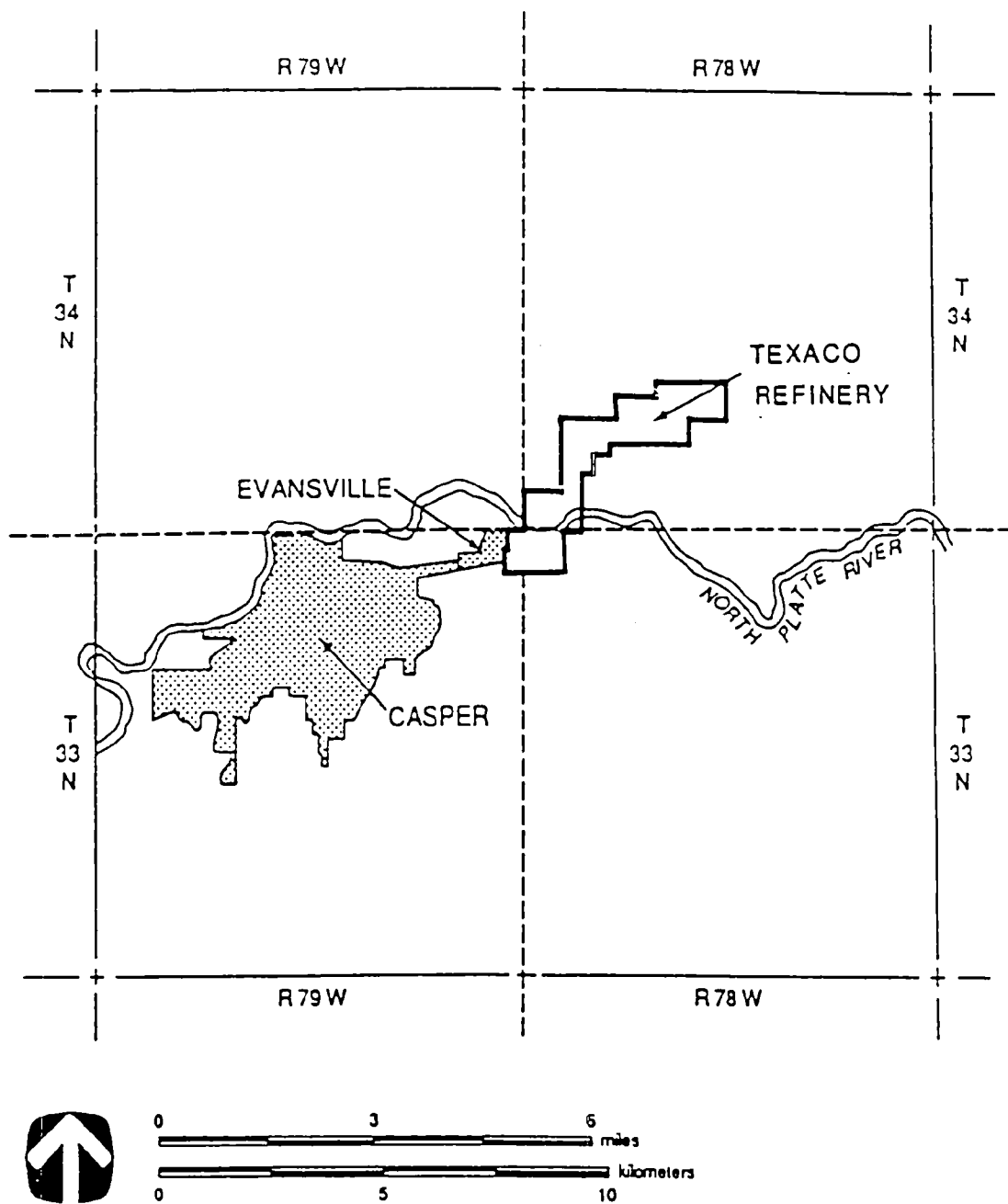


Figure 1 Facility Location Map

Source: Modified from WWC, 1982a

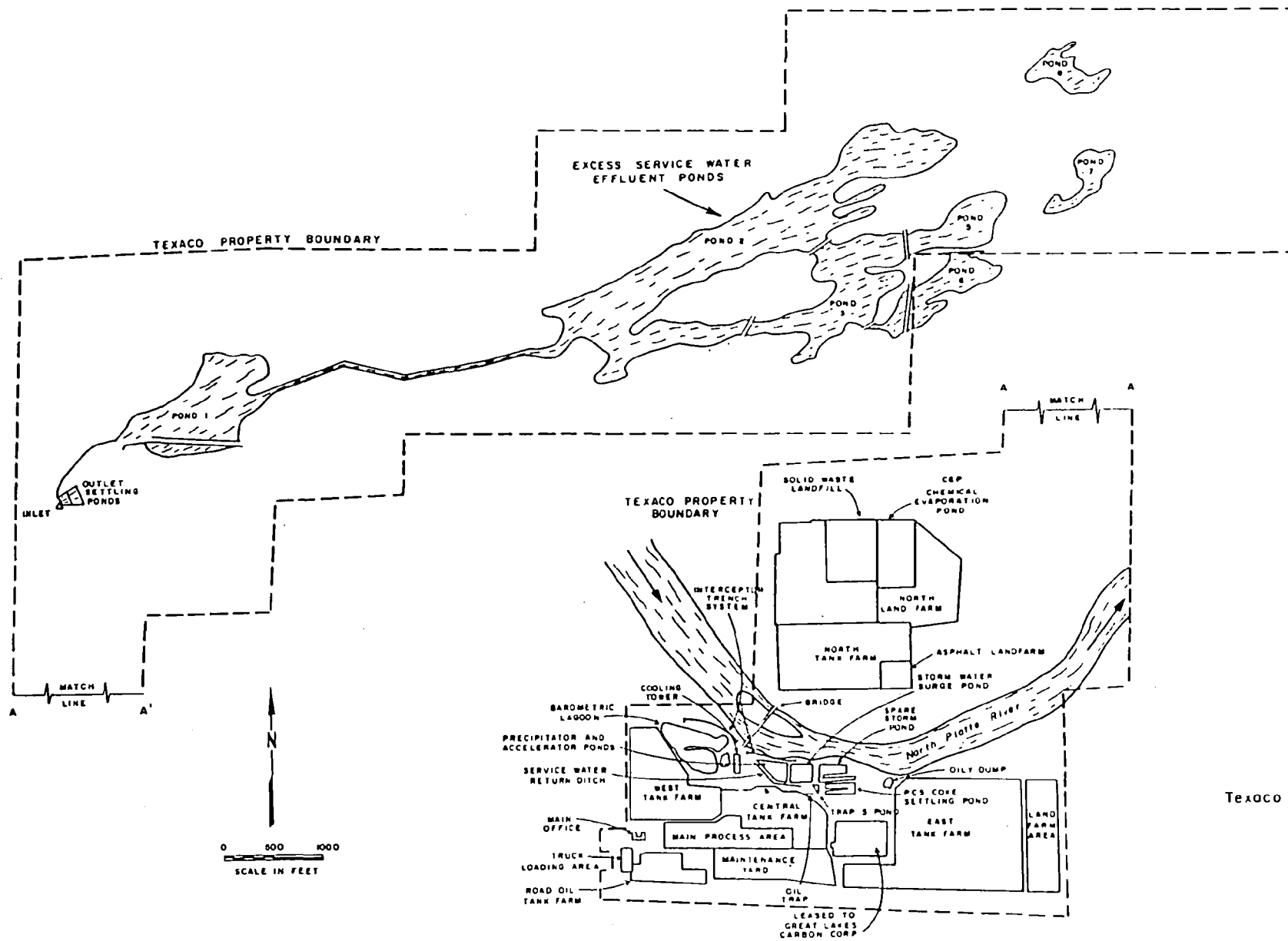
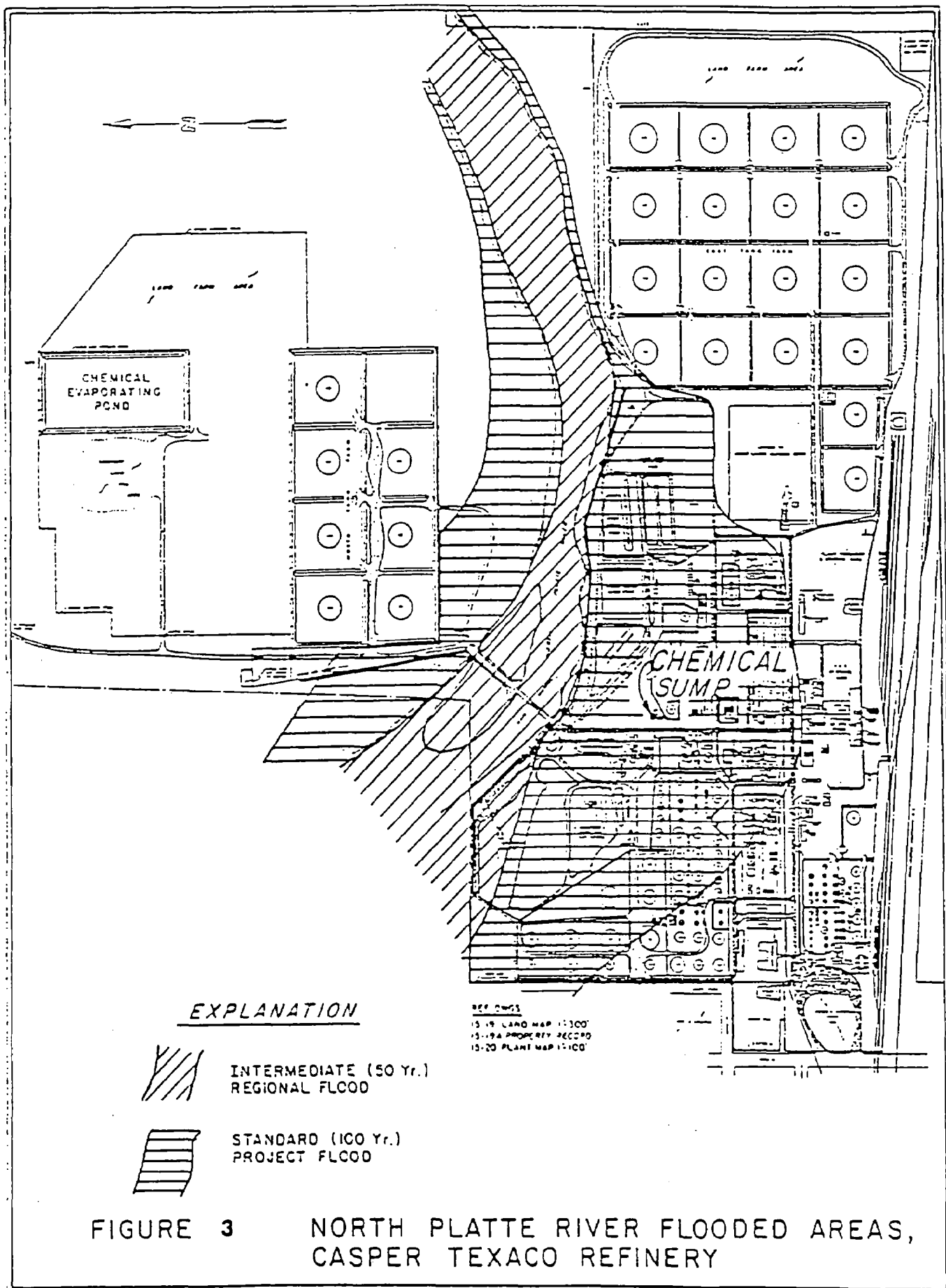


FIGURE 2
Facility Map
Texaco Refinery, Casper, Wyoming

Source: Modified from Western Water Consultants, 1987.



Source: Texaco, 1983

Precipitation averages 11.4 inches per year with approximately half of the total occurring as rain and wet snow during the spring. Precipitation occurs principally in low-intensity small events. Evaporation in Casper averages 46 inches per year. The average evaporation rate exceeds the average precipitation rate in all months of the year (A.T. Kearney, 1986).

The wind rose for the Casper area shows that winds are moderately strong and predominantly southwesterly during all months of the year. The mean wind speed is 13.3 miles per hour with stronger winds occurring during the winter months (A.T. Kearney, 1986).

Adjacent land use information is minimal. The property bordering Texaco's North Area is privately owned, except for a small parcel of state-owned land in Section 36 near the North Platte River. The private land is used for grazing of horses.

The land contiguous with the South Area is more varied. To the west lies the town of Evansville. South of the refinery lies Burlington Northern Railroad, various industrial properties, a frontage road and U.S. Highways #20, 26 and 87. Immediately east of the facility is Sinclair Oil Corporation's Little America Refinery (Texaco, 1985).

2. Regulatory Background

On November 14, 1980, Texaco submitted a Part A Permit Application and identified itself as a generator, treater and disposer of hazardous waste. Revised Part A applications were submitted on the following dates: March 2, 1982, August 2, 1982 and June 16, 1983. Table 1 lists the regulated hazardous waste codes and descriptions, the estimated annual quantity of waste, and the associated treatment, storage or disposal units as taken from the June 16, 1983 Part A Application.

On June 13, 1983 Texaco submitted a RCRA Closure Plan for the CEP. EPA disapproved this closure plan and Texaco submitted a revised plan on October 5, 1984. EPA modified and approved this closure plan and a public notice was held regarding the plan in March 1985. During June 1985, Texaco entered a lawsuit against EPA in the U.S. Court of Appeals, 10th Circuit, challenging EPA modifications to the closure plan and also requesting a stay of the modified plan. The court granted Texaco's request for a stay. During August 1986, Texaco and EPA entered into a consent agreement concerning the CEP closure plan. On September 26, 1986 Texaco notified EPA pursuant to 40 CFR section 265.115 that the CEP had been closed according to the approved closure plan and that closure occurred pursuant to 40 CFR 265.228(b), clean closure.

On November 5, 1985, Texaco submitted a Part B Permit Application for the North Land Farm. This was revised in July 1986. On May 6, 1987, EPA issued a Land Treatment Demonstration Permit pursuant to the requirements of 40 CFR section 264.272. On June 15, 1987, Texaco submitted a reconnaissance report of the North Land Farm identifying 11 hazardous constituents in the soil. A letter dated December 1, 1987 was submitted to EPA stating that six hazardous constituents were detected below the treatment zone (vadose zone) of the North Land Farm. Although this information was presented after the Task Force investigation, it is relevant to the proposed 40 CFR 264 Subpart F ground-water monitoring system discussion later in this report.

Table 1

Summary of Wastes Handled by Texaco

<u>Waste Code</u>	<u>Waste Description</u>	<u>Estimated Annual Quantity of Waste</u>	<u>Waste Management Unit</u>
K049	Slop oil emulsion solids	2583 T	Tank storage, land application
K050	Heat exchanger bundle cleaning sludges	5 T	Land application
K051	API Separator sludge	2 T	Land application
K052	Leaded tank bottoms	1542 T	Tank storage, land application
D001	Ignitable wastes	7741 T	Tank storage, land application
D002	Corrosive wastes	575 T	Surface impoundment
D003	Reactive wastes	870 T	Tank storage, land application
D008	EP toxic wastes - lead	1358 T	Tank storage, land application

Source: Texaco Part A Permit Application, June 16, 1983

3. Facility Operations

The Texaco facility generates, treats, stores and disposes of hazardous waste during normal operations. Since its closure in 1982, the majority of the waste applied to the North Land Farm has been wastes generated at the refinery during cleanup operations.

Twenty-one solid waste management units (SWMUs) have been identified at the Texaco facility. Two of these, the CEP and the North Land Farm, are considered HWMUs, and are RCRA-regulated. A brief description of the SWMUs follows, as most of these units have a potential to contribute to the degraded ground water at the facility. The information on the SWMUs is taken from the A.T. Kearney RCRA Facility Assessment Report dated October 1986 (A.T. Kearney, 1986). During the Task Force investigation, it was confirmed that all of the SWMUs at the site met the regulatory definition of a SWMU. In the past, Texaco maintained that several SWMUs were process units and did not meet the definition. The locations of all SWMUs and HWMUs are presented on Figure 2.

4. RCRA-Regulated Units

North Land Farm This unit is located in the North Area as shown on Figure 2. The North Land Farm consists of 13.5 acres on a bluff, adjacent to the CEP. The North Land Farm received refinery wastes until plant shutdown in 1982. Landfarming continues at present with wastes generated from both tank and pond closure activities. Both listed wastes and non-listed wastes are land farmed. The listed hazardous wastes as identified in 40 CFR 261 Subparts C and D include:

- Slop oil emulsion solids (K049)
- Heat exchanger bundle cleaning sludge (K050)
- API separator sludge (K051)
- Leaded tank bottoms (K052)
- Possibly ignitable wastes (D001)
- Possibly reactive wastes (D003)
- Possibly EP-toxic wastes (D008)

CEP This unit is also located in the North Area, contiguous to the North Land Farm (Figure 2). The 6.6-acre surface impoundment had a maximum operating capacity of 16,000,000 gallons. The depth of the unit was nine feet. The pond was built on the site of an old tank farm and occupies the area within two of the abandoned tank levees. Four levee raisings were done to provide additional storage capacity. These raisings added approximately four feet to the original levee.

The pond received wastewater from the plant which was pumped intermittently through a four-inch pressurized pipeline. Flow into the pond averaged 42 gallons per minute.

None of the waste streams which contributed to the CEP were classed as RCRA hazardous wastes based on being listed or characteristic wastes. However, the waste streams did contain a number of hazardous constituents found in Appendix VIII. Organic analyses of the pond wastewaters and sludge were performed in 1982 and 1983. In these analyses, nine organic constituents from Appendix VIII were found as follows:

Chemical Evaporation Pond Wastewater Analysis
1982/1983

Toluene
2,4-dimethylphenol
Phenol
Naphthalene
Diphenylamine
Benzenethiol

Chemical Evaporation Pond Sludge Analysis
1982/1983

Toluene
2,4-dimethylphenol
Phenol
Naphthalene
Chrysene
Benz(a)anthracene
Benzo(a)pyrene

5. Solid Waste Management Units

Asphalt Landfill This landfill is located within the North Tank Farm (Figure 2). The area of the landfill is unknown; however, visually, the area affected appears to be approximately 150 feet wide by 300 feet long. The waste management technique was apparently to back trucks to the edge of the bank and dump loads down the slope.

There was only one waste stream reported for this landfill, that being loads of off-specification asphalt. Asphalt was dumped from the top of the slope and flowed/moved downslope. The more liquid portion, present within the waste or generated by radiant heating of the asphalt, flowed downslope and collected in a "pool." This "pool" is approximately 30 feet by 50 feet and of unknown depth. The entire downslope is covered with asphalt in varying stages of decomposition.

Solid Waste Landfill This unit is often referred to as the North Landfill. According to Texaco, it occupies 3.2 acres west of the CEP (Figure 2). About 2.5 acres have an incorporation depth of four feet, and the remaining 0.7 acre has an incorporation depth of about 12 feet.

There are three topographic "benches" which should be included (instead of only the uppermost). The lower "benches" appear to have been used for the random disposal of asphalt and coke.

Approximately 24 tons of solid wastes were placed in the landfill each year from 1957 until shutdown of the refinery in mid-1982. The reported waste stream included:

Scrap lumber
Lime pit sludge
Oily wipers
Office waste paper

Limited amounts of scrap metal

As indicated earlier, large areas both in and adjacent to the landfill have been used for the disposal of asphalt, coke and in at least one area, empty drums. Dumped loads of asphalt, coke and pooled tar-like material were observed randomly across the surface.

Excess Service Water Effluent Ponds This unit is comprised of eight separate ponds located approximately 4,500 feet north of the North Platte River (Figure 2). Water is pumped from the refinery into the first three ponds, which operate in series. The water from these ponds discharges into pond 4, which is connected to four subsequent ponds via a ditch. The total area covered by the ponds is approximately 160 acres with an average water depth of four feet and an estimated volume of 200,000,000 gallons. All the ponds are unlined and non-discharging to other surface water bodies (the ponds are approximately 110 feet above the North Platte River). Water levels are managed through evaporation. Presently, and since refinery shutdown, the ponds are essentially not being used since the plant requires no cooling water. The water levels are now quite depressed with alkali flats developing around the perimeter of the various ponds.

The Excess Service Water Effluent Ponds received overflow from the service water system of the refinery. The following six wastewater streams discharged to the service water system and hence to the Excess Service Water Effluent Ponds:

- Process unit drainage system
- PCS coke drum blowdown system
- VPS barometric condensate system
- Water treating plant blowdown system
- Storm water system
- Interceptor system

The water from these systems was temporarily stored on the south refinery property and then pumped to the ponds through a 12-inch pipeline. All water initially entered three small ponds (the pretreatment ponds) which are connected in series. In these ponds, any oil present in the water collects at the surface. When sufficient quantities are collected, the ponds are skimmed using a vacuum truck. Water from the pretreatment ponds enters the remaining ponds (also in series) as the flow from the refinery dictates.

Flow into these ponds has been limited to water produced from the underground hydrocarbon recovery system since the refinery shutdown in 1982.

Wastewaters were analyzed for organic priority pollutants during refinery operations. At that time, three hazardous constituents were identified. These were:

- Endosulfan
- 1,1,1-trichloroethane
- Chrysene

Subsequent pond water analyses were performed that indicated there were no organic priority pollutants present in the retained water.

East Land Farm The East Land Farm is located near the eastern boundary of the plant's South Area as shown on Figure 2. Only an access road separates this unit from Little America's refinery property limits. The Land Farm occupies an area of approximately nine acres.

The Land Farm is reported to have received tank bottoms, oily wastes, and weathered leaded sludge. The East Land Farm primarily treated the lighter petroleum fraction wastes, with the heavier petroleum wastes going to the North Land Farm. Among the RCRA listed wastes which were applied to the Land Farm (disposal was prior to RCRA regulations) are:

- Slop emulsion solids (K049)
- Heat exchanger bundle cleaning sludge (K050)
- API separator sludge (K051)
- Leaded tank bottoms (K052)

Also included in the waste stream were not otherwise specified (NOS) tank sludges.

Asphalt Landfill This area, located in the South Area, was used for the disposal of truck loads of off-specification asphalt. The area in which loads were dumped is fairly widespread; however, the entire area has not been "covered" with asphalt. Tar-like liquids either in the off-specification product, or those developed by the radiant heating of the material, flowed to low points and collected. The active area affected by waste disposal was not provided; however, visually, the area appears to be approximately 200 feet by 400 feet.

The only waste stream reported for this unit is off-specification loads of asphalt. In the early history of the unit, asphalt was burned. Generally, waste thickness averages approximately three to four inches with the pooled material areas (mentioned above) reaching three to four feet in depth.

Chemical Evaporation Pond Sump This unit consists of a concrete-lined sump, approximately 20 feet square, that was used to collect the various waste streams prior to their final disposal in the chemical evaporation pond. Minimal information regarding the construction or operational details of the unit was provided.

Details of the wastes managed in this unit were not provided. Since the unit collected all the various waste streams prior to their being pumped into the chemical evaporation pond, it can be inferred that the wastes reported for the pond are essentially the same as the sump. These waste streams include wastewaters from the following:

- Hydro Treater Unit (HTU)
- Catalytic Polymerization Unit (Poly)
- Fluid Catalytic Cracking Unit (FCCU)
- Pressure Coke Stills (PCS)
- Catalytic Reforming Unit (CRU)
- Stabilizers

In addition, the unit apparently received oily wastes, based on the fact that the sump is equipped with a skimming type oil removal system.

Landfill/Burning Ground This unit was located in the South Area. Relatively little information exists regarding this unit as it has not been used for approximately 30 years.

The waste stream to this landfill is reported to have contained:

- Drums, bricks
- Scrap lumber
- Oily wipers
- Office waste paper
- Scrap metal

Plant Trap The Plant Trap (oil trap) is located south of the Trap S. Pond and the Service Water Return Ditch as shown on Figure 2. This unit is an early model API Separator designed to remove oil from the incoming wastewaters. The trap has a number of cells from which oil was skimmed. Construction of the unit is of concrete which extends approximately one foot above ground surface and six to seven feet below ground surface.

This unit was operated to remove oil from the water produced in process area washdown. The recovered oil was pumped to nearby tanks for storage (tank area is bermed). The stored oil was eventually returned to the process inflow.

Service Water Return Ditch/Trap S. Pond This unit includes the Trap S. Pond and the Service Water Return Ditch as shown on Figure 2. The ditch appears to be approximately 10 feet in width and four feet deep. Both units are unlined.

Water enters this system from the refinery into the Plant Trap which separates the oil from the water. Discharge from the trap goes into the Trap S. Pond. From the pond, water enters the Service Water Return Ditch which flows northwestward to the pump. Water from the system is either returned to the process areas for reuse or is pumped across the river to the Excess Service Water Effluent Ponds where it is allowed to evaporate.

There are six refinery water and wastewater systems discharged to the service water system during refinery operations. These waste streams are:

- Process unit drainage system
- PCS coke drum blowdown system
- VPS barometric condensate system
- Water treating plant blowdown system
- Storm water system
- Interceptor system (currently uses Service Water Return Ditch)

Storm Water Surge Pond and Spare Storm Pond This unit is comprised of two interconnected ponds which retain the same wastewaters. The units are located on Texaco's South Area along the North Platte River as shown on Figure 2. The units are unlined and below grade.

Texaco has indicated that only runoff from the non-process areas of the refinery flow into this unit and therefore, there are no hazardous constituents present. Texaco did not define what they considered a "non-process" area.

Indications that the Plant S. Trap Pond (and possibly others known or strongly suspected of containing hazardous constituents) can flow into the storm water surge pond (and by connection to the spare storm pond) through overflow pipes located near the top edge of the pond.

In addition, it is suspected (based upon the information provided) that these ponds, as well as the PCS pond, the precipitator and accelerator ponds and the Trap S. Pond, are in connection with one another via the ground water.

PCS Coke Settling Pond This surface impoundment is located east of and adjacent to the Trap S. Pond as shown on Figure 2. The pond is unlined and below grade.

The pond was apparently used for coke process cooling water make-up and blowdown. As such, coke dust accumulated in the water which settled out into the pond.

Presently, the pond receives waste water from the ground-water recovery well (RW-1) located approximately 300 feet east northeast of the pond. In the recovery well, a skimmer pump suctions the oil off the ground water. A lower submersible pump is used to constantly pump ground water to create an artificial gradient towards the well. The ground water itself is very oily and the pond has a scum of floating oil on it as a result. The pond area has a very heavy hydrocarbon odor.

Precipitator and Accelerator Ponds This unit is comprised of two ponds which receive the identical waste stream. The eastern pond is located as shown on Figure 2. The western pond is not shown on the figure, but is located directly north of the precipitator and west of the eastern pond and the cooling tower. The capacities and design information for these ponds was not provided.

The two ponds received clarifier solids and blowdown from the water treatment plant. The purpose of the ponds was to allow the lime sludge to settle out of the water. Water from the ponds was directed to the service water system after the solids were removed. Periodically, solids were dredged from the pond and disposed either in the North Land Farm or placed on the levees of Excess Service Water Effluent Pond #1.

Texaco states "No known hazardous wastes or hazardous constituents were managed at the precipitator and accelator ponds (A.T. Kearney, 1986)."

Barometric Separator This unit is constructed of concrete and is completely below ground. The depth of the structure was not provided although it was stated to be similar in construction to the plant oil trap previously described. The unit is located immediately north of the West Tank Farm (Figure 2).

The separator is essentially an early model API Separator. Oily wastewaters originating in the Vacuum Tower Still are processed in this unit to remove the oil. The oil is skimmed/suctioned off the water in a series of individual compartments. The recovered oil is pumped to tankage and eventually returned to the process stream. Sludges are periodically removed from the unit and stored in tanks as a listed hazardous waste (K049 and K052).

Barometric Skimming Pond This unit consists of a single unlined pond which is approximately 1200 feet long by 50 feet wide. The pond is located between the precipitator and the barometric oil trap. No other details of the construction of the pond were provided.

This unit receives the outflow from the barometric separator. The separator removes a quantity of oil although some remains in the water and is present in this pond. The pond drains by gravity to the barometric ponds through an oil skimming device. The oil collected by this equipment was eventually returned to the process stream.

Barometric Ponds and Spray Field (referred to as barometric lagoon on Figure 2). This unit is comprised of two large ponds which are interconnected through a narrow neck. Details of the ponds' construction were not provided.

These ponds are located on the northwest portion of the South Area as shown on Figure 2. The southernmost portion of the pond is equipped with three spray lines. The spray lines were used to cool the water during warm weather.

These ponds received the wastewater from the Vacuum Tower Still after the oil had been removed in both the barometric separator and the barometric skimming pond. Water was occasionally pumped through the spray lines as the process and ambient heat loads dictated. Water from these ponds eventually discharges to the service water system where it is either returned to the process for reuse or pumped for final disposition into the Excess Service Water Effluent Ponds in the North Area.

Leaded Sludge Disposal Areas Texaco has identified four areas in which leaded sludge was disposed within tank farm containment areas. Since all these areas are similar, they have been grouped together. These areas are located within the east and west tank farms on the south property (Figure 2).

The four areas included in this description are immediately adjacent to Tanks #142, #147, #157 (west tank farm), and #307 (east tank farm). It should be noted that tank bottom disposal may have occurred near any of the storage tanks but these are the only ones which have been identified as containing leaded tank bottoms.

The waste managed in these areas consisted of leaded tank bottoms which are now a listed RCRA hazardous waste (K052). Management practice consisted of digging a pit adjacent to the tank door sheet or manway, opening the access, dumping the collected sludge into the pit, and finally covering the pit.

Unknown N.O.S. Tank Bottom Disposal Areas Disposal practices similar to those used for the leaded tank bottoms may have been employed at practically any other tanks which were cleaned prior to about 1970. The general locations of the tank farms which may have been affected are shown on Figure 2 as the east, central and west tank farms on the southern property.

The wastes which would have been placed in these pits include any non-leaded tank bottom sludges (N.O.S. [not otherwise specified] tank bottoms).

Tankage These are 38 tanks at the Texaco facility which contain stored hazardous waste. The wastes are classified as hazardous based upon being either listed or characteristic wastes.

The tankage is divided into three groups based on the waste type stored. The first group of five tanks store leaded tank bottoms which is a listed hazardous waste (K052). Six tanks store slop oil emulsion solids which are also a listed hazardous waste (K049). The remaining 27 tanks store residual wastes generated from crude oil or products. These tanks are included since the wastes may be characteristic wastes based on ignitability, reactivity, or possible EP-toxicity. Each group is discussed in more detail below.

Leaded Tank Bottoms - These five tanks have been taken out of service and all recoverable material has been removed. There are currently 8,810 barrels of water and wastes in the tanks which corresponds to approximately 1,500 tons.

Slop Oil Emulsion Solids - These six tanks currently contain 4,067 barrels of water and waste, which corresponds to approximately 700 tons.

Not Otherwise Specified (N.O.S.) Tank Bottoms - These tanks are included in the Part A Application and the closure plan since the waste contained in the tanks may exhibit one or more of the characteristics of a hazardous waste. Texaco intends to perform, or has performed, testing of the wastes to determine the need for continued management as hazardous.

Recovery Yard/Junk Yard This area is adjacent to and behind the maintenance facilities. Only a small portion of the area is used as a junk yard which is located directly behind the shop.

This area is used as a salvage yard for pipes, metal wastes and other equipment. Here, valves are taken off pipes for reuse, wire is salvaged for the copper, parts are saved from scrapped machinery, etc. The salvaged parts are stored in various areas according to their type. Waste material is sent to the junk yard. Periodically, a local scrap hauler is called to the plant to remove the recyclable material. Anything remaining is landfilled.

Oily Dump (South Area) According to Texaco (WWC, 1982c), the source of a floating hydrocarbon phase in the groundwater adjacent to the North Platte River is a result of an oily dump. This dump (Figure 2) reportedly was used to lay sample oil and waste oil barrels over the edge to drain them. Texaco refers to this area as the refinery dump and shows it as being active in 1973 (WWC, 1982c). No further details were included.

Interceptor Trench System/Recharge Groundwater Recovery System Technically the Interceptor Trench System and the recharge wells installed as part of a hydrocarbon recovery system in the South Area meet the definition of a SWMU. The trench system (two trenches) contains two perforated culverts which intersect the water table and recover floating hydrocarbons. These trenches are drained to a sump which pumps the oil water phase to a separator and excess wastewater is pumped to the service water return ditch which is also considered a SWMU.

The recharge wells and surface water bodies used to recharge the aquifer with wastewater pumped from the recovery wells all meet the definition of a SWMU. This waste water pumped from the water table depressant pump (i.e. not the oil recovery pump) probably contains dissolved concentrations of organics such as benzene, toluene and total xylenes. In addition to recharge wells, the wastewater is also pumped to the PCS coke settling basin for recharge, thus this unit as previously mentioned meets the definition of a SWMU.

Both the interceptor trenches, service water ditch and the PCS coke settling basin are presented on Figure 2 while the recharge wells are discussed in detail in the hydrocarbon recovery system South Area discussion.

C. HYDROGEOLOGY

1. Regional Geologic Setting

The study area is located on the southwestern flank of the Powder River Basin, a structural and topographic basin. Approximately 17,000 feet of sedimentary rocks fill the basin. Several of these sedimentary rock units, of Late Cretaceous age, outcrop in the area of the refinery. Here, along the outcrop belt, the units are erosionally truncated at the surface. In the vicinity of the refinery, the rocks have a structural strike of about north 35 degrees west, and a dip to the northeast of 5 degrees to 8 degrees (WWC, 1981).

The sedimentary rocks in this portion of the basin were deposited in marine, marginal marine, and continental depositional settings during the last stages of the interior seaway. Thick marine shales, nearshore sandstones and interbedded sandstones, coals, and shales were deposited. The eroded edge of these lithified rocks is unconformably overlain by unconsolidated sediments of Quaternary age. These consist of eolian deposits of fine sand and silt, and alluvial sand and gravel deposited by the North Platte River at various stages of its history.

2. Regional Hydrologic Setting

The hydrology of the southwestern Powder River Basin is influenced by several factors. Climate, surface water hydrology and geology all influence the occurrence and nature of ground water.

Mean annual precipitation at Casper is 11.80 inches (Hodson, et al, 1973). Evaporation is very high, up to several times the precipitation.

Surface water hydrology consists of perennial and ephemeral streams and is dominated by the North Platte River drainage.

Mean annual discharge of the North Platte is given at 1,194 cfs (Crist and Lowry, 1972) for the river below Alcova Dam during the years 1933 to 1966. During the years 1929 through 1959, the mean annual discharge below Casper (and near the site) is given as 1,321 cfs (Hodson, et al, 1973).

There are several geologic influences on the availability, quality, recharge, and flow components of the ground-water system. The unconsolidated, recent alluvium along the present course of the North Platte is directly influenced by the river stage. Recharge and discharge to the alluvial aquifer are directly tied to the surface water hydrology.

The bedrock hydrologic system in this area is more complex. Partial recharge is provided by infiltration of precipitation over permeable units. Due to the large evaporation rate, the recharge from precipitation is probably only significant during storms with enough rainfall to infiltrate below the depth of soil moisture evaporation. Recharge from the North Platte River and other streams occurs where the surface water crosses outcrops permeable enough for infiltration (Hodson, et al, 1973). Movement of water between formations also occurs, but is poorly documented in published literature.

Discharge is primarily from evaporation, seepage to springs, lakes, and streams, plant transpiration and well pumpage (Hodson, et al, 1973). Regional flow components are poorly documented and mapped in the published literature.

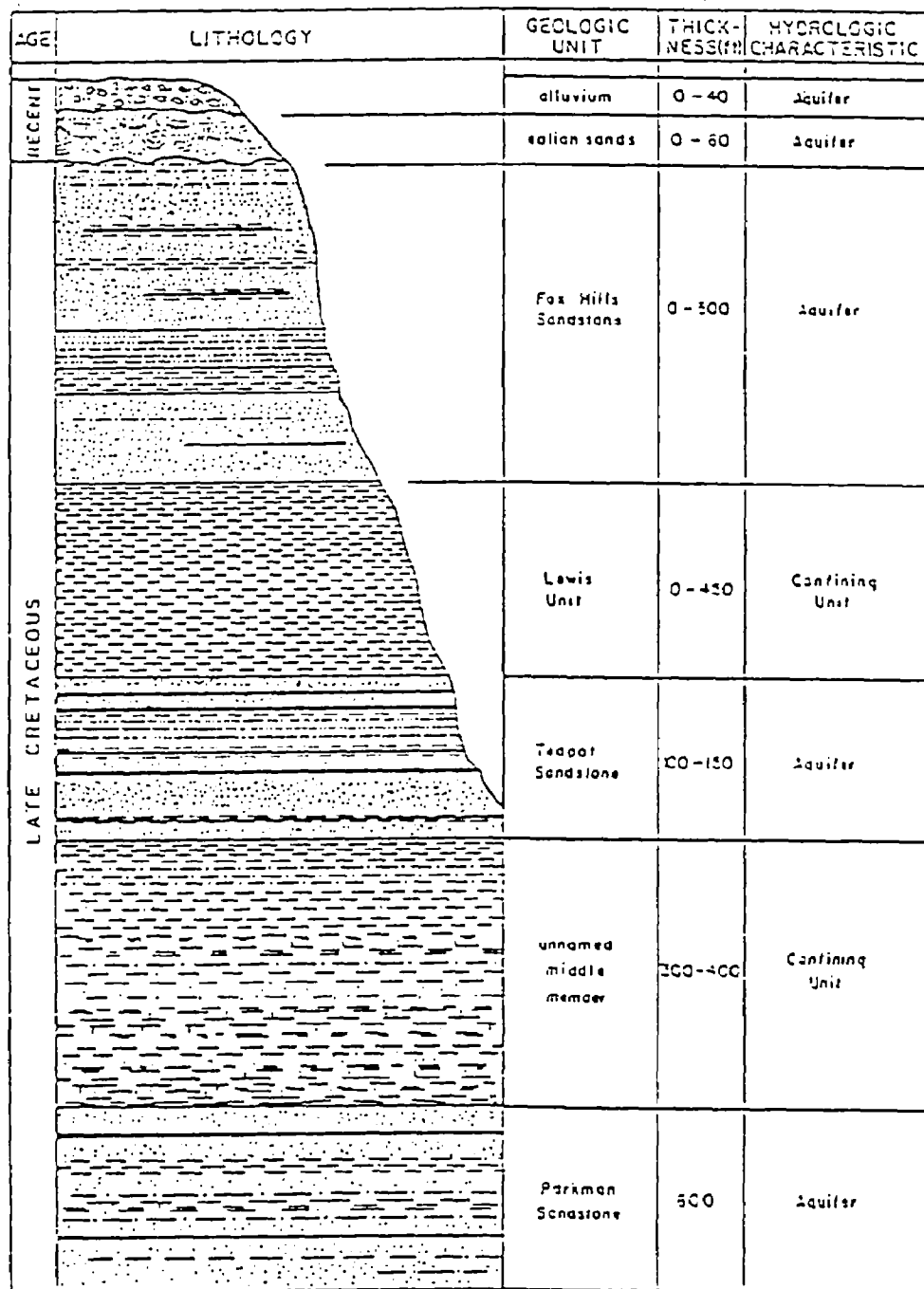
Water quality is generally good for the surface water and alluvial aquifers. Eolian and bedrock aquifers produce water of lesser quality due to soluble salts in the Mesozoic aged rocks, principally the shales and coal beds. Waters found in Cretaceous rocks of the Mesaverde Formation are dilute waters of calcium or sodium bicarbonate type (less than 600 mg/l TDS) or sodium sulfate waters with TDS concentrations of 1,360 to 3,980 mg/l (Feathers, et al, 1981). Recharge by fresh surface water and precipitation probably further dilutes these concentrations near the outcrops of these aquifers.

3. Site Geology and Hydrogeology

The Casper Texaco Refinery area is underlain by Late Cretaceous sedimentary rocks as previously stated. Stratigraphic units present in the site area are shown in Figures 4 and 5. The stratigraphic nomenclature is from the work of Wiloth (1961), and Crist and Lowry (1972). Geologic units of interest in the site vicinity, in ascending stratigraphic order, are the Mesaverde Formation, Lewis Shale, Fox Hills Sandstone, Quaternary eolian sand, and the Quaternary alluvium.

The Late Cretaceous Mesaverde Formation is approximately 1,000 to 1,150 feet thick in the area of the Texaco Refinery. Here, the unit has an outcrop width of nearly two miles due to its gentle dip toward the center of the basin. The members of the Mesaverde are the bedrock units underlying all of the facility, both north and south of the North Platte River (Figure 6). The Mesaverde Formation is divided into three members in this area. These members in ascending stratigraphic order are the Parkman Sandstone Member, the unnamed middle member, and the Teapot Sandstone Member. The geologic and hydrogeologic properties of these units are as follows:

Parkman Sandstone Member - The Parkman is the basal member of the Mesaverde Formation in this area. The Parkman is composed of fine to very fine grained, micaceous, glauconitic, and calcareous sandstones (Purcell, 1961) with interbedded carbonaceous shale and coal (Headley, 1958). The sand grains are angular and moderately well sorted. Bedding is discontinuous with lensing and lateral pinch out of individual beds common. Bedding ranges from thin to massive. Net thickness of porous sandstone units is up to 250 feet in Natrona County (Headley, 1958) or about 50 percent of the unit's total thickness. Total thickness of the member is given as 470 feet (Hodson, et al, 1973), 500 feet (Crist and Lowry, 1972), and 600 feet (WWC, 1981).



EXPLANATION

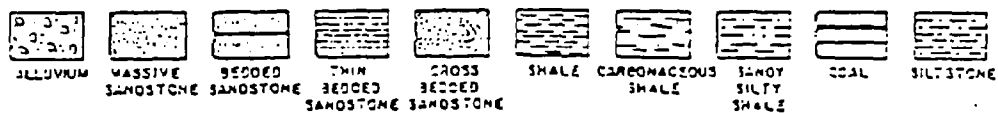


FIGURE 4 AGES, LITHOLOGIES, THICKNESSES, AND HYDROLOGIC CHARACTERISTICS FOR THE SEDIMENTARY ROCKS IN THE CASPER TEXACO REFINERY AREA

modified from; Western Water Consultants, Inc. 1981

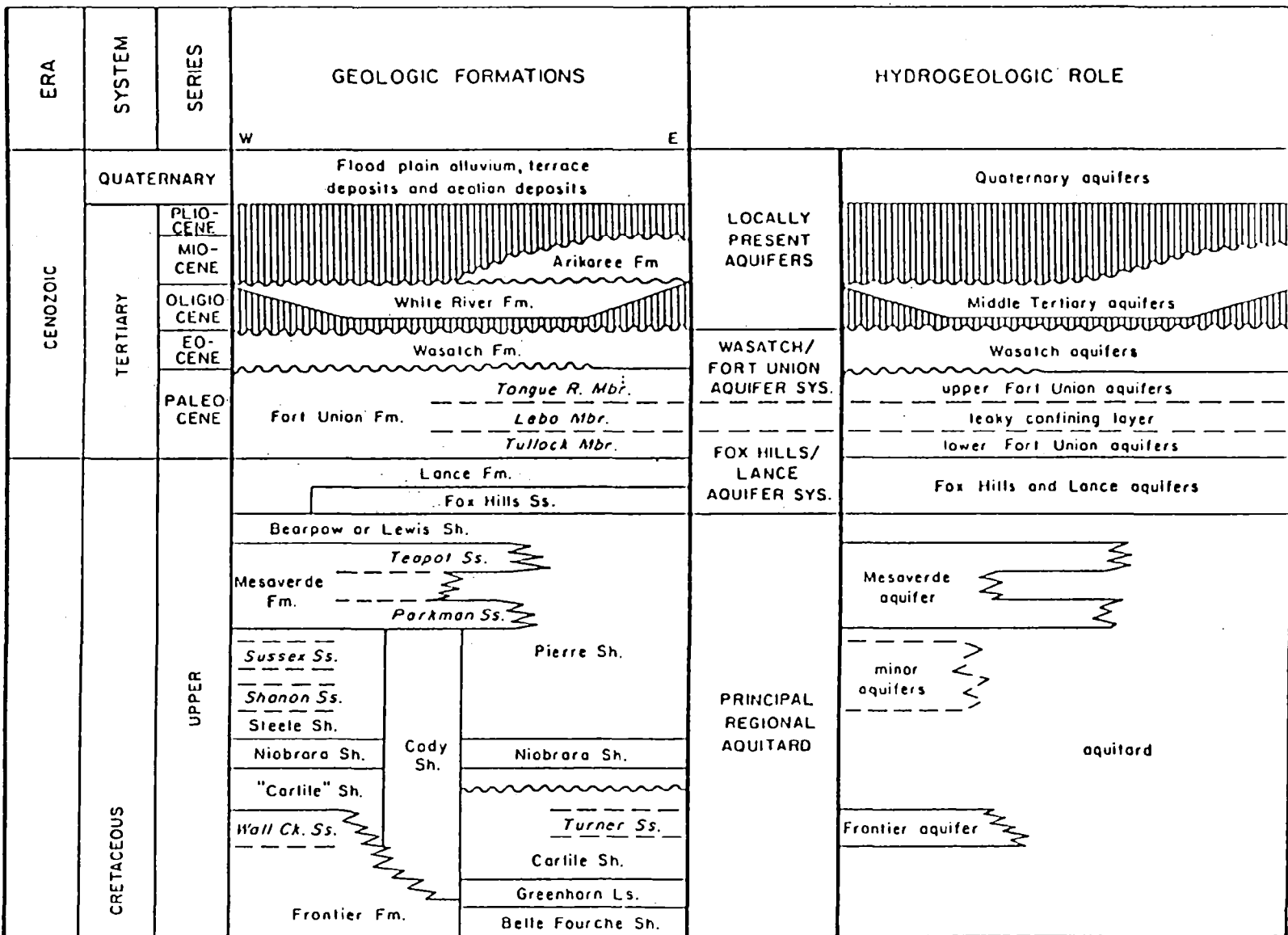


Figure 5 Diagrammatic hydrostratigraphy of the Powder River basin.
modified from: Feathers, et al, 1981

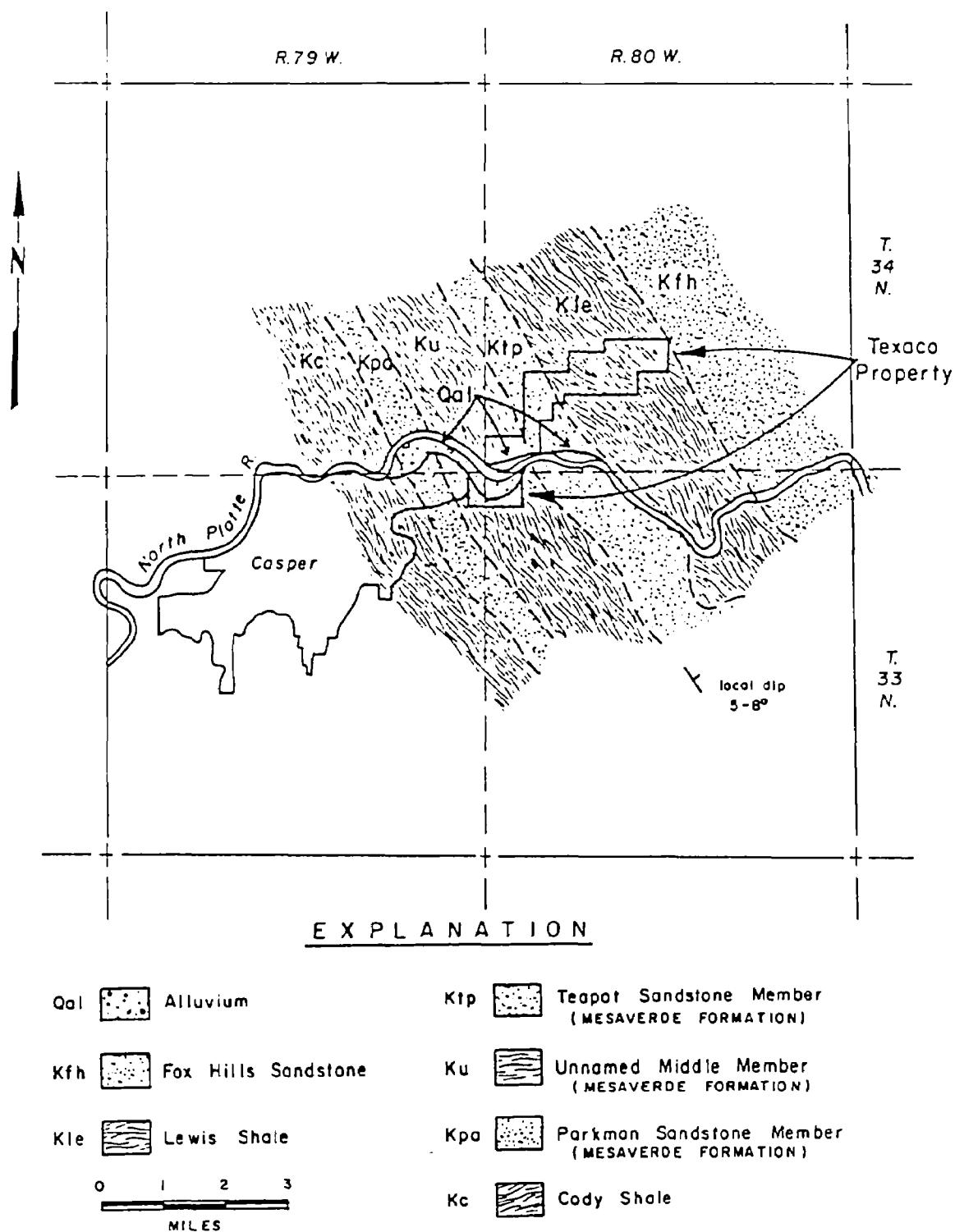


Figure 6
Generalized Geologic Map
Casper Texaco Refinery Area
(After Crist and Lowry, 1972)
(Modified from Western Water Consultants, 1982)

The Parkman functions as a confined aquifer in the subsurface to the east of the outcrop belt. In this area, it is underlain by the Cody Shale and overlain by the unnamed middle member of the Mesaverde Formation, both shaly, low permeability units. Published values (Feathers, et al, 1981) give a porosity of 15 to 21 percent, a hydraulic conductivity of less than 5 gpd/ft², and a calculated transmissivity of 120 gpd/ft. Expected well yields are 10 to 20 gpm, although one well north of Casper had a reported yield of 100 gpm (Crist and Lowry, 1972).

The Parkman Sandstone aquifer is in probable hydraulic isolation from the potential sources of contaminants at the Texaco Refinery. This is due to the overlying unnamed middle member of the Mesaverde Formation which is approximately 350 to 400 feet thick and considered a confining unit. The outcrop/recharge area of the Parkman is upgradient and up dip from the Texaco facility.

Unnamed Middle Member - The unnamed middle member of the Mesaverde Formation is composed of interbedded carbonaceous shale, thin to massive siltstone, sandy shale, bentonitic shale, thinly bedded low rank coals, and lenticular beds of fine grained dirty sandstone. Documentation is poor, but it appears the shaly lithologies comprise 60 to 80 percent of the unit. Net thickness of permeable sandstones and siltstones is unknown. Hydraulic conductivities of sandstone and siltstone beds are comparable to the "uppermost aquifer" (WWC, 1983a); however, the probable depositional environment would indicate the likelihood of these permeable units being lenticular and laterally discontinuous. The total thickness of the middle member could be considered as saturated below the water table, however the low hydraulic conductivity and low specific capacity, high sulfate and total dissolved solids (TDS) make the unit unfit for water supply. The literature (Hodson, et al, 1973; Crist and Lowry, 1972) describe the unnamed middle member as a regional confining unit. There are no water supply wells completed in the unnamed middle member in the refinery area.

The middle member is the bedrock unit underlying all of the regulated units on-site and the primary refinery area except for the portion of the Texaco property extending northeast of the evaporation pond on the north property (Figure 6). In the site vicinity, the unnamed middle member is approximately 350 to 400 feet in maximum thickness. The unit probably functions as an effective barrier to downward flow of possible contaminants to the Parkman Sandstone member aquifer below. Lateral migration of contaminants above low permeability beds occurring at the interface of the unnamed middle member with the overlying alluvium or eolian sands is possible, however. The possibility also exists of lateral migration of contaminants within any of the member's permeable beds lying at or below this interface or the contact with the stratigraphically overlying Teapot Sandstone aquifer. Given a basinward hydraulic potential in the Mesaverde members, down dip and down gradient transport of contaminants could occur, with resultant possibility of contaminant introduction to the Teapot Sandstone aquifer.

Teapot Sandstone Member - The Teapot Sandstone is the uppermost member of the Mesaverde Formation in this area. The member is approximately 100 to 150 feet thick based on electric logs from oil wells and logs from water wells (WWC, 1983a). The unit conformably overlies the unnamed middle member of the Mesaverde. Lithologically, the Teapot consists of fine to coarse grained sandstone with thin interbeds of lignitic coal and bentonitic shale. The sandstone is thin to medium

bedded. Sandstone beds are white to gray and friable. Interstitial cements are primarily calcareous, although argillaceous cementing material has been noted (Purcell, 1961).

The Teapot outcrops as a bluff along the North Platte River downstream from the Texaco Refinery. The Teapot subcrops the unconformably overlying eolian and old alluvial deposits north and south of the North Platte River. The subcrop belt is not well defined in the area. Projections on published geologic maps (Crist and Lowry, 1972; Hodson, et al, 1973) indicate the subcrop belt to lie within approximately one quarter mile east of the CEP and North Land Farm on the north property. Due to the strike of the Mesaverde Formation, the subcrop of the Teapot Sandstone lies about the same distance east of the easternmost tank farm in the South Area. Borings are not known to penetrate the Teapot on the south property. No borings have definitely penetrated the Teapot Sandstone on the north property; however, the boring for well M-31m encountered "interbedded gray shale and fine to coarse grained gray sandstone" at approximately 5,102 feet above mean sea level (WWC, 1982a). Geologic logs for borings in the North Area and South Area are presented in Appendices B and C, respectively.

Based on nearby borings which encountered carbonaceous shale and siltstone (M-29 and M-20, respectively, Appendix B) the contact of the Teapot Sandstone with the underlying unnamed middle member can only be vaguely defined in the subsurface. The nature of this contact is not documented in the literature, although it is probably gradational and interbedded because of the environment of deposition.

Hydrologically, the Teapot Sandstone is considered an aquifer in the western Powder River Basin (Feathers, et al, 1981; Crist and Lowry, 1972; Hodson et al, 1973). Tabulations of data from the Wyoming State Engineer's Office water well permit files (WWC, 1982d) indicate substantial use of water from the Teapot Sandstone within a two mile radius of the site. Because the outcrop/subcrop of the Teapot is east of the site, the structural dip is to the east, and most importantly, the probable potentiometric surface decreases in elevation to the northeast (northeastward flow), the Teapot water supply wells are all across or downgradient from the Texaco Refinery. These wells are primarily for domestic or livestock use.

Regionally, the aquifer is considered confined in the subsurface, with the underlying unnamed middle member of the Mesaverde and the thick, overlying Lewis Shale acting as confining units (Crist and Lowry, 1972; Hodson, et al, 1973; Feathers, et al, 1981). This is discussed in further detail under Hydrogeology of the North Area.

Thin interbeds of shale and bentonite probably act as confining layers to create "a series of semi-confined to confined subaquifers within the Teapot aquifer" (WWC, 1981). The producing aquifer is characterized as "about 50 feet thick, although the formation [sic] is 100 to 150 feet thick" (WWC, 1981). This has not been substantiated during this study. Net thickness of Teapot porosity, based on oil well data, indicates as much as 100 feet (Headley, 1958). Well yields from the Teapot are generally five to 45 gpm. Hydrologic data for local water wells completed in the Teapot aquifer are presented in Table 2.

Table 2 Hydrologic data arranged by formation for selected water wells within two miles of the Casper Texaco Refinery vicinity.^a

Well Owner	Well Name	Location ^b	Well Depth (feet)	Reported Production (GPM)	Drawdown (feet)	Saturated Thickness or Well Completion Interval (feet)	Estimated ^c Transmissivity (gpd/ft)	Specific Capacity (gpm/ft)	Estimated ^d Permeability (gpd/ft ²)	Pump Test Duration (hours)
<u>Mesaverde Formation (Teapot Sandstone Member)</u>										
Tank Service Inc.	Tank Service 1	33-70-5da	100	45	50	10	1.0×10^3	0.9	1.0×10^2	N.A.
Pittman, J.	Pittman 1	33-70-5da	130	25	3	30	1.7×10^3	0.3	5.5×10^2	36
Forsberg, L.	Pratt 2	33-70-5dc	60	10	6	10	3.4×10^4	1.7	3.3×10^2	1
Birkle, V.	Birkle 1	33-70-5bb	54	10	1	20	2×10^3	10	1×10^1	1
Hiller, R.	Hiller 1	33-70-5aa	60	15	20	25	1.5×10^3	0.8	6×10^2	.5
Hiller, R.	Clark 1	33-70-5ad	60	8	1	20	1.6×10^4	8	8×10^2	N.A.
Stoneking, J.	Little Stone 1	33-70-5ac	60	10	1	26	2×10^4	10	7.7×10^2	N.A.
Oil & Gas Processors Inc.	OGP 1	33-70-5hc	60	15	5	10	6×10^3	3	3.3×10^2	24
Volh, R.	Volh 1	33-70-5hc	60	15	45	20	6.7×10^2	0.3	3×10^1	0
Piel, A.	Brookhurst 10	33-70-5hd	60	15	1	20	3×10^4	15	1.5×10^3	2
Piel, A.	Brookhurst 16	33-70-5hd	60	15	1	20	3×10^3	15	1.5×10^2	2
Rice, J.	Eve Star 1	33-70-5ac	60	40	30	10	2.7×10^3	1.3	2.7×10^2	2
Gallion, D.	Gallion 1	33-70-5hc	60	16	12	25	2.7×10^4	1.3	1×10^2	2
Lathrop Feed Co.	Lathrop Feed	33-70-6db	55	20	1	17	4×10^2	20	2.4×10^3	.5
Halshaway, D.	Carnlyn 1	33-79-1cc	577	22.5	330	540	1.4×10^2	15	1	3
Green, I.	Green 1	33-79-2cc	54	5	44	38	2.3×10^2	0.1	6	6
Dent Hall Corp.	Sandy 47-A	34-70-27cb	700	12	23	200	1×10^3	0.5	5	1
Schott, A.	Mystery 1	34-70-33ca	775	45	1	75	9×10^2	45	1.2×10^3	600
Strand, W.	Strand 10	34-70-34aa	300	10	70	70	2.9×10^2	0.1	4	1
Smith Cattle Co.	K-13	34-79-13ca	420	5	40	20	2.5×10^2	0.1	1×10^1	1

^a Sources for data are Wyoming State Engineers Office 1981, Crist 1974, Hodson and others 1973, Crist and Lowry 1972; Dana 1962; Weltz and others 1954.

^b Township-north, range-west, section, quarter section; quarter-quarter section: U.S. Geological Survey well numbering system.

^c Transmissivity estimated using $T = 2000 Q/S$, where T = transmissivity (gal/day/ft), Q = yield (gallons/minute) and S = drawdown (feet).

^d Permeability estimated using $K = (2000 Q/S)/b$, where K = permeability (gal/day/ft²), Q = yield (gallons/minute), S = drawdown (feet), and b = saturated thickness or completion interval.

modified from; Western Water Consultants, Inc., 1981

The characterization of on-site hydrologic parameters of the Teapot Sandstone is slightly more complex than the regional characterization. The eolian and older or "paleo" alluvial deposits overlying the Teapot subcrop are similar in composition, texture, and hydrologic properties. Pumping tests conducted in the North Area "proved that the two geologic strata are in hydraulic connection and have similar permeabilities" (WWC, 1983a). Based on this interpretation, these two units have been defined as one aquifer and designated the uppermost aquifer in conformity with the definition of 40 CFR section 260.10. Five single well pumping tests conducted in 1982 indicate the uppermost aquifer has ranges of hydraulic conductivity and transmissivity of two to 1,000 gpd/ft² and 2.2×10^3 feet to 1.6×10^4 gpd/ft, respectively (WWC, 1983a).

Recharge to the Teapot Sandstone aquifer takes place along the outcrop belt, and possibly by leakage from the adjacent bedrock units. The leakage, if any, is undefined. Primary outcrop recharge is probably from precipitation directly on outcrops and infiltration from overlying unconsolidated eolian and alluvial deposits. Infiltration of water from the North Platte River where it flows across the outcrop belt is another possible primary source of recharge, although this is undefined. During this study, a preliminary assessment of potentiometric data from local water supply wells was made. These data, compiled from Wyoming State Engineer files, Crist and Lowry, 1972, and several other sources, indicate a decreasing potential toward the basin axis. This basinward gradient would create flow towards the basin center, and consequently could conceivably introduce contaminants into the Teapot aquifer.

Lewis Shale The Lewis Shale conformably overlies the Teapot Sandstone member of the Mesaverde Formation. The Lewis is primarily a gray shale to sandy shale with lenticular bodies of fine-grained sandstone. The formation interfingers with continental deposits west of the study area. Near the Texaco Refinery, the lower 300 feet of the Lewis Shale is a thick-bedded shale which grades upward into interbedded sandstone with decreasing amounts of shale. The unit is approximately 470 feet thick in this area (Crist and Lowry, 1972), however the Lewis is truncated by erosion to zero feet at its westernmost outcrop.

Hydrologically, the Lewis Shale acts as a confining layer for the underlying Teapot Sandstone. The lower shaly portion of the unit has generally low permeability, and is recognized in the literature as a regional confining aquitard (Crist and Lowry, 1972; Hodson, et al, 1973; Feathers, et al, 1981). Discontinuous saturated lenses of siltstone and sandstone yield small amounts of water (generally <10 gpm) locally. One well in this area reportedly yielded 50 gpm, however sustained yield in the Lewis Shale is probably much lower.

The unit outcrops or subcrops the unconsolidated surficial deposits about 6,000 feet northeast of the refinery proper, and underlies the Excess Service Water Effluent Ponds.

Logs for boreholes M-1 through M-6b indicate the Lewis Shale is overlain by from five to 34 feet of old alluvial deposits consisting of fine through coarse sand with some clay and fine gravel. These deposits are overlain in turn by eolian deposits one to greater than 55 feet thick, composed of silt and fine sand. Potentiometric surface maps for the area indicate a southward ground water flow direction in the deposits overlying the Lewis Shale. Three local private water supply wells located in section 28, south of the easternmost Texaco ponds, possibly indicate a lower potential surface in the Lewis Shale than in the overlying deposits. These three

wells reach total depths of 380, 460, and 480 feet below ground surface, and produce from the Lewis Shale, presumably from lenticular sandstones within the shale. The potential difference between these units indicates a probable poor hydraulic connection between permeable beds in the Lewis Shale and the overlying deposits. Borehole M-5 was drilled 40 feet into dark gray shale and abandoned as a dry hole at a total depth of 100 feet (Appendix B). These data indicate the saturated eolian and old alluvial deposits constitute a perched zone above the shale.

Data presented for potentiometric elevations in Lewis Shale wells (Crist and Lowry, 1972, Plate 1) and well records from the Wyoming State Engineer's files indicate a basinward gradient in the formation. This potentiometric surface is poorly defined due to sparse well control.

Potential for contamination of the formation is considered low. The presence of the lowest permeability beds in the stratigraphically lowest portion of the formation, which is closest to the facility, would retard migration into the permeable sandstone lenses which produce potable water from a stratigraphically higher portion of the formation.

Fox Hills Sandstone The last bedrock unit of possible concern is the Fox Hills Sandstone. The Fox Hills outcrops approximately two miles northeast of the Texaco Refinery. It is considered a regional and local aquifer (Feathers, et al., 1981).

The Fox Hills is a fine-to-medium-grained sandstone with interbedded sandy shale to carbonaceous shale, especially in the upper half of the unit. The sandstone is thin to massive bedded, poorly cemented, and friable. The sandstone is about 700 feet thick in Natrona County (Crist and Lowry, 1972).

Well yields are generally less than 20 gpm. Although the sands are porous, Fox Hills conductivity is estimated at 34 gpd/ft² (Crist and Lowry, 1972). Transmissivity values range from 100 to 2,000 gpd/ft, although there is some uncertainty in these values (Feathers, et al, 1981). The Fox Hills forms a regional scale aquifer system with the overlying Lance Formation (continental sandstones). An extensive discussion of the Fox Hills/Lance aquifer system is presented in Feathers, et al. (1981).

Potential effects on the Fox Hills aquifer from the Texaco Refinery are considered very small. The aquifer's outcrop area lies well to the northeast of the facility. Flow in the unconsolidated materials in the intervening area is generally to the south. The low permeability, thick Lewis Shale is the intervening bedrock unit and serves as an effective aquitard.

Quaternary Alluvial Deposits The alluvial aquifers in the vicinity of the Casper Texaco Refinery are composed of unconsolidated clay, silt, sand and gravel ranging up to cobble size. The sediments occur as discontinuous bars and lenses along streams, with the largest deposits along the North Platte River. The deposits underlie the floodplains and bordering terraces. Deposits along the Platte form a blanket of irregular width and thickness which conforms to the erosional surface cut by the Platte through time.

The alluvium consists of poorly to moderately sorted deposits of clay through cobble size rocks. The deposits exhibit a generally fining-upward point bar

sequence, with coarser sands and gravels near the bottom of the alluvium and fine gravels to sands in the uppermost portions of the deposits. Clay lenses and moderately sorted sand lenses occur in places.

The South Area is nearly completely underlain by recent alluvium, except for two exposed outcrops of bedrock. The outcrops are of the unnamed middle member of the Mesaverde Formation. The unnamed middle member underlies all of the alluvium in the South Area. Alluvial thickness is zero to 55 feet (Figure 7) thick.

The North Area has two separate alluvial deposits. The "lower aquifer" forms a deposit along the inside of a major bend in the North Platte River. This alluvium is about 700 feet wide at its widest point (WWC, 1983a), and occurs from nearly the east property boundary to beyond the west property boundary. The bedrock bluffs of the exposed unnamed middle member and the Teapot Sandstone member of the Mesaverde Formation bound the alluvium on the north. These bedrock units also underlie the alluvium. The deposit is bounded on the south by the North Platte River. The alluvium here is approximately zero to 15 feet thick. Composition is similar to the alluvium south of the river.

The second deposit of alluvium, in the North Area, occurs as a now elevated channel fill, deposited during an earlier river stage before erosion of the North Platte produced the elevation of the present river channel. This alluvium fills a "horseshoe" shaped depression eroded by the "paleo" North Platte. This "horseshoe" wraps around the bedrock high (erosional remnant) which underlies the land farm. The apparent axis of the channel lies just north of the CEP. The paleo channel was cut into the bedrock from approximately 5,110 feet above sea level to 5,080 feet above seal level. This is well illustrated by the bedrock surface contour map (Figure 8).

This downcut channel was filled by alluvium consisting of clay to medium gravel sized material. The sediment is moderately sorted and contains well sorted sand, silt, and clay lenses. Clay lenses are more common in this older alluvium than in the more recent alluvium, based on borehole descriptions. Grain size and possibly the composition of this deposit also differs from the more recent alluvium, probably due to changes in sediment source areas. The older alluvium ranges in thickness up to about 30 feet. The deposit is overlain by an irregular veneer of eolian sand. Previous reports have designated all these materials as "eolian" deposits. For simplicity in nomenclature, description, and hydraulic calculations, this is probably an acceptable practice. However, the hydraulic conductivity and other hydrodynamic parameters, including such properties as cation exchange capacity, may be affected differently by these older alluvial deposits than by the overlying eolian silts and sands. It should be noted that due to variable screened intervals and other factors, results of pump/bailer tests and other tests performed provide an "average" of this system and are not indicative of any possible differences between the older alluvium and the overlying eolian material.

Ground water in the South Area alluvial aquifer has a general flow direction to the north and east. The potentiometric contours are affected by the presence of the bedrock shale outcrop near the river which apparently acts as an "island" in diverting subsurface flow around it (Figure 9). The natural flow system is also affected by the Refinery's hydrocarbon recovery wells and interceptor system, which is a French drain designed to induce flow from the alluvium near the North

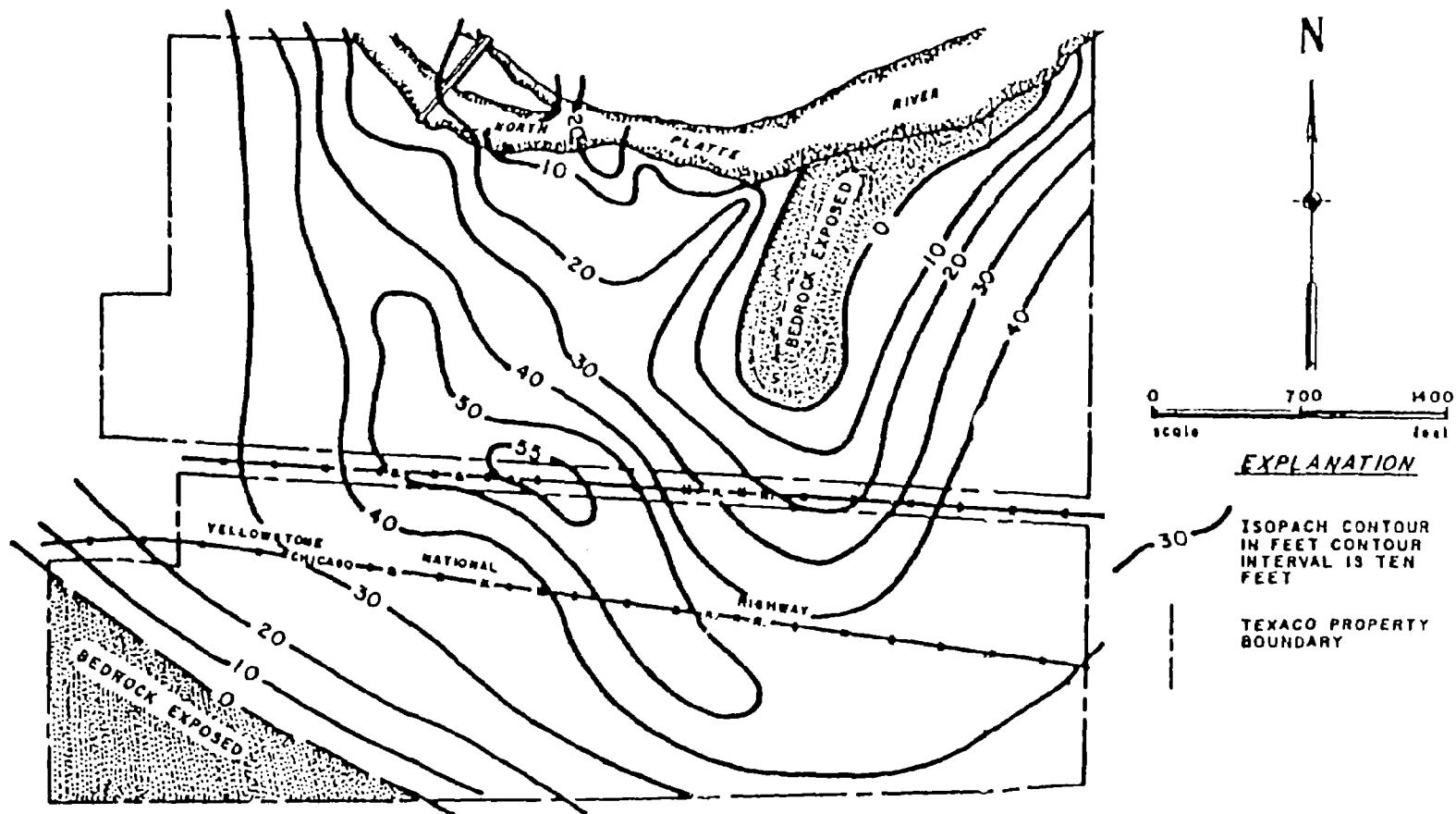
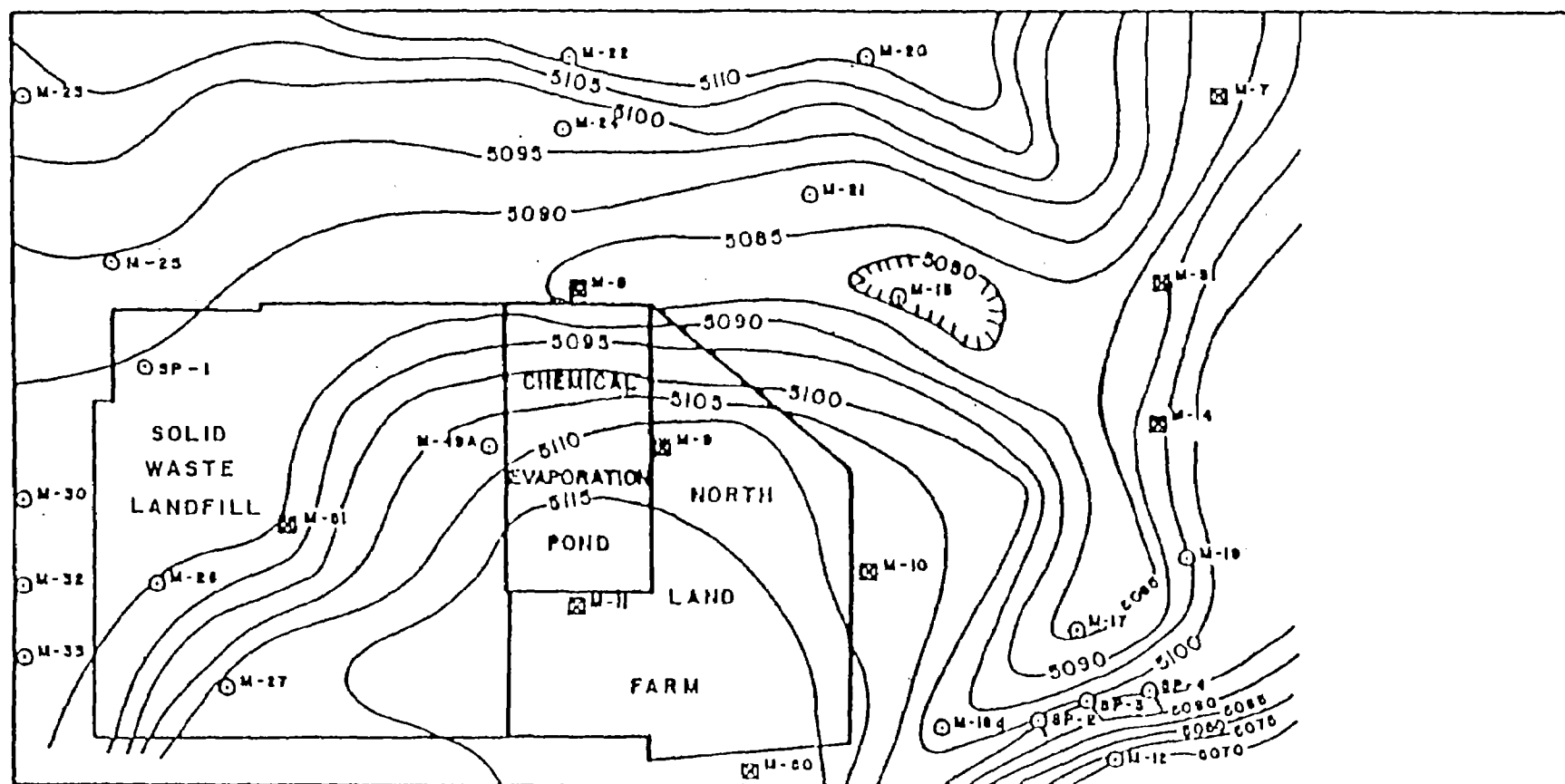


FIGURE 7 ISOPACHOUS MAP FOR THE ALLUVIUM,
CASPER TEXACO REFINERY

modified from; Western Water Consultants, Inc., 1982



EXPLANATION

- M-27 LOCATION OF SINGLE MONITOR WELL
- ⊠ M-51 LOCATION OF HATCHED WELL SITE
- SP-1 SEEP DRIVE POINT
- 5100 — CONTOUR (Feet above M.S.L.)

0 200 400 Feet
SCALE
CONTOUR INTERVAL 5 FEET

FIGURE 8 : BEDROCK SURFACE CONTOURS, UNNAMED MIDDLE MEMBER NORTH PROPERTY, CASPER TEXACO REFINERY.

modified from; Western Water Consultants, Inc.; 1982

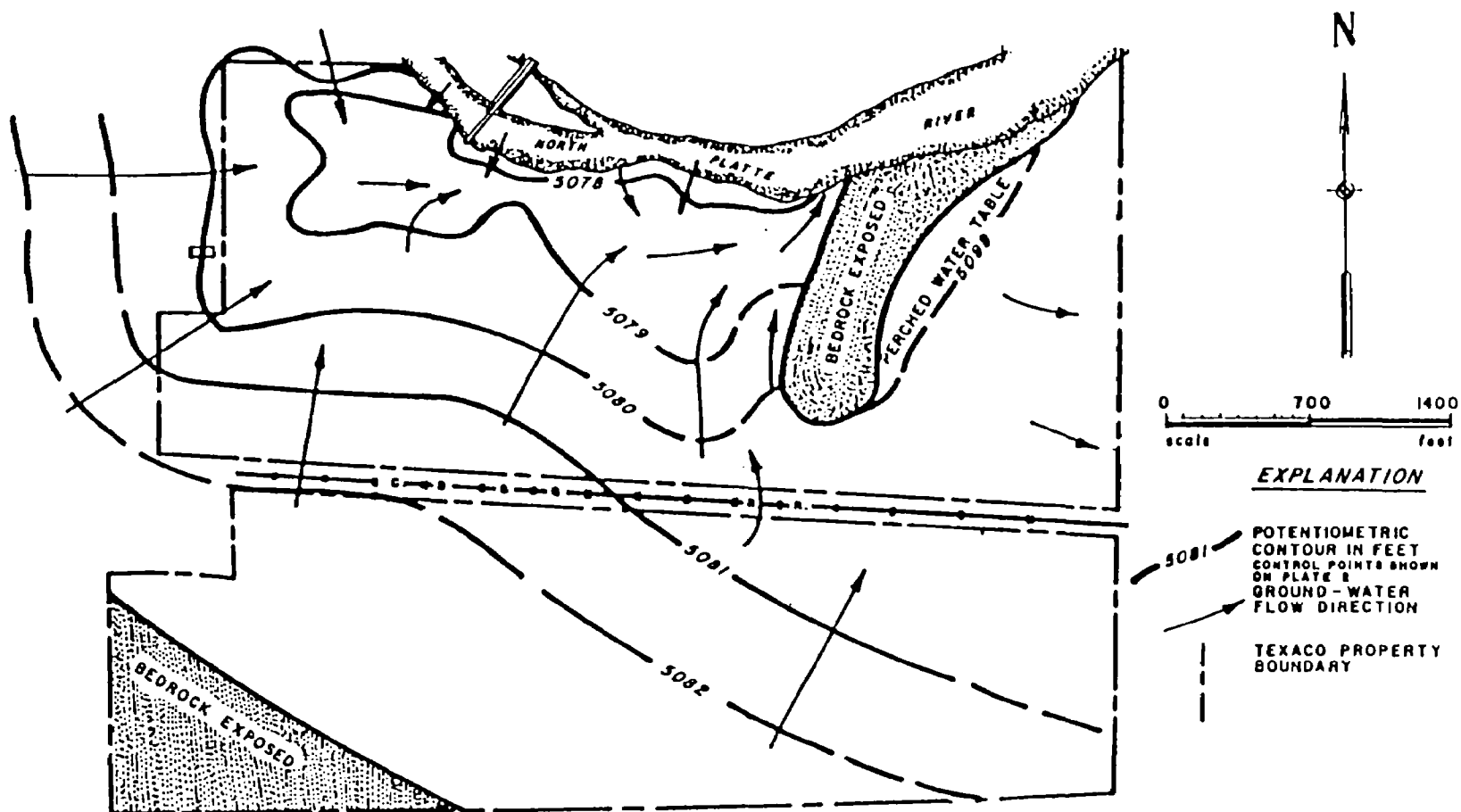


FIGURE 9 : GENERALIZED POTENTIOMETRIC SURFACE CONTOUR MAP AND IDEALIZED GROUND-WATER FLOW DIRECTIONS FOR THE ALLUVIAL AQUIFER, CASPER TEXACO REFINERY.

modified from; Western Water Consultants, Inc., 1982

Platte River bank to the alluvium under the South Area. The upgradient end of the French drain is located near the intersection of the western boundary of the south property and the North Platte.

Recharge to the aquifer primarily comes from the hydraulic connection with the North Platte, infiltration of precipitation and perched water flowing overland in the uppermost unnamed middle member of the Mesaverde Formation plus possible leakage from the middle member. Recharge has also taken place by artificial infiltration of water through recharge wells and ponds in addition to product from the refinery. No specific source at the refinery is known, but the presence of free hydrocarbons in the aquifer substantiates this source.

Alluvium thickness ranges from zero to greater than 55 feet (Figure 7). Saturated thickness of the alluvium ranges from 5 to 30 feet, with an approximately 20 foot average thickness (WWC, 1982b). Aquifer tests were performed by Western Water Consultants, Inc. between March 9 and April 6, 1982. "One multiple well pump and recovery test, four single well pump and recovery tests and one bailer recovery test were conducted at the Casper Texaco Refinery" at this time (WWC, 1982b). Based on these tests, hydraulic conductivity was estimated to range from 2×10^3 to 8×10^4 gallons/day/foot². Estimated transmissivities ranged from 8×10^3 to 6×10^5 gallons/day/foot. Calculated average storage coefficient was 0.1 and estimated specific capacity ranged from 30 to 100 gallons/minute/foot of drawdown.

Gradient in the alluvial aquifer is approximately 1 foot/500 feet. Maximum probable flow rate is approximately 22 feet/day.

Ground water in the alluvial aquifer of the north property has a generalized flow direction to the southeast to east toward the North Platte. Potentiometric contours are relatively uncomplicated. The potentiometric surface is responsive to changes in the stage of the North Platte, with which it is in direct hydraulic communication. Recharge to this alluvium is accomplished through several sources. Recharge from the North Platte, which is variable (and is probably mostly discharge into the Platte at low river stage), recharge from infiltration of precipitation, and ponded seepage emerging from the bluffs bordering the north side of the alluvium are all primary sources. These seeps emerge where the relatively high permeability "upper aquifer" contacts the underlying and relatively low permeability unnamed middle member of the Mesaverde Formation at the bluff face (Plate 1, Section C-C'). Another possible source of recharge is discharge from the unnamed middle member into the alluvium. This recharge is undefined in quantity and quality.

The seeps at the bluff face are the major obvious pathways for introducing contaminants from the chemical evaporation pond and land farm areas on the bluffs above to the alluvial aquifer. Potential for migration of contaminants through the unnamed middle member and their introduction by discharge into the alluvium is undetermined. Sampling by Texaco in the past has indicated the presence of organic contaminants seeping from the bluffs into the alluvial aquifer.

Saturated thickness for the north alluvial aquifer probably averages about 10 feet. The alluvium ranges from zero to about 15 feet thick based on boring logs. Pumping or bailer tests were not conducted in the alluvium on the north property.

Several tests were conducted in the alluvium south of the river, and due to the close similarity in composition and grain size between these two deposits, these south property data should be applicable to the north property alluvium. As in the south property alluvium, hydraulic conductivity in the north alluvium probably ranges from 2×10^{-3} to 8×10^{-4} gpd/ft². Due to the saturated thickness in the north alluvium being approximately half of the saturated thickness of the south alluvium, the transmissivity of the north alluvium should be approximately half of the transmissivity of the south property alluvium. Gradient in the north property alluvium and flow rates should also be approximately the same as the south alluvium or one foot/500 feet and about 22 feet/day, respectively. Although not stated by Texaco in their data evaluation, porosity is assumed to be 0.25.

Baseline water quality data indicate generally poor drinking water quality as ammonia, sulfate, and TDS exceeded domestic use standards. Due to probable introduction of contaminants from the evaporation pond/land farm area at the upgradient end of the alluvial aquifer, the background water quality is poorly defined.

Quaternary Eolian Deposits Eolian sand and silt deposits of Quaternary age blanket the surface over a large area near the Texaco Refinery. These unconsolidated sediments form a variably thick veneer which unconformably overlies major portions of the bedrock units in this area. The eolian deposits occur over much of the north property, but are not well documented on the south property. Several borehole logs from the south property indicate there is one to two feet of eolian sediment overlying portions of the alluvium. Grading, filling, and other surface disturbances in the South Area probably mask this eolian material.

The eolian sediments are composed of well sorted silt and fine sand. These are typically rounded and the sand grains are "frosted." Source material for the sediments may be primarily from Teapot Sandstone outcrops. This would explain the textural similarity of these units. The eolian sands in the local area are typically less than 50 feet thick (Hodson, et al, 1973). The sands are present as active and inactive dunes. Deposits on the north property of the Texaco Refinery range from generally less than eight feet thick near the chemical evaporation pond and land farm, to about 40 to 50 feet thick in areas near the excess service water effluent ponds (borehole log M-5, Appendix B). Some of the sediments previously interpreted as eolian are probably best classified genetically as older alluvium. This interpretation is based on presence of gravels and plastic clay lenses, moderate to poor sorting, oxidation differences (color changes), deposit geometry and bedrock surface contours. This interpretation is made from reexamination of various data, especially the borehole logs.

This genetic distinction may have low importance in terms of the hydrologic system. The eolian sediments do possess high porosity and permeability. This aids infiltration and subsequent recharge to underlying bedrock units which have much slower infiltration rates. If precipitation events are heavy enough, the water can infiltrate to depths below the depth of effective evaporative discharge, thereby protecting loss of the moisture to the atmosphere. Retention of moisture by the eolian materials is generally poor as indicated by the ineffectiveness of the four lysimeter locations. There may be a possibility the lysimeters were not properly used. The tubes were left open to equilibrate with atmospheric pressure rather than applying a vacuum and sealing the tubes at the conclusion of a sampling event.

Ground water flow in the eolian deposits is defined in the potentiometric maps for the north property presented under the Hydrogeology of the North Area Section. Subsurface flow in the eolian deposits north and east of the evaporation pond and land farm is generally to the south, toward the North Platte River. This is presented in several reports as the "regional flow direction," however this is only true for the ground water in the eolian deposits. The underlying bedrock units have a flow direction to the northeast, towards the basin axis. The ground water in the eolian deposits north and east of the chemical evaporation pond, in the area of the excess service water effluent ponds, is in a perched condition due to the underlying, low permeability Lewis Shale. Where the eolian deposits overlie the Teapot Sandstone, the direct hydraulic communication probably causes the ground water from the eolian deposits to infiltrate the Teapot Sandstone.

Hydraulic parameters for the eolian deposits were not truly measured directly, as the aquifer tests were conducted in wells screened in the older alluvium previously described. However, in practical usage, the same values for hydraulic conductivity previously ascribed to the "eolian"/older alluvium can be considered adequate.

Contamination migration in the eolian deposits is probably rapid and relatively unattenuated. The sand and silt has a low potential for sorption or cation exchange. Filtration and possible biodegradation are the only expected contaminant mitigation effects.

4. Hydrogeology of the North Area

The North Area of the Casper Texaco Refinery has two regulated units, the Chemical Evaporation Pond and the North Land Farm. These units are sited on a topographic high overlooking the North Platte River. Figure 10 presents the location of monitoring wells completed in the North Area. As previously stated, geologic and well completion logs are presented in Appendix B. The topographic high is underlain by a bedrock high of the unnamed middle member of the Mesaverde Formation. The bedrock high represents an erosional feature, which was left when the ancestral North Platte River eroded a channel to the immediate north of the bedrock high. The contour map of the bedrock surface, Figure 8, shows the bedrock low mapped from borings and a seismic refraction geophysical survey (WWC, 1982d). The axis of this bedrock low lies approximately 100 feet north of the regulated units. From this area, the axis of the paleochannel bends southward, towards the North Platte River where it intersects the face of the bluffs along the river approximately 600 feet southeast of the regulated units. Plate 1 presents Cross Sections A-A', B-B' and C-C' which are referenced hereafter in the following sections.

The paleochannel is filled with an alluvial deposit consisting of medium to coarse sand with fine to medium gravel common in the lower portions of the deposit. The alluvium also contains lenses of clay. This deposit is overlain by eolian fine sand and silt deposits of variable thickness. The eolian sediments are typically less than eight feet thick. These sediments, both paleo alluvium and eolian, were all described as eolian in previous works.

The bedrock low is eroded into the unnamed middle member of the Mesaverde Formation. The Teapot Sandstone Member also underlies the eastern portion of the bedrock low, but the location of the lower contact of the Teapot with the middle

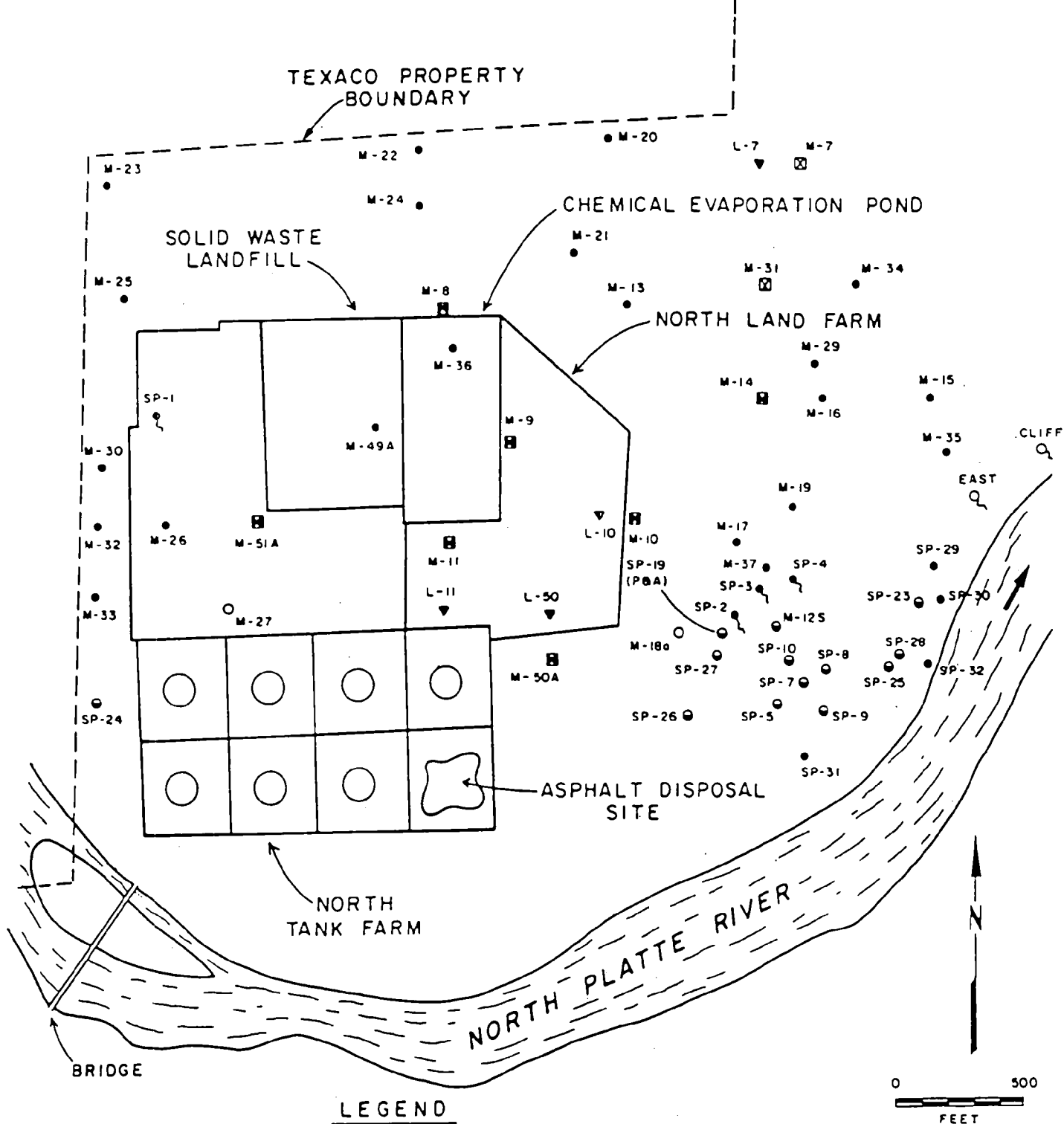


FIGURE 10
Location of North Area Monitoring Wells
Texaco Refinery, Casper, Wyoming

member is conjectural to date (Plate 1, Section A-A'). The contacts were not mapped on the bluffs along the river, and borehole data are poorly documented and inconclusive. Two wells which may have penetrated this contact and the lowermost portions of the Teapot Sandstone are M-31m and M-14d (Figure 10, Appendix B). These boreholes intercepted sandstone with a similar description as the Teapot. Borehole M-3 to the northeast, Figure 10, also may have intercepted the Teapot in a stratigraphically higher portion of the unit based on the presence of coal in the borehole. Based on these sparse data, the subcrop of the Teapot can be considered to lie within 750 to 1000 feet east of the regulated units. The thick blanket of paleo alluvium and eolian sand overlying the Teapot are in direct hydraulic contact with the Teapot Sandstone, as previously stated (WWC, 1982d). Stratigraphic position, topographic position, and pumping test data substantiate that the Teapot Sandstone and overlying unconsolidated alluvium and eolian deposit can all be considered hydraulically interconnected. Therefore these units collectively constitute the "upper aquifer" as defined in 40 CFR Section 260.10. Exact relationships in the subsurface are presently undefined by borings and geophysics. The borehole logs presented by the facility are insufficient in lithologic description and lack information such as penetration rates, fluid loss, etc. which could help clarify the subsurface contacts.

The Chemical Evaporation Pond and Land Farm overlie eolian sand and paleo alluvium from 21 feet thick in M-9d to 50 feet thick in M-8d. Recharge to this deposit is taking place by infiltration from the Chemical Evaporation Pond, which has been "refilled" with water from the North Platte by Texaco.

The infiltration of river water produced recharge to the ground-water system of the upper aquifer underneath the Chemical Evaporation Pond, which has created a ground-water mound. This mounding effect has fluctuated in magnitude through time depending on the volume of water introduced to the pond. The mounding of the water table creates an increase of gradient, and radial flow away from the pond in all directions except south where the shale bedrock high blocks the flow path. Flow paths diverge radially with water flowing towards the river on the west and east. Flow northward probably responds to change in gradient and splits to flow southeast or southwest towards the river. The potentiometric maps produced by the Task Force (Figures 11, 12, 13 and 14) substantiate earlier potentiometric mapping. Flows to the west infiltrate the alluvium of the "lower aquifer" which lies along the North Platte. Flows to the southeast surface as seeps at the shale/alluvium-eolian interface. Flow volumes of the seeps are not documented.

Radial flows to the east and north encounter the bedrock low, which would act as a preferentially permeable "channel" compared to the confining shaly middle member. This bedrock low may also act as a "sink" for any dense immiscible phases present ("sinkers"). If a dense immiscible phase were present, it may tend to collect in the bedrock low. Due to the probable subcrop of the Teapot Sandstone along this bedrock low (see Plate 1, cross section B-B') and the probability of recharge to the Teapot at the subcrop/outcrop, dense phases could migrate into the Teapot aquifer. Dissolved phases may also be introduced to the Teapot through recharge at the subcrop.

Potentiometric maps of the North Area plotted by Western Water Consultants, Inc. are accurate for the eolian sand and paleo alluvium north of the river. However, published data (Crist and Lowry, 1972, Plate 1) on the Teapot Sandstone indicate a

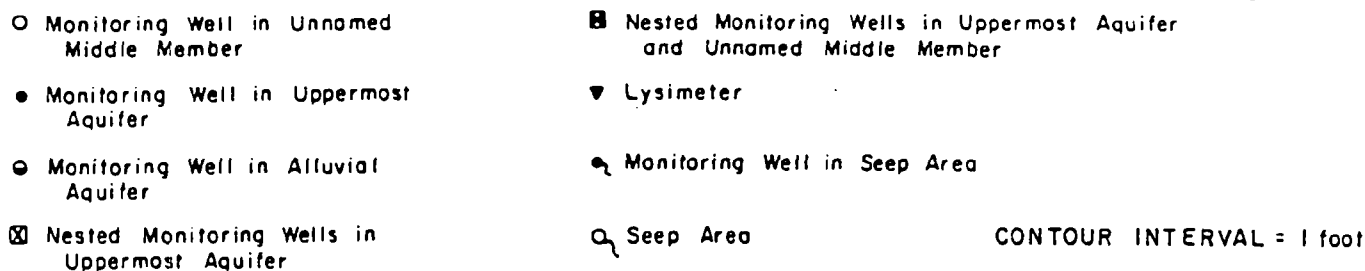


FIGURE 11

Potentiometric Surface Map
Upper Aquifer
October, 1982
Texaco Refinery Casper, Wyoming
(Approx. Historic High)

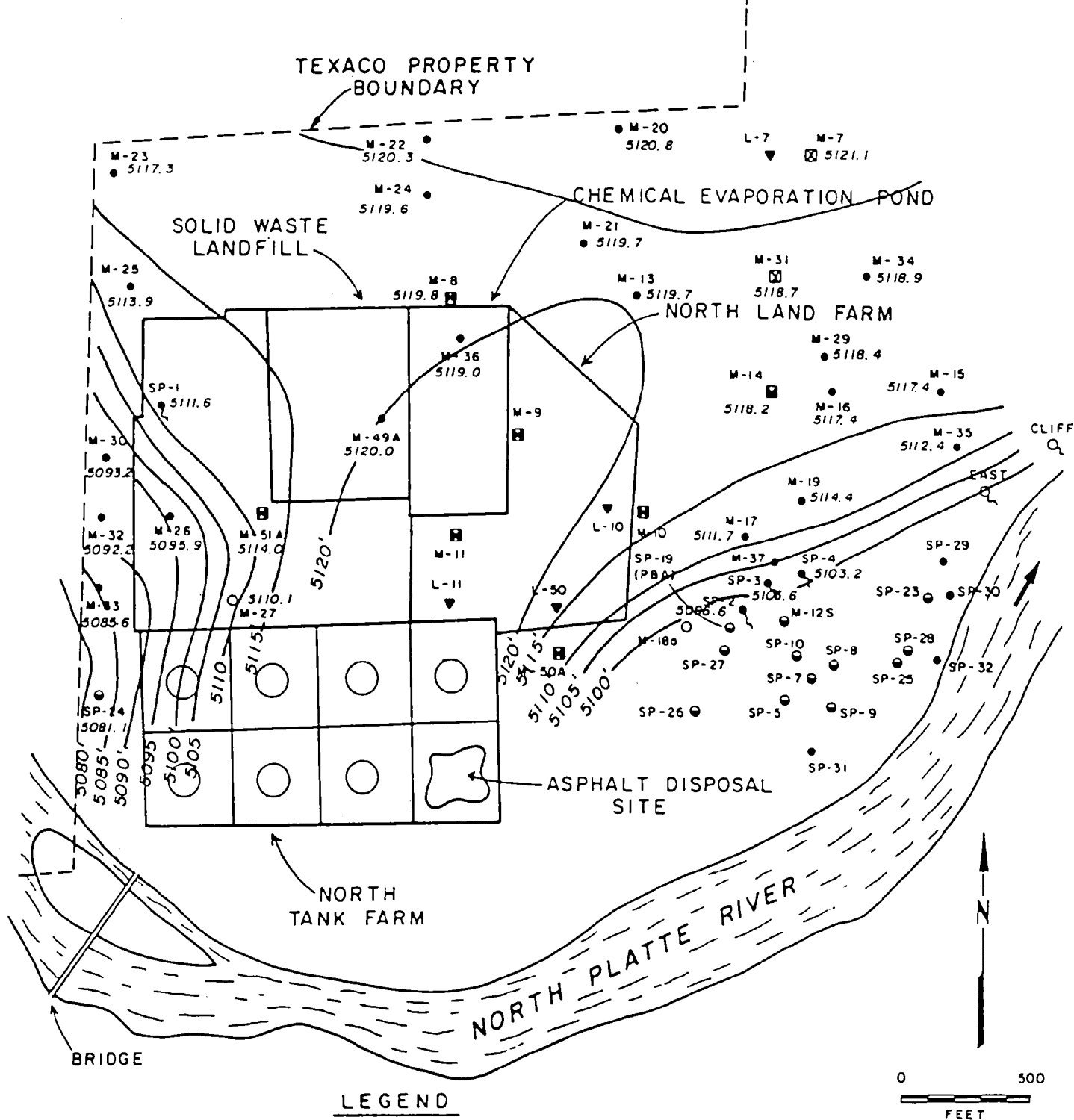


FIGURE 12
 Potentiometric Surface Map
 Upper Aquifer
 September, 1985
 Texaco Refinery, Casper, Wyoming

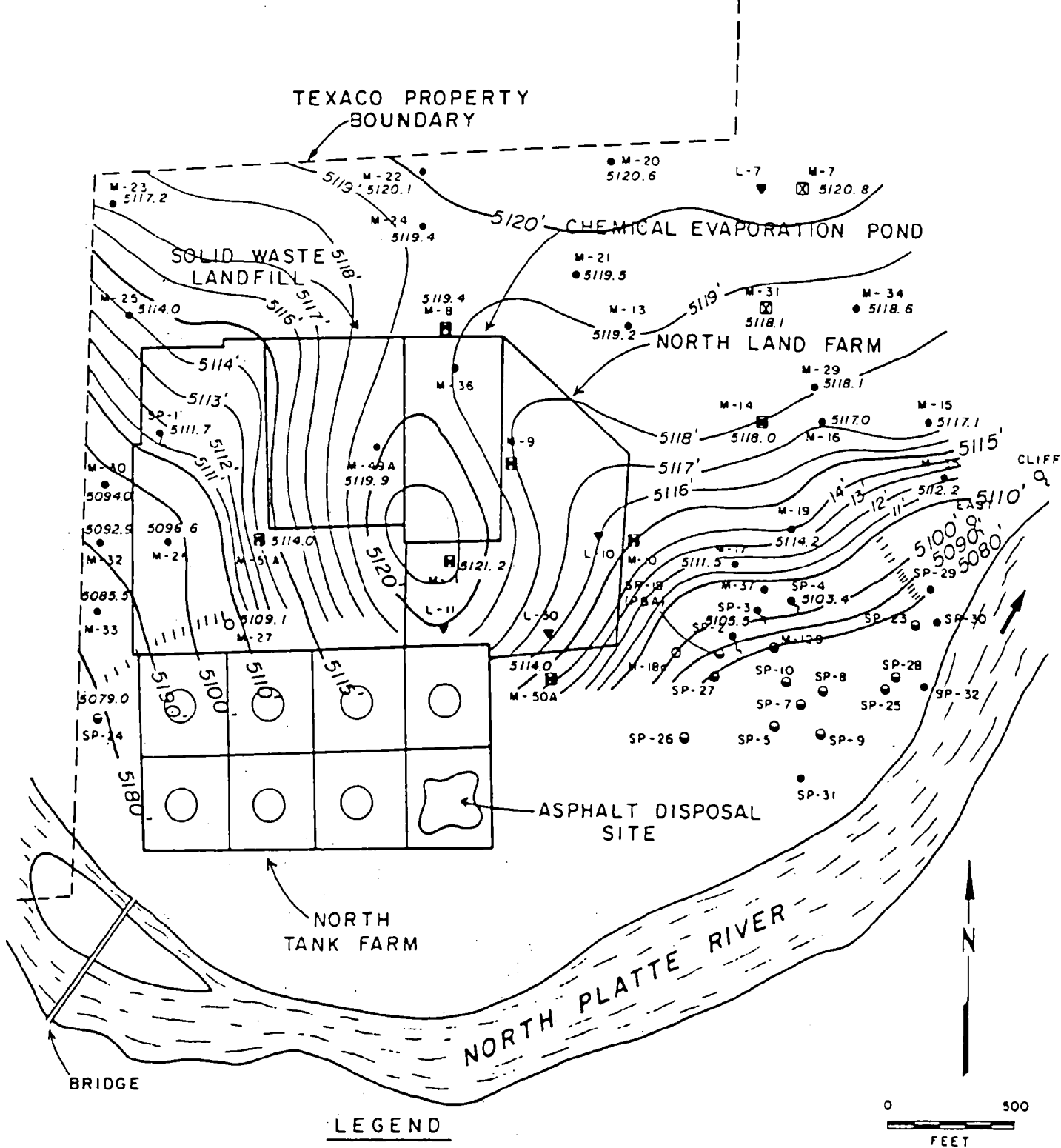


FIGURE 13

Potentiometric Surface Map
Upper Aquifer
December, 1985
(Approx. Historic Low)
Texaco Refinery, Casper, Wyoming

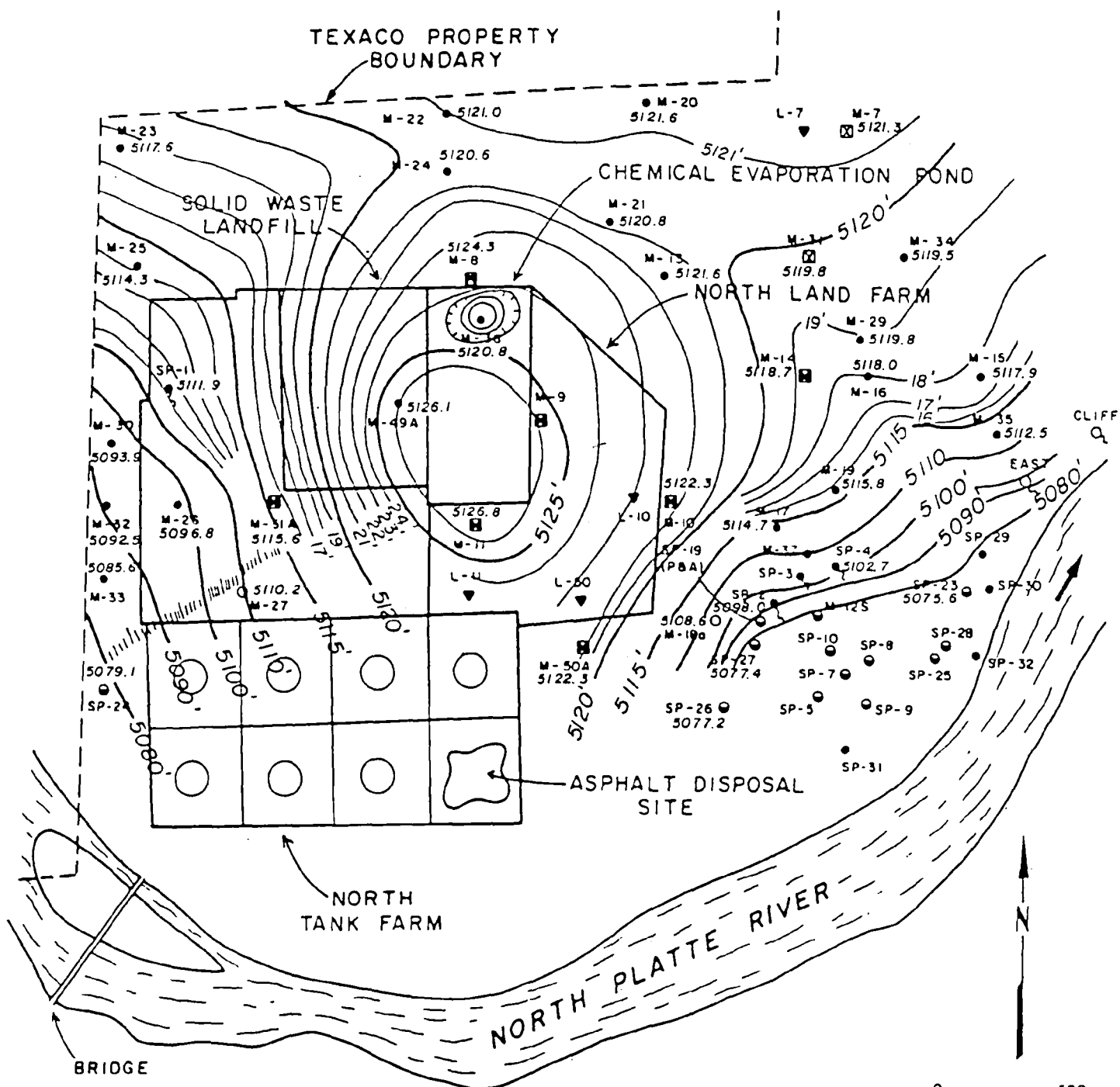


FIGURE 14

Potentiometric Surface Map
Upper Aquifer
September, 1987
Texaco Refinery, Casper, Wyoming

basinward (northeast) gradient and flow direction for this aquifer east of the site. The existing monitor wells do not substantiate this because few are probably completed in the Teapot and none are completed in the Teapot to the east where it is overlain by the confining Lewis Shale. Local water supply wells completed in the Teapot Sandstone east of the site, and tabulated by Western Water Consultants, Inc. (WWC, 1982d) from data held by the Wyoming State Engineer's Office, also substantiates a probable northeastward decline in the Teapot's potentiometric surface. Due to poor elevation and screened interval control, these data are difficult to obtain accurate potential elevations from. Careful re-evaluation of the data from water supply wells in this area may possibly allow accurate potential maps to be drawn for the Teapot Sandstone. An evaluation of the ground-water monitoring system in the North Area is discussed in detail in Section D.

Potentiometric contour maps were constructed by the Task Force for the approximate average historic high water levels in the uppermost aquifer in October, 1982 and the approximate historic low in December, 1985. These are presented in Figures 11 and 13, respectively. Both maps show approximately the same configuration with a prominent mound at the Chemical Evaporation Pond. Flow directions and gradients are approximately the same for both maps. Fluctuations of the water level for individual wells range from about five to six feet in monitor wells close to the Evaporation Pond to only one tenth of a foot in monitor well M-23 cross gradient and located several hundred feet from the pond (Figure 10).

One anomalous feature, a potentiometric "low", shows up on the map constructed for the September, 1987 water level measurement event (Figure 14). This low is also indicated in a potentiometric map constructed by Texaco for June, 1987 (WWC, 1988). These lows are unexplained. Review of the data does not indicate a transcription or measurement correction error.

The hydraulic properties of the geologic units of the North Area are tabulated in Table 3. These data were compiled from various reports by Western Water Consultants, Inc., who performed single well pumping tests and bailer tests at nine wells. Laboratory permeameter tests were also conducted on two cores from the unnamed middle member. The permeameter tests measured vertical hydraulic conductivity at 2×10^{-2} gpd/ft² and 8×10^{-4} gpd/ft². No description or other analysis of the cores was provided, and it is assumed they were from the shaly lithology portions of the member. Data for tests of two wells (M-51Am and M-51Ad) completed in shale gave hydraulic conductivity values of 0.2 gpd/ft². The unnamed middle member is predominantly a shaly lithology and can generally be considered a confining unit, especially because of its thickness of 350 to 400 feet. Sandy siltstone lenses however have a conductivity comparable in magnitude to the "uppermost aquifer." Tests in wells M-8d and M-10d, which are screened in shale and silty sandstone lenses, respectively, had hydraulic conductivities of approximately 100 gpd/ft². It is unknown how much communication the relatively permeable lenses have with the overlying unconsolidated deposits of the uppermost aquifer. The vertical gradient between nested wells M-51Am and M-51Ad, screened seven feet and 27 feet into the shale of the middle member, respectively, showed a 0.05 downward gradient in the unit. Lateral continuity of the permeable lenses within the unnamed middle member is probably restricted. Due to this, the long distance lateral transport of potential contaminants would be confined to the permeable lenses only. Leakage to other units is possible. No documented water supply wells are completed in this unit in the vicinity of the Texaco Refinery.

Table 3

Hydrologic Properties
North Area Geologic Units

<u>Geologic Unit</u>	<u>Estimated Hydraulic Conductivity</u>	<u>Estimated Transmissivity</u>	<u>Gradient Range</u>	<u>Calculated Maximum Flow Velocity</u>
Eolian Sand	2 to 1000 gpd/ft ²	2.2×10^2 to 1.6×10^4 gpd/ft	-1 foot/100 feet	1.5 ft/day
Paleo Alluvium	2 to 1000 gpd/ft ²	2.2×10^2 to 1.6×10^4 gpd/ft	-1 foot/100 feet	1.5 ft/day
Recent Alluvium	2×10^3 to 8×10^4 gpd/ft ²	1.2×10^{-1} to 3.3×10^5 gpd/ft	-1 foot/500 feet	22 ft/day
Teapot Sandstone	-2 to 1000 gpd/ft ²	7.5×10^2 to 1.6×10^4 gpd/ft	-1 foot/100 feet	1.5 ft/day
Unnamed Middle Member				
- shale	0.2 gpd/ft ²		-1 foot/100 feet	0.01 ft/day
- siltstone/sandstone	100 gpd/ft ²	undefined	-1 foot/100 feet	0.2 ft/day
- permeameter tests	2×10^{-2} gpd/ft ²			
Vertical permeability (2 tests)	8×10^{-4} gpd/ft ²			

Data compiled from:

Western Water Consultants, Inc., 1982 and 1983

Vertical gradients at the North Area were calculated for well nests. All water level data are from 1987. These data are presented in Table 4. Downward gradients were observed at seven well nests. Upward gradients were observed at three well nests. The largest downward gradient, 0.56, was observed at the M-6 well nest (Figure 10). This probably represents the downward flow component into the Teapot Sandstone from the water in the eolian deposits south of the Excess Service Water Effluent Ponds. The borehole logs for holes near these ponds indicate a variable thickness of eolian sand overlying shale. The borehole log for M-5 encountered 40 feet of shale near the M-6 well nest. Borehole M-5 was abandoned as dry. It is probable the water in the eolian deposits is perched over this shale and rapidly infiltrates the Teapot Sandstone wherever erosion has exposed the Teapot through the shale or where the shale tapers to an erosional zero thickness knife edge at the shale/Teapot contact. This shale may be the Lewis Shale which stratigraphically overlies the Teapot Sandstone.

The next larger downward gradients were observed in well nests M-9, M-10, and M-11 southeast of the Chemical Evaporation Pond (Figure 10). The effect of the ground-water mound under the pond is probably responsible for determining the magnitude of these gradients.

Well nests at M-7 and M-14 both exhibited upward gradients of 0.02. Well nest M-31, between M-7 and M-14 nests, has a downward gradient of 0.03. Explanation for this distribution is lacking, however it may be associated with the configuration of the bedrock low as these well nests are all located along the bedrock depression (Figure 8).

Hydraulic connection of the uppermost aquifer to the alluvium along the North Platte River (lower aquifer) occurs through the seeps along the bluffs southeast of the Chemical Evaporation Pond, by probable direct connection of the uppermost aquifer adjacent or overlying the alluvium west of the pond, and possibly by downward leakage into permeable siltstone lenses in the middle member of the Mesaverde which could migrate laterally to the bluff face for discharge or subsurface leakage to the alluvium.

The alluvium of the lower aquifer is situated between the bluffs and the North Platte River. No pump or bailer tests were conducted in this alluvium. Five tests conducted in the correlative alluvium south of the river indicated hydraulic conductivities of 2×10^3 to 8×10^4 gpd/ft² (WWC, 1982d). This aquifer is zero to greater than 15 feet thick with a saturated thickness of about 10 feet, depending on river stage. The direct hydraulic connection of the alluvium to the river is responsible for primary recharge, with recharge also coming from the uppermost aquifer. Discharge is also primarily into the North Platte. The gradient is low, approximately 1 foot per 500 feet. Estimated maximum flow rates are about 22 feet per day (WWC, 1982d). Attenuation of pollutants from the uppermost aquifer is probably by discharge to the North Platte and dilution. The North Platte creates a hydraulic barrier (discharge point) to any migration further southward.

In summary of the potential contaminant pathways in the North Area, the principle potential water supplies affected are the North Platte River and its adjacent alluvium, and possibly the Teapot Sandstone aquifer northeast (down dip and probably down gradient) of the site. Both of these aquifers and the surface water are used for water supply east of the site.

Table 4

Vertical Potential Gradients Determined from Well Nests, North Area

<u>Well #</u>	<u>Screened Interval</u>	<u>Midpoint of Screen</u>	<u>Static Water Level</u> ¹	<u>Date of Measurement</u>	<u>Screen Elevation Difference</u>	<u>Static Elevation Difference</u>	<u>Gradient</u>	<u>Direction of Gradient</u>
M-6a	27.0' - 30.0'	28.5'	5152.8	12/14/87	7.0'	3.9'	<u>3.9</u>	Downward
M-6b	19.0' - 24.0'	21.5'	5156.7	12/14/87			7.0 = 0.56	
M-7s	23.5' - 26.5'	25.0'	5121.4	12/14/87	25.5'	0.4'	<u>0.4</u>	Upward
M-7d	49.0' - 52.0'	50.5'	5121.8	12/14/87			25.5 = 0.02	
M-8s	14.0' - 17.0'	15.5'	5123.8	12/14/87	53.0'	3.1'	<u>3.1</u> =	Downward
M-8d	67.0' - 70.0'	68.5'	5120.7	12/14/87			53.0 0.06	
M-9s	18.0' - 21.0'	19.5'	5124.9	12/14/87	16.0'	2.7'	<u>2.7</u>	Downward
M-9d	34.0' - 37.0'	35.5'	5122.2	12/14/87			16.0 = 0.17	
M-10s	19.5' - 22.5'	21.0'	5121.8	12/14/87	9.5'	1.1'	<u>1.1</u>	Downward
M-10m	29.0' - 32.0'	30.5'	5120.7	12/14/87			9.5 = 0.12	
M-11s	18.0' - 21.0'	19.5'	5125.7	12/14/87	26.0'	3.7'	<u>3.7</u>	Downward
M-11d	44.0' - 47.0'	45.5'	5122.0	12/14/87			26.0 = 0.14	
M-14s	22.0' - 28.0'	25.0'	5118.9	12/14/87	22.3'	0.5'	<u>0.5</u>	Upward
M-14d	44.3' - 50.3'	47.3'	5119.4	12/14/87			22.3 = 0.02	
M-31s	27.1' - 33.1'	30.1'	5119.8	9/14/87	14.7'	0.05'	<u>0.5</u>	Downward
M-31m	41.8' - 47.8'	44.8'	5119.3	9/14/87			14.7 = 0.03	
M-50As	18.0' - 21.0'	19.5'	No Data		34.0'	--	--	--
M-50Ad	52.0' - 55.0'	53.5'	5121.8	12/14/87				
M-51As	10.0' - 13.0'	11.5'	5116.0	12/14/87	30.0'	1.0'	<u>1.0</u>	Upward
M-51Am	40.0' - 43.0'	41.5'	5117.0	12/14/87			30.0 = 0.03	
M-51Ad	61.0' - 64.0'	62.5'	5116.0	12/14/87	21.0'	1.0'	<u>1.0</u>	Downward
							21.0 = 0.05	

¹ Water Level Data; Western Water Consultants, Inc., 2/29/88

The potential for contamination of the Teapot aquifer is undefined at the present time. Testing of down gradient Teapot wells for contaminants is recommended, as is additional characterization of this aquifer on-site.

Potential for contamination of the paleo alluvium/colian deposits and the unnamed middle member of the Mesaverde also exists and has been documented locally. This is not considered to be as great a concern for contaminant ingestion by people or livestock as these units are not used for water supply. The primary concern for these units is their documented and possibly some still undocumented effects on the Teapot and alluvial aquifers which they recharge to a greater or lesser degree.

5. Hydrogeology of the South Area

The South Area of the Casper Texaco refinery is located on the floodplain along the south side of the North Platte River. Covering the floodplain is a blanket of alluvium deposited by the North Platte River. Figure 15 presents the location of monitoring wells completed on the South Area. Geologic and well completion logs for the South Area are presented in Appendix C. The alluvium consists of unconsolidated fine to coarse sand with variable amounts of fine to coarse gravel. Underlying the alluvial deposits is the bedrock subcrop of the unnamed middle member of the Mesaverde Formation. The unnamed middle member of the Mesaverde consists primarily of shale with minor amounts of siltstone occurring as discontinuous lenses.

The unnamed middle member of the Mesaverde Formation is defined as a confining unit in the literature (Hodson, et al., 1973; Feathers, et al., 1981; Crist and Lowry, 1972). The member is predominantly shale as previously discussed. Descriptions of the outcrop along the North Platte River indicate the unit here consists of bentonitic siltstone and claystone. One well, SS-8, was "located within 30 feet of the North Platte River and drilled to a depth approximately 35 feet below the surface elevation of the river" (WWC, 1982b) and was dry at depth.

A bailer recovery test on well SS-5 gave an estimated hydraulic conductivity of 8.9×10^{-3} to 1.4×10^{-1} gpd/ft². Transmissivity for this unit based on 13.5 feet of saturated thickness was calculated at 1.2×10^{-1} to 1.9×10^0 gpd/ft. Core samples from three wells gave vertical conductivity values of 2.2×10^{-5} to 1.1×10^{-4} gpd/ft². The vertical conductivity is two or three orders of magnitude lower than horizontal conductivity as pointed out by Western Water Consultants, Inc. (WWC, 1982b). This is the normal case in most stratified sedimentary rocks. The dip of the strata does however expose the eroded horizontal "edges" of the strata to infiltration. Therefore the horizontal conductivity would be regarded as the "best" estimate for indicating fluid flow.

As in the North Area, there are no known water supply wells producing from the middle member in this area. Thicknesses of the member are probably in excess of 250 feet under the site. Published values of 350 to 400 feet thickness are for a maximum section. The Texaco Refinery is located in the middle of the outcrop belt where the dipping strata are erosionally truncated, therefore they are not at full thickness. All these properties indicate the validity of designating the unnamed middle member a confining unit.

The alluvium is the only aquifer present in the South Area. Extensive alluvial deposits equivalent to this alluvium lie east and west of the site. Thickness of

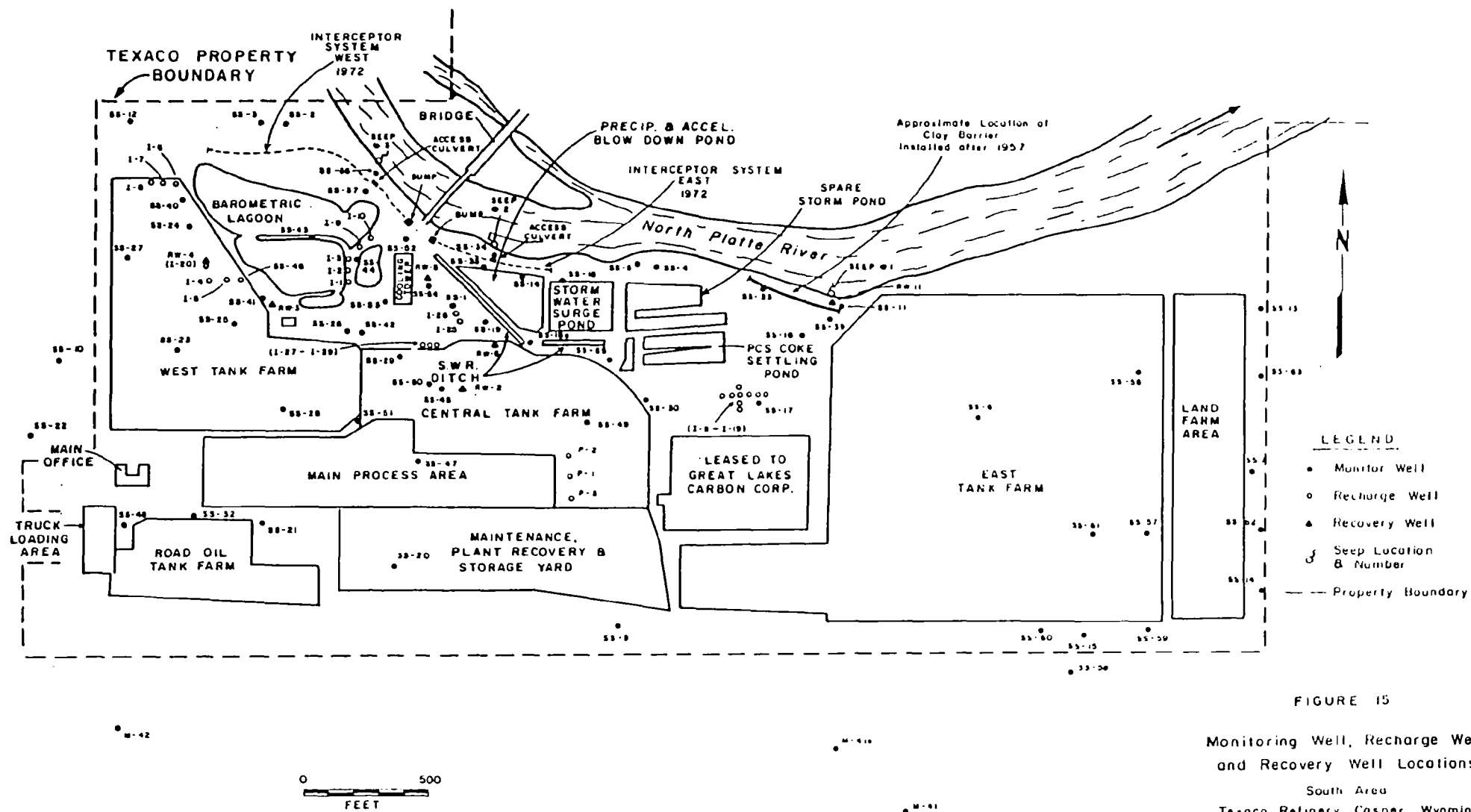


FIGURE 15

Monitoring Well, Recharge Well
and Recovery Well Locations
South Area
Texaco Refinery, Casper, Wyoming

alluvium ranges from zero to greater than 55 feet (Figure 7). The deposit covers the entire site except for bedrock outcrops in the northeast and southwest portions of the area. The alluvium is underlain by, and fills, a paleo channel cut into the underlying bedrock by the North Platte River. Figure 16 presents a bedrock contour map constructed by the Task Force which shows evidence of this paleo channel. Saturated thickness of the alluvium ranges from approximately five feet to 30 feet. An average saturated thickness for the alluvial aquifer has been given as about 20 feet. The Task Force evaluation supports this as approximately correct.

During March and April, 1982, pumping and bailer recovery tests were performed on four wells and single well pumping tests were performed on three wells in the alluvial aquifer. These data have been tabulated by Western Water Consultants, Inc. (WWC, 1982b). Hydraulic conductivities for the alluvium were calculated to range from 8.3×10^2 to 2.1×10^4 gpd/ft². Estimated transmissivities ranged from 7.6×10^3 to 3.3×10^5 gpd/ft.

Gradients for the alluvial aquifer vary due to the bedrock high, man-made structures, pumping, and natural slope. Calculations on "local" scale maps by Western Water Consultants, Inc. (WWC, 1982b) give a gradient of 50 feet/mile. Task Force measurements of potentiometric maps of the site indicate gradients ranging from approximately one to two feet per 600 feet. The gradients near pumped wells would be much steeper but available map scales and data do not allow quantification of this.

Flow directions are generally east and north for the central portion of the site (Figure 17), while flow for the southeastern corner is to the northeast/east (Figure 18). The bedrock high of low conductivity shale in the northeast portion of the area creates a diversion of flow around it. Perched water is documented to occur along the east side of the high. This is an inconsequential differentiation, however, as the entire aquifer overlies the shaly bedrock. The potentiometric surface map for the southeast corner of the facility (Figure 18) shows a flat gradient at the corner with general flow to the east towards the Little America Refinery. Insufficient data exist to evaluate seasonal fluctuations.

A potential for mistakes in contouring of the potentiometric surfaces and in prediction of flow directions in the central portion of the South Area is possible due to the presence of an immiscible hydrocarbon phase on the water table. Hydrocarbons are documented to occur in a relatively large part of the South Area. Water level data measured before May 8, 1985 are not corrected for depression of the water table by the hydrocarbon phase. This can have a significant effect on potentiometric contour maps. If these uncorrected data are used, anomalous or incorrect potentials and flow directions may result.

Flow directions and gradients are also modified by several man-made features. An interceptor trench enters the area from the northwest. This trench induces flow to the alluvium. Other interceptor trenches parallel the North Platte River. These trenches are excavated to a depth below the water table. They function as a cut-off or open drain where hydrocarbon accumulations can be removed from the water table. During pumping, the gradient near these trenches would steepen.

A 'clay barrier' (ground-water barrier) was installed during the 1950's. This barrier parallels the North Platte and is located just south of the river. It extends

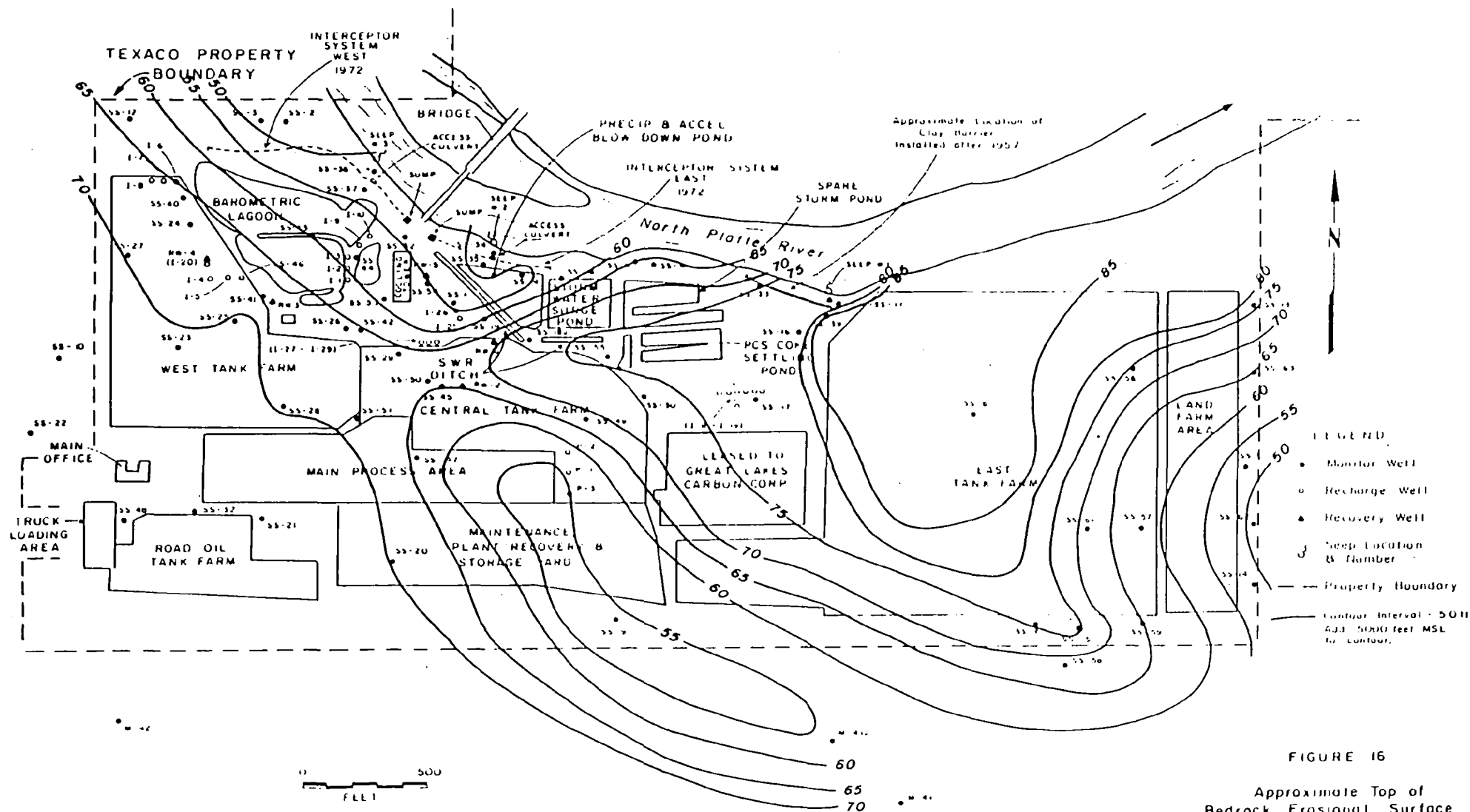


FIGURE 16

Approximate Top of
Bedrock Erosional Surface
Texaco Refinery, South Area
Task, Force Analysis

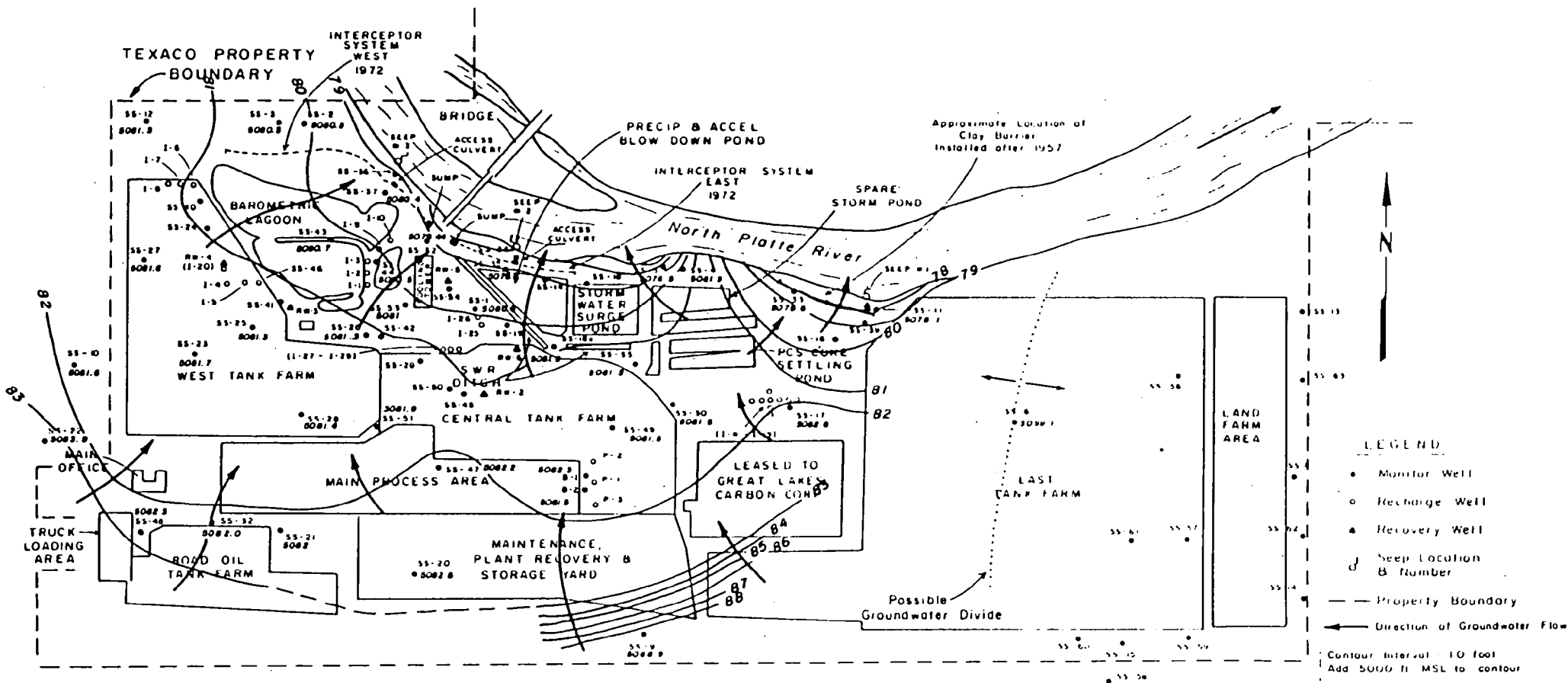


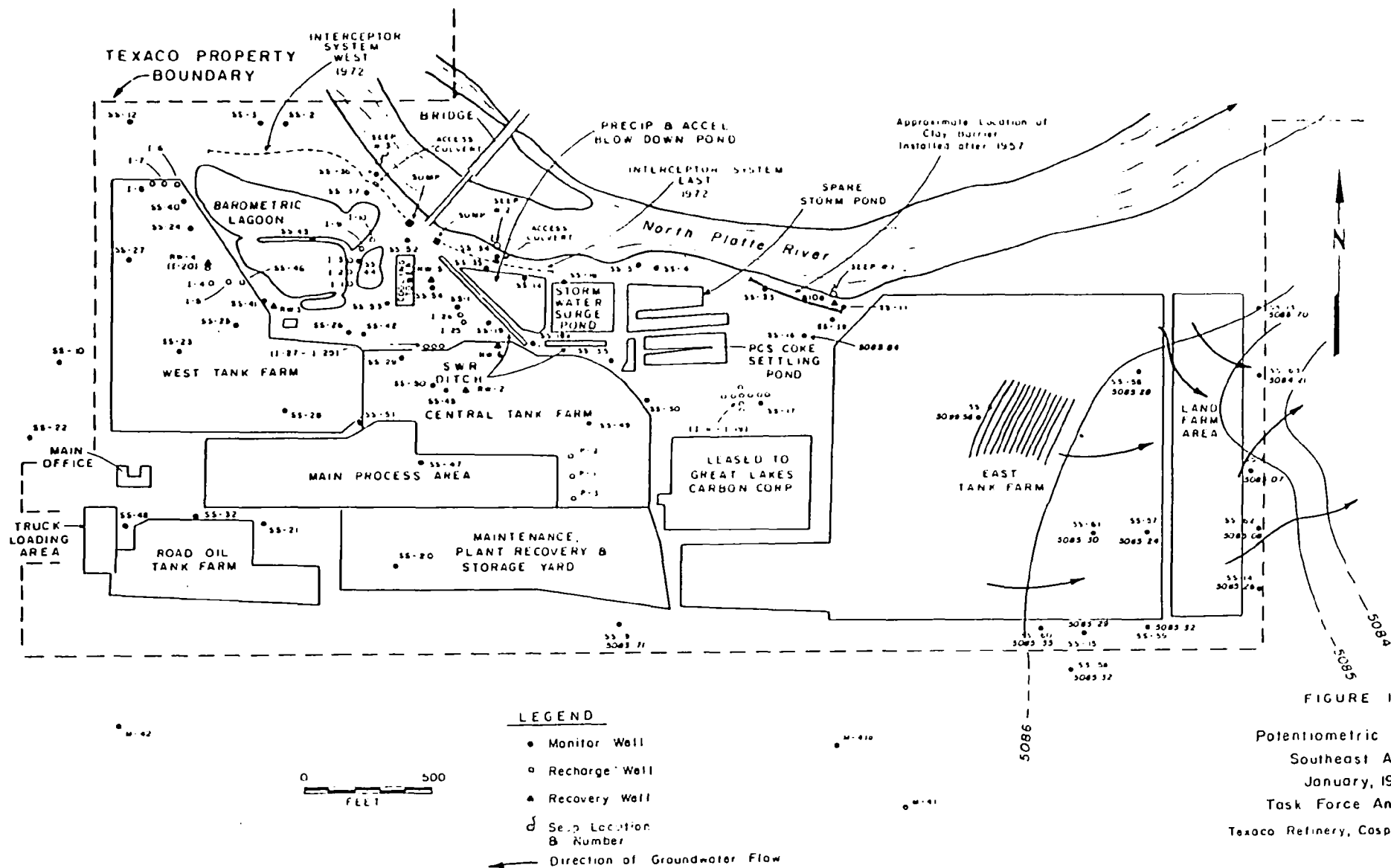
FIGURE 17

Potentiometric Map

11-5-85

Recovery System In Operation
Task Force Analysis

South Area
Texaco Refinery, Casper, Wyoming



from the bedrock high to the west about 400 feet. This presumably acts as a dam to hydrocarbons migrating toward the Platte. Some of the effect of these structures on the local flow paths is unknown although Figure 18 appears to indicate an effect. The probability of leaks or breaches in the containment structures is suggested by the presence of hydrocarbon seeps along the bank of the North Platte.

Pathways for potential migration of contaminants off-site are limited. The paleo-channel appears to direct flow around the bedrock high in the northeast corner of the property. This pathway may allow contaminants to flow eastward around the bedrock high and the interceptor system, although insufficient data exist to document this. The lowest areas of the paleo channel may act as 'sinks' for dense phase immiscibles. These could conceivably infiltrate siltstone lenses in the unnamed middle member and migrate laterally, however the effects from this possible pathway are considered to be minor on water supply aquifers.

The major impacts from the contaminants would probably be to the North Platte River. Continuing seepage around the barriers and interceptor system allows contaminants to reach the river. Escape of contaminants to the east, around the bedrock high and through permeable lenses in the middle member are possible pathways to the river. While no bedrock aquifers underlie the South Area, migration to the northeast of contaminants may impact the Teapot aquifer. This pathway is presently undefined and conjectural. To reach the subcrop of this aquifer, migration off-site to the northeast must take place. The distance to the subcrop of the Teapot Sandstone from the eastern boundary of the waste management area is not defined. Characterization of the uppermost aquifer including the Teapot Sandstone is required under 40 CFR 265.90(a).

D. GROUND-WATER MONITORING SYSTEM

Ground-water monitoring at the Texaco facility began in the 1940's. Dozens of wells were installed in the South Area between 1947 and 1957 to define the hydrogeology of the area, and to define the thickness and areal extent of oil contamination existing at that time. In the early 1980's numerous wells were installed in both the South and North Areas in an attempt to bring the system into compliance with State and Federal regulations. A minor number of wells have been installed since 1982 in both areas. As of August, 1986, at least 208 wells exist at the facility. Most are still in use today for water quality and/or water level measurements. A minor number of wells were and are used for production, oil recovery, injection and pumping and observation purposes.

Most monitoring wells at the Texaco facility have a unique alpha-numeric designation. In general, the M- and SP- series wells are located in the North Area, designed to monitor the uppermost aquifer and unnamed middle member, and the alluvial aquifer, respectively. Some of the wells located in the North Area are nested. The alpha-numeric sequence in these wells is followed by an "s, m or d," indicating shallow, medium, or deep. In addition, some well designations are followed by an "A", indicating alternate. The South Area predominantly consists of simple numeric and SS- series wells. The numeric series wells were installed in the 40's and 50's, with the SS series installed since 1981.

For clarification purposes, the remainder of this Section is subdivided into four major Subsections. Subsection 1 assesses the current ground-water monitoring system under interim status in the North Area. The second Subsection assesses the proposed ground-water monitoring system of the North Area for permitting purposes. Subsection three

details the regulatory adequacy of both the interim status and the proposed ground-water monitoring systems mentioned above. Finally, Subsection 4 assesses the South Area ground-water monitoring system, including a discussion of the oil recovery system currently in place. Texaco's Sampling and Analysis Plan, and past water quality data will be assessed in Section E of this report.

1. Ground-water Monitoring System under Interim Status (North Area)

Two units are currently subject to the regulatory requirements of 40 CFR 265 Subpart F. These are the North Land Farm, currently operating under interim status, and the CEP, a former interim status unit which, according to Texaco, ceased excepting waste in June 1982. A Part B Permit Application has been developed by Texaco and was received by U.S. EPA Region VIII in 1985. The land farm will be operated under interim status until such time as a decision on whether to grant or deny a permit is issued. The CEP was operated under interim status until September, 1986, when the pond was clean closed under 40 CFR 265. Because wastes were not disposed of in the CEP after July 26, 1982, ground-water monitoring pursuant to 40 CFR 264 is not required.

a. History of Interim Status Monitoring

As part of the ground-water monitoring requirements of 40 CFR 265, Texaco installed four monitoring wells near the CEP in early 1982 (WWC, 1984b). One well was designated as an upgradient well (M-7s), and three as downgradient (M-8s, M-10s and M-51As) (Figure 10). These four wells served as the detection monitoring system for the CEP. Detection monitoring wells specific to the North Land Farm have not been designated by Texaco under the interim status program. It should be noted that 25 monitoring wells existed in the North Area prior to the first round of sampling during March 1982. Analytical results of this sampling event indicated that ground water was degraded below and downgradient of the CEP and North Land Farm. During the remainder of 1982 and again in 1984, a total of 52 additional monitoring wells were installed in the North Area.

Because of the degraded ground water known to have existed in early 1982, Texaco implemented what they state is a "voluntary" ground-water assessment program. The Task Force considers this to be an assessment monitoring program under 40 CFR 265.93(d). This program consisted of monitoring 23 wells in the vicinity of the CEP and North Land Farm. These wells were used to obtain water level and ground-water quality data on a quarterly basis. Data have been collected semi-annually or annually for the other wells in the North Area. This program remains virtually unchanged presently, with the exception of eight additional wells which are monitored on a quarterly basis.

Texaco has maintained that since the inception of the assessment program, the degraded ground water is due to leakage from the CEP, and not the North Land Farm. According to Texaco, "unsaturated zone monitoring data collected under the pond and North Land Farm during interim status confirm that the pond, and not the North Land Farm, is the source of the groundwater quality degradation" (Texaco, 1985). Texaco further maintains that because contamination has not migrated from the land farm,

compliance monitoring (40 CFR 264.99) or corrective action monitoring (40 CFR 264.100) is not appropriate under operating standards regulations, and that detection monitoring (40 CFR 264.98) is the alternative. The detection monitoring program proposed by Texaco in their Part B Application is assessed in Subsection 2.

The chemical evaporation pond ground-water monitoring system, although currently operating under 40 CFR 265.93(d) assessment monitoring, will be subject to 40 CFR 264.101 which addresses correction action from SWMUs as this unit does not meet the regulatory definition of a regulated unit under 40 CFR 264.90 (i.e. ceased receiving wastes in June, 1982).

b. Assessment Program Under Interim Status

The assessment program implemented in 1982 was designed to determine the rate, extent and concentrations of contaminants in the ground water in the North Area. As was introduced earlier in this report, two HWMUs and four SWMUs exist in the North Area. They include the North Land Farm and CEP (HWMUs), and the Asphalt Landfill, North Tank Farm, Solid Waste Landfill and the Excess Service Water Effluent Ponds (SWMUs). All the above units have at least some potential to contribute to the degraded ground water. With the exception of the wells designed to monitor ground water near the Excess Service Water Effluent Pond (Figure 19), the assessment program cannot differentiate between the remaining units in terms of detecting a release from a single unit.

According to Texaco, monitoring frequency for each well is defined as follows: If contamination has been detected, that well will be monitored quarterly [40 CFR 265.93(d)(7)(i)]. The monitoring frequency of wells with contamination will continue on a quarterly basis until that well achieves water quality objectives (as set forth by Texaco) for four consecutive quarters. If contamination has not been detected, that well will be monitored yearly. Because a potential exists for most wells located in the North Area to exhibit contamination, all wells were assessed for design, placement, and construction deficiencies.

According to well inventory sheets and well completion details, 77 ground-water monitoring wells were installed within the North Area between 1981 and 1984. Locations of all wells in the North Area are presented in Figures 10 and 19. The majority of wells installed in 1981 and 1982 were to define the geology and hydrogeology near the North Land Farm and CEP (Texaco, 1983). Two additional wells were installed on March 29, 1984 (M-36 and SP-28). Four more were installed in September of 1984 (SP-29 - SP-32) to characterize water quality in the alluvial aquifer near the North Platte River (WWC, 1984b).

Currently, 65 wells are monitored for ground water quality. Of the 77 wells in the North Area, 12 records of well completions were not provided to the Task Force. Of these 12, six wells are currently used for monitoring purposes. These are SP-1 and SP-31 (uppermost aquifer), SP-2 and SP-4A (unnamed middle member), and M-12s and SP-26 (alluvial aquifer). An assessment of these wells is obviously limited. It should be noted that wells SP-31, SP-1 and M-12s are currently monitored on a quarterly basis as part of the assessment program.

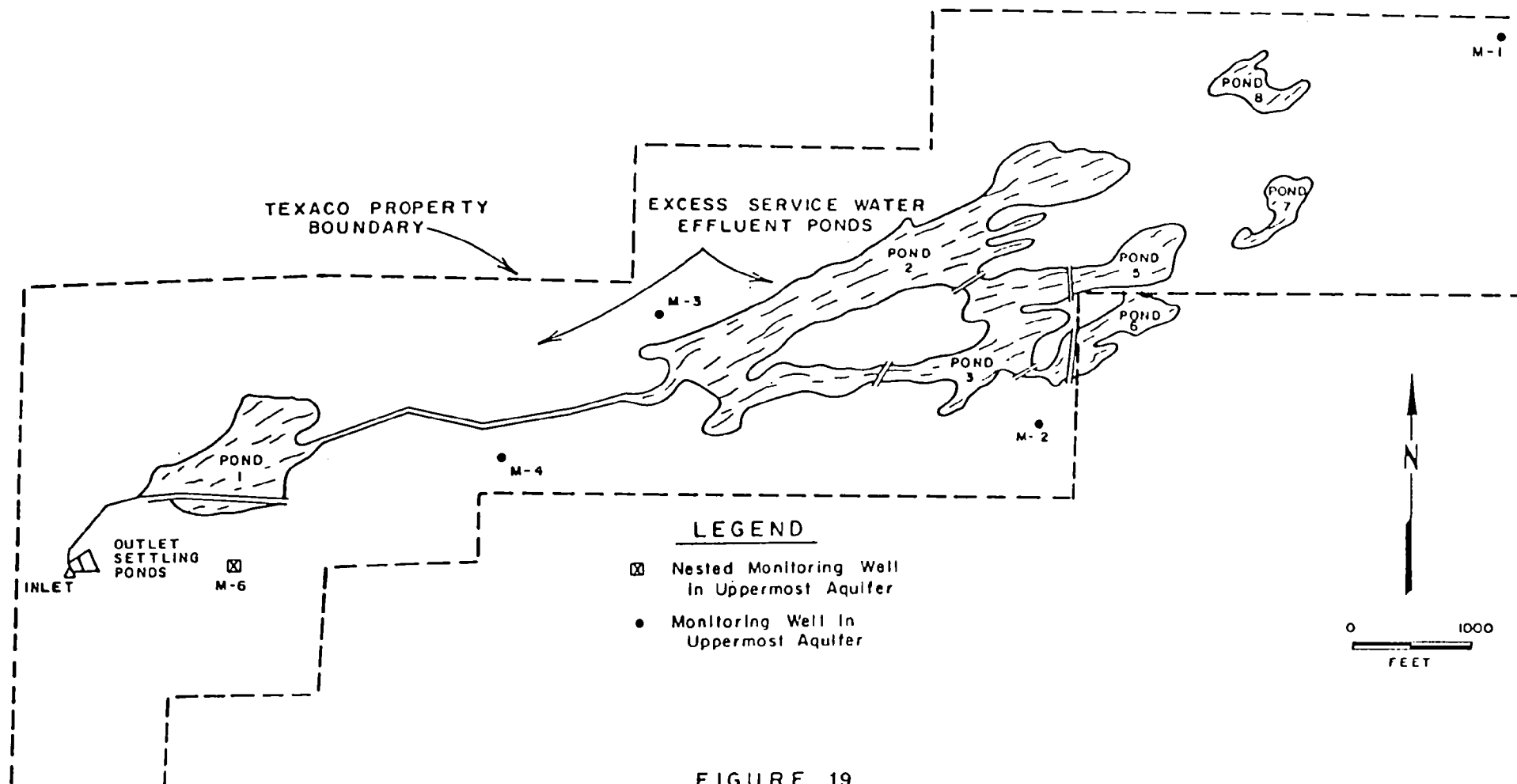


FIGURE 19

Location of Excess Service Water Effluent Ponds Monitoring Wells
Texaco Refinery, Casper, Wyoming

Monitoring Well System Design/Placement/Construction The ground-water monitoring system was originally implemented to define the geology and hydrogeology in the North Area. Subsequently, the system was and is used to define water quality under the assessment program and provide hydraulic properties of the two aquifers and the confining unit.

Horizontal locations of these wells were based on regional and local ground-water flow. The vertical locations of the screened intervals were designed to provide ground-water samples from the upper and alluvial aquifers, in addition to the unnamed middle member.

Based on the refinery waste constituents (Table 5), the monitoring system should be capable of monitoring the water table during high and low water level stages for light phase immiscibles. The system should also be capable of detecting dense phase immiscible components. Table 6 presents historic high and low water elevations of all monitoring wells located in the North Area between 1982 and 1987, and compares these with the screened elevations. Table 6 also presents the adequacy of the intervals to detect light phase immiscibles during both historic high and low water level periods. Finally, the table addresses the adequacy of the monitoring system to detect any dense phase immiscibles. The criterion used by the Task Force to verify the latter was that a well had a portion of the screened interval located at the aquifer/unnamed middle member (aquitard) interface.

As indicated in Table 6, only seven wells are capable of detecting light phase layers for all previous water level elevations. Based on potentiometric maps and water quality data, these wells are located hydraulically up or cross gradient, or so far away from the HWMUs so that dilution or other natural factors affect the ability to obtain a sample representative of any potential floating layers being transported from the units. Wells M-6b and M-23 are located near the Excess Service Water Effluent Pond No. 1 and approximately 1200 feet northwest of the CEP, respectively (Figures 19 and 10). Wells M-17 and M-37 are both located at least 400 feet east of the North Land Farm, and wells SP-29, SP-30 and SP-31 are located in the alluvial aquifer near the North Platte River (Figure 10).

Table 6 also indicates that 35 wells are unable to detect a light phase immiscible during any past water level. However, many of these are designed and constructed to monitor other sections of the uppermost aquifer, in addition to other stratigraphic units. Examples of the latter include the m and d- series wells, and the wells screened in the unnamed middle member.

Finally, Table 6 presents the wells whose screens are capable of detecting potential dense phase immiscibles. Discounting most of the SP- series wells located at the alluvial aquifer/unnamed middle member contact, 12 wells are screened such that dense phase immiscibles could be detected.

The horizontal locations of all monitoring wells in the North Area are shown on Figures 10 and 19. Based on the local geology and hydrogeology, in addition to past analytical results, complete characterization of the uppermost aquifer is not possible. Two areas of concern were noted by the

Table 5

Select Physical Constants of Known Groundwater Contaminants

CHEMICAL	DENSITY (g/ml)	WATER SOLUBILITY (g/m3)
Anthracene	1.25	0.075
Benzene	0.8787	1780
Benzenethiol	1.0766	Insoluble in H ₂ O
Chlorodane	1.59-1.63	Insoluble in H ₂ O
Chrysene	1.274	.002
Cresols	1.030-1.038	Soluble in about 50 parts H ₂ O
1-2 Dibromoethane	1.5389	4.310
2,4-Dimethylphenol	1.0276	Slightly soluble
2,4-Dinitrophenol	1.683	Very sparingly soluble in H ₂ O
Ethylbenzene	0.8672	1780
Fluoranthene	1.252	0.260
Fluorene	1.203	1.98
Heptachlor	1.5050	Insoluble
Methyl Ethyl Ketone (2-butanone)	1.3814	61.4
1-Methyl-Napthalene	1.025	27
2-Methyl-Napthalene	1.0058	
2-Methylphenol	1.047	Soluble in about 40 parts H ₂ O
4-Methylphenol	1.5395	100 ml H ₂ O dissolves about 2.5 g at 50°F
Napthalene	1.145	34.4
4-Nitrophenol	1.495	Moderately soluble in H ₂ O
Phenanthrene	1.179	1.18
Phenol	1.0722	93.0
Pyrene	1.271	0.148
Toluene	0.8669	515
Xylene	0.8968	185

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CRC Handbook of Chemistry and Physics, The Chemical Rubber Co., 1969.

Dangerous Properties of Industrial Materials, Van Nostrand
Reinhold Co., 1984.

The Merck Index, Merck & Co., Inc., 1976.

Soil Gas Sensing for Detecting and Mapping of Volatile Organics, National
Water Well Association, 1987.

Table 6

Historic High, Low and Screened Interval Elevations
(North Area)
(Elevations in feet above mean sea level)

WELL I.D.	HISTORIC HIGH ELEVATION	HISTORIC LOW ELEVATION	SCREENED INTERVAL ELEVATIONS	ADEQUATE TO DETECT LIGHT IMMISCIBLE COMPONENTS AT HISTORIC HIGH ELEVATIONS?	ADEQUATE TO DETECT LIGHT IMMISCIBLE COMPONENTS AT HISTORIC LOW ELEVATIONS?	ADEQUATE TO DETECT DENSE PHASE IMMISCIBLE COMPONENTS?
M-1	5210.9	5208.5	5183 - 5188	No	No	No
M-2	5183.8	5180.0	5175 - 5180	No	Yes	No
M-3	5187.6	5185.3	5186 - 5191	Yes	No	No
M-4	5187.9	5186.2	5177 - 5182	No	No	No
M-6a	5154.1	5153.0	5149 - 5152	No	No	No
M-6b	5158.9	5156.2	5154 - 5159	Yes	Yes	No
M-7s	5121.9	5120.6	5115.5-5118.5	No	No	No
M-7d	5121.9	5120.0	5090 - 5093	No	No	No
M-8s	5124.9	5121.8	5121 - 5124	No	Yes	No
M-8sa	5124.9	5119.4	5115 - 5118	No	No	No
M-8d	5120.8	5119.1	5070 - 5073	No	No	No
M-9s	5127.3	5123.3	5123 - 5126	No	Yes	No
M-9d	5122.9	5118.6	5107 - 5110	No	No	No
M-10s	5122.3	5118.1	5121.5-5124.5	Yes	No	No
M-10m	5121.7	5117.2	5112 - 5115	No	No	Yes
M-10d	5120.7	5116.3	5096 - 5099	No	No	No
M-11s	5128.5	5121.1	5120 - 5123	No	Yes	No
M-11d	5122.8	5117.6	5094 - 5097	No	No	No
M-12s	5080.3	5076.9	*1			
M-13	5121.8	5119.1	5113.25-5119.25	No	Yes	No
M-14s	5119.3	5117.4	5107 - 5113	No	No	No
M-14d	5119.6	5117.3	5084.7-5090.7	No	No	Yes
M-15	5118.4	5117.0	5104.5-5110.5	No	No	No
M-16	5118.9	5116.9	5107.5-5113.5	No	No	No
M-17	5114.7	5112.0	5105 - 5115	Yes	Yes	No
M-18d	5108.6	5105.4	5075.5-5081.5	No	No	Yes
M-19	5116.1	5114.2	5108 - 5114	No	No	No
M-20	5121.7	5120.6	*1			
M-21	5121.1	5119.5	5090.5-5096.5	No	No	No

*1 No log available.

Table 6 (continued)

WELL I.D.	HISTORIC HIGH ELEVATION	HISTORIC LOW ELEVATION	SCREENED INTERVAL ELEVATIONS	ADEQUATE TO DETECT LIGHT IMMISCIBLE COMPONENTS AT HISTORIC HIGH ELEVATIONS?	ADEQUATE TO DETECT LIGHT IMMISCIBLE COMPONENTS AT HISTORIC LOW ELEVATIONS?	ADEQUATE TO DETECT DENSE PHASE IMMISCIBLE COMPONENTS?
M-22	5121.1	5120.1	*1			No
M-23	5117.6	5116.8	5112.7-5117.7	Yes	Yes	No
M-24	5120.7	5119.4	5096.5-5102.5	No	No	Yes
M-25	5114.5	5113.5	5093.5-5099.5	No	No	Yes
M-26	5098.9	5095.3	5088.5-5094.5	No	No	No
M-27	5110.9	5108.5	5083.2-5089.2	No	No	No
M-29	5119.7	5118.0	5109 - 5119	No	Yes	Yes
M-30	5095.8	5093.3	5085.4-5091.5	No	No	Yes
M-31s	5120.4	5118.4	5106.5-5112.5	No	No	No
M-31m	5119.5	5118.1	5091.7-5097.7	No	No	Yes
M-32	5094.7	5092.2	5082 - 5092	No	No	Yes
M-33	5089.1	5085.5	5077 - 5087	No	Yes	Yes
M-34	5120.2	5118.5	5100.4-5110.4	No	No	No
M-35	5115.3	5112.2	5099.9-5109.9	No	No	No
M-36	5120.8	5118.5	5098.6-5118.6	No	Yes	No
M-37	5111.4	5109.2	5089.1-5114.5	Yes	Yes	Yes
M-49A	5126.1	5121.2	5119 - 5122	No	Yes	No
M-50As	No data	No data	5124 - 5127			Yes
M-50Ad	5122.3	5114.0	5121 - 5124	Yes	No	No
M-51As	5115.7	5114.0	5111 - 5114	No	Yes	No
M-51Am	5117.0	5115.2	5081 - 5084	No	No	No
M-51Ad	5115.7	5113.8	5059 - 5062	No	No	No
SP-1	5112.2	5110.9	*1			
SP-2	5098.8	5096.6	*1			
SP-3	5105.9	5105.5	*1			
SP-4	5103.5	5103.0	*1			
SP-4a	5102.7	5102.7	*1			
SP-5	5080.4	5076.6	5070.5-5074.2	No	No	Yes
SP-7	5080.4	5076.5	5071.0-5074.5	No	No	Yes
SP-8	5080.4	5076.4	5071.5-5075.1	No	No	Yes
SP-9	5080.3	5076.4	5073.5-5077.2	No	Yes	Yes
SP-10	5080.6	5076.7	5071.0-5074.5	No	No	Yes
SP-19	5077.4	5077.0	5071.0-5076.5	No	No	Yes
SP-23	5077.5	5075.4	5072.1-5075.4	No	Yes	Yes
SP-24	5084.2	5079.0	5076.4-5079.4	No	Yes	Yes

Table 6 (continued)

WELL I.D.	HISTORIC HIGH ELEVATION	HISTORIC LOW ELEVATION	SCREENED INTERVAL ELEVATIONS	ADEQUATE TO DETECT LIGHT IMMISCIBLE COMPONENTS AT HISTORIC HIGH ELEVATIONS?	ADEQUATE TO DETECT LIGHT IMMISCIBLE COMPONENTS AT HISTORIC LOW ELEVATIONS?	ADEQUATE TO DETECT DENSE PHASE IMMISCIBLE COMPONENTS?
SP-25	5080.1	Dry	*1			
SP-26	5080.3	5076.5	*1			
SP-27	5080.3	Dry	*1			
SP-28	5080.1	5076.2	5071.5-5079.5	No	Yes	No
SP-29	5077.0	5075.3	5074.3-5077.8	Yes	Yes	Yes
SP-30	5077.5	5076.0	5070.6-5079.8	Yes	Yes	Yes
SP-31	5077.9	5076.4	5073.0-5080.0	Yes	Yes	Yes
SP-32	5077.4	5075.8	*2			Yes

*2 Log does not indicate elevation.

Task Force. The first area is located east of the CEP and North Land Farm. As noted in Plate 1 Section A-A', a paleo-channel (top of bedrock depression) occurs east of the HWMUs. In addition, the Teapot Sandstone subcrops in or near this bedrock depression. Based on well logs, the Teapot Sandstone has at best a single well located so as to monitor ground-water quality of this unit. Because this unit is used as a water supply down-dip (towards the northeast), the Task Force recommends both the installation of additional wells to characterize water quality on Texaco property, and sampling of wells down-dip to determine if contamination has migrated off-site.

The second area of concern noted by the Task Force is the lack of monitoring wells located south and southwest of the HWMUs. This area is characterized by the shaley unnamed middle member. Previous technical reports submitted by Texaco indicate that this unit acts as a ground water barrier, and that flow is diverted on both sides of this unit (i.e. to the southwest and southeast). However, it appears that locally this shaley unit may be hydraulically connected with the surrounding units (i.e., the colian and alluvial deposits). Evidence to substantiate this is based on the fact that two wells (M-9d and M-10d) have shown contamination in the past. The Task Force recommends that additional wells be installed south and southwest of the HWMUs in the unnamed middle member. The installation of additional wells in this area would also provide data on the impact that the SWMUs may have on ground water. In addition, it is evident based on Figure 19 that an inadequate number of wells are installed adjacent to the Excess Service Water Effluent Ponds to evaluate potential release from this SWMU. Based on the geology and hydrogeology of the area and past analytical data, the wells located along the western property boundary are adequately located from a horizontal viewpoint.

Design and specifications of the wells located within the North Area are presented in Table 7. Additional information related to the technical adequacy of the construction of these wells are presented in Table 8. In assessing the technical merit of the monitoring system, only generalized inadequacies will be mentioned. The reader is referred to Tables 7 and 8 for specific construction inadequacies of each monitoring well.

All wells were drilled by rotary or hollow stem auger methods. The Task Force noted that two different types of drilling fluids were used during construction of some of the wells. Table 9 lists the type of drilling fluid and the associated wells. All other wells used air and/or water, or used a hollow stem auger where no fluid is necessary.

tab-b
slh

Table 7
Monitoring Well Specifications
(North Area)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
M-1	11/24/81	5227	50'	4"	Sch 40 gv st	39-44'	0.10"	8-12 frac sand	Eolian Sand	Uppermost aquifer
M-2	11/25/81	5201'	32'	4"	Sch 40 gv st	21-26'	0.10"	1/4" pea grav & 8-12 frac sd.	Eolian Sand	Uppermost aquifer
M-3	12/2/81	5201'	15'	4"	Sch 40 gv st	10-15'	0.10"	1/4" pea grav & 8-12 frac sd.	Eolian Sand Teapot Sand	Uppermost aquifer
M-4	12/4/81	5201'	26'	4"	Sch 40 gv st	19-24'	0.10"	1/4" pea grav & 8-12 frac sd.	Eolian Sand Teapot Sand	Uppermost aquifer
M-5	12/1/81	NA	100'						DRY, PLUGGED AND ABANDONED	
M-6a	12/4/81	5179'	40'	4"	Sch 40 gv st	27-30'	0.020"	12-20 frac sand	Eolian Sand Teapot Sand	Uppermost aquifer
M-6B	12/11/81	5178'	33'	4"	Sch 40 gv st	19-24'	0.10"	1/4 pea grav & 8-12 frac sd.	Eolian Sand Teapot Sand	Uppermost aquifer
M-7s	1/8/82	5142'	26.5'	4"	Sch 40 gv st	23.5-26.5'	0.020"	12-20 frac sand	Eolian Sand Teapot Sand	Uppermost aquifer
M-7d	12/5/81	5142'	60'	4"	Sch 40 gv st	49.52'	0.020"	Drill cuttings	Eolian Sand Teapot Sand	Uppermost aquifer
M-8s	1/8/82	5138'	20'	4"	Sch 40 gv st	14-17'	0.020"	12-20 frac sand	Eolian Sand	Uppermost aquifer

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
M-8sa	1/10/82	5137'	40'	4"	Sch 40 gv st	19-22'	0.020	8-12 frac sand	Eolian Sand	Uppermost aquifer
M-8d	1/18/82	5140'	70'	4"	Sch 40 gv st	67-70'	0.200"	Drill cuttings	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-9a	1/27/82	5144'	22'	4"	Sch 40 gv st	18-21'	0.020"	12-20 frac sand	Eolian Sand Teapot Sand	Uppermost aquifer
M-9d	1/27/82	5144'	38'	4"	Sch 40 gv st	34-37'	0.020"	12-20 frac sand	Unnamed Middle Mbr.	Unnamed Middle mbr.
M-10a	1/11/82	5144'	25'	4"	Sch 40 gv st	19.5-22.5'	0.020"	12-20 frac sand	Eolian Sand Teapot Sand	Uppermost aquifer
M-10a	1/25/82	5144'	35'	4"	Sch 40 gv st	29-32'	0.020"	Drill cuttings	Teapot Sand Unnamed M. Mbr.	Uppermost aquifer
M-10d	1/25/82	5144'	50'	4"	Sch 40 gv st	45-48'	0.020"	Drill cuttings	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-11a	1/26/82	5141'	22'	4"	Sch 40 gv st	18-21'	0.020"	Drill cuttings	Eolian Sand Teapot Sand	Uppermost aquifer
M-11d	1/26/82	5141'	50'	4"	Sch 40 gv st	44-47'	0.020"	Drill cuttings	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-12a	4/15/82	*1	9.5'			5-9'			Alluvium	Alluvium
M-13	6/25/82	5143'	67'	2"	PVC	21.75-27.75'	0.020"	8-16 & 12-20 Eolian Sand	Eolian Sand	Uppermost aquifer

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
M-14a	7/10/82	5135'	28'	2"	PVC	22-28'	0.020"	12-20 Silica Sand	Eolian Sand	Uppermost aquifer
M-14d	7/9/82	5135'	70'	2"	PVC	44.3-50.3'	0.020"	12-20 Silica Sand	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-15	7/11/82	5137'	32.5'	2"	PVC	26.5-32.5'	0.020"	12-20 Silica Sand	Basal Clay	Uppermost aquifer
M-16	7/10/82	5135'	28'	2"	PVC	21.5-27.5'	0.020"	12-20 Silica Sand	Eolian Sand Basal Clay	Uppermost aquifer
M-17	7/13/82	5131'	27.8'	2"	PVC	16-26'	0.020"	12-20 Silica Sand	Eolian Sand Basal Clay	Uppermost aquifer
M-18d	7/12/82	5129'	53.5'	2"	PVC	47.5-53.5'	0.020"	12-20 Silica Sand	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-19	7/11/82	5128'	20'	2"	PVC	14-20'	0.020"	12-20 Silica Sand	Eolian Sand	Uppermost aquifer
M-20	6/17/82	NA	32'	4"	Sch 40 st	22.5-25.5'	0.020"	12-20 frac sand	Eolian Sand	Uppermost aquifer
M-21	7/8/82	5137'	52'	2"	PVC	40.5-46.5'	0.020"	12-20 Silica Sand	Eolian Sand	Uppermost aquifer
M-22	6/16/82	NA	44.8'	4"	Sch 40 gv st	24-30'	0.016"	12-20 frac sand	Eolian Sand	Uppermost aquifer
M-23	6/19/82	5130'	27.5'	2"	PVC	12.3-18.3'	0.020"	12-20 frac sand	Eolian Sand	Uppermost aquifer

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
M-26	7/7/82	5144'	48'	2"	PVC	41.5-47.5	0.020"	12-20 Silica Sand	Sandy siltstone	Uppermost aquifer
M-25	7/7/82	5124'	36'	2"	PVC	24.5-30.5'	0.020"	12-20 & 8-16 Silica Sand	Basal siltstone	Uppermost aquifer
M-26	6/20/82	5101'	16'	2"	PVC	6.5-12.5	0.020"	12-20 Silica Sand	Eolian Sand	Uppermost aquifer
M-27	6/20/82	5116'	33'	2"	PVC	26.8-32.8'	0.020"	12-20 Silica Sand	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-28	7/13/82	NA	26'	HOLE PLUGGED AND ABANDONED						
M-29	7/13/82	5135'	27.5'	2"	PVC	16-26'	0.020"	12-20 Silica Sand	Eolian Sand Basal Clay	Uppermost aquifer
M-30	6/20/82	5099'	16'	2"	PVC	7.5-13.6'	0.020"	12-20 Silica Sand	Eolian Sand	Uppermost aquifer
M-31s	6/29/82	5140'	33.5'	2"	PVC	27.1-33.1'	0.020"	Clean drill cuttings	Eolian Sand	Uppermost aquifer
M-31m	6/30/82	5139.5'	59'	2"	PVC	41.8-47.8'	0.020"	Clean drill cuttings	Basal Clay	Uppermost aquifer
M-32	7/15/82	5095'	14'	2"	PVC	3-13'	0.020"	12-20 Silica Sand	Eolian Sand, Basal Clay, Unn. M. Mbr.	Uppermost aquifer

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
M-33	7/15/82	5099'	23'	2"	PVC	12-22'	0.018"	8-16 Silica Sand	Basal Clay Unnamed M. Mbr.	Uppermost aquifer
M-34	7/15/82	5140'	39.5'	2"	PVC	29.6-39.5'	0.018"	12-20 Silica Sand	Basal Clay	Uppermost aquifer
M-35	7/15/82	5128'	29.5'	2"	PVC	18.1-28.1	0.018"	8-16 & 12-20 Silica Sand	Basal Clay	Uppermost aquifer
M-36	3/29/84	5138.6'	40'	4"	Sch 40 PVC	20-40'	0.020"	Drill cuttings	NA	Uppermost aquifer
M-37	9/20/84	5119.9'	31.5'	4"	Sch 40 PVC 1120	5.4-30.8'	0.025"	8-16 frac sand	Sand & gravel	Uppermost aquifer
M-49A	1/24/82	5141'	25'	4"	Sch 40 gv st	19-22'	0.020"	Drill cuttings	Eolian Sand	Uppermost aquifer
M-50Aa	1/26/82	5142'	22'	4"	Sch 40 gv st	18-21'	0.020"	Yes	Eolian Sand	Uppermost aquifer
M-50Ad	1/12/82	N.A.	56'	4"	Sch 40 gv st	52-55'	0.020"	12-20 frac sand	Unnamed Middle Mbr.	Unnamed Middle Mbr.
M-51Aa	1/10/82	5124'	15'	4"	Sch 40 gv st	10-13'	0.020"	12-20 frac sand	Backfilled Eolian Sand	Uppermost aquifer
M-51Am	1/20/82	5124'	45'	4"	Sch 40 gv st	40-43'	0.020"	Drill cuttings	Unnamed Middle Mbr.	Unnamed Middle Mbr.
A-51Ad	1/22/82	5123'	70'	4"	Sch 40 gv st	61-64'	0.020"	Drill cuttings	Unnamed Middle Mbr.	Unnamed Middle Mbr.

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
SP-1	3/26/82	*1	9'			5-8.5'			Eolian Sand	Uppermost aquifer
SP-2	4/15/82	*1	8'			4-7.5'			Unnamed Middle Mbr.	Unnamed Middle Mbr.
SP-3	4/15/82	*1	5'			1-4.5'			Eolian Sand	Uppermost aquifer
SP-4	4/15/82	*1	11'			7-10.5'			Unnamed Middle Mbr.	Unnamed Middle Mbr.
SP-4A										
SP-5	6/22/82	5079'	9'	2"	Sch 40 gv st	4.8-8.5'	0.020"	12-20 Silica Sand	Alluvium	Alluvium
SP-7	6/22/82	5081'	13.2'	2"	Sch 40 gv st	6.5-10'	0.020"	12-20 Silica Sand	Alluvium	Alluvium
SP-8	6/22/82	5082'	11.2'	2"	Sch 40 gv st	6.9-10.5'	0.020	12-20 Silica Sand	Alluvium	Alluvium
SP-9	6/22/82	5082'	9'	2"	Sch 40 gv st	4.8-8.5'	0.020"	12-20 Silica Sand	Alluvium	Alluvium
SP-10	6/22/82	5081'	14'	2"	Sch 40 gv st	6.5-10'	0.020"	12-20 Silica Sand	Alluvium	Alluvium
SP-19	6/28/82	5081'	8.5'	2"	Sch 40 gv st	4.5-7.8'	0.020"	Clean drill cuttings	Alluvium	Alluvium

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
SP-20	"2									
SP-21	"2									
SP-22	"2									
SP-23	6/29/82	5080'	9.3'	2"	Sch 40 gv st	4.6-7.9'	0.020"	Clean drill cuttings	Alluvium	Alluvium
SP-24	7/15/82	5089'	13'	2"	gv st	9.6-12.6'	0.020"	8-16 Silica Sand	Alluvium	Alluvium
SP-25	"2									
SP-26	"2									
SP-27	"2									
SP-28	3/29/84	5081.5'	10'	2"	PVC	2-10'	0.020"	Clean drill cuttings	Sand and gravel	Alluvium
SP-29	9/19/84	5079.8'	5.7'	4"	Sch 40 PVC 1120	2-5.5'	0.025"	8-16 frac sand	Soil - clay - sand	Alluvium
SP-30	9/19/84	5083.3'	12.9'	4"	Sch 40 PVC 1120	3.5-12.7'	0.025"	Clean sand and gravel	Sand and gravel	Alluvium

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Table 7 (continued)

WELL I.D.	DATE DRILLED	SURFACE ELEVATION (feet above mean sea level)	TOTAL DEPTH (feet below surface)	CASING DIAMETER (inches)	CASING TYPE	SCREENED INTERVAL (feet below surface)	SLOT OR PERF. SIZE (inches)	SAND PACK	SCREENED UNIT	WATER BEARING UNIT
SP-31	9/19/84	5083.0'	10.0'	4"	Sch 40 PVC 1120	3-10'	0.025"	Natural sand and gravel	Sand and gravel	Alluvium
SP-32	9/21/84	NA	10.5'	4"	Sch 40 PVC 1120	3.6-10.4'	0.025"	Natural sand and gravel	Sand and gravel	Alluvium

*1 No log; partial information obtained from well inventory sheets.

*2 Information unavailable.

NA Information not specified on completion details.

Table 8

Technical Adequacy of Monitoring Wells (North Area)
(Depth and Thicknesses in Feet)

Well I.D.	Water Bearing Unit	Total Depth of Borehole	Bentonite Bottom Seal Implaced in Borehole?	Thickness of Filter Pack and/or Drill Cuttings Above Well Screen	Thickness of Bentonite Seal	Thickness of Drill Cuttings Above Bentonite Seal	Cement Annular Seal?	Surface Seal?
M-1	upper aquifer	50	Yes	0	*1	-25	No	Yes
M-2	upper aquifer	32	Yes	0	*1	-10	No	Yes
M-3	upper aquifer	15	No	0	*1	- 4	No	Yes
M-4	upper aquifer	24	No	0	*1	-12	No	Yes
M-6a	upper aquifer	30	No	12	*1	- 5	No	Yes
M-6b	upper aquifer	24	No	3	*1	- 5	No	Yes
M-7s	upper aquifer	26.5	No	8.5	*1	- 6	No	Yes
M-7d	upper aquifer	52	No	1	8	-37	No	Yes
M-8s	upper aquifer	17	No	2	*1	- 5	No	Yes
M-8sa	upper aquifer	22	No	7	3	6	No	Yes
M-8d	unnamed Midl. Mbr.	70	No	10	*1	-47	No	Yes
M-9s	upper aquifer	21	No	3	*1	- 7	No	Yes
M-9d	unnamed Midl. Mbr.	37	No	2	*1	-17	No	Yes
M-10s	upper aquifer	22.5	No	2.5	*1	- 9	No	Yes
M-10m	upper aquifer	32	No	1	*1	-22	No	Yes
M-10d	unnamed Midl. Mbr.	43	No	2	*1	-32	No	Yes
M-11s	upper aquifer	21	No	-15	0	N/A	No	Yes
M-11d	unnamed Midl. Mbr.	47	No	4	*1	-30	No	Yes
M-12s	alluv. aquifer	*2						
M-13	upper aquifer	67	No	4.75	14.75	0	Yes	Yes

*1 Thickness unknown, but appears adequate.

N/A Not applicable.

*2 Well log unavailable; information taken from well inventory data sheets.

Table 8 (continued)

Well I.D.	Water Bearing Unit	Total Depth of Borehole	Bentonite Bottom Seal Implaced in Borehole?	Thickness of Filter Pack and/or Drill Cuttings Above Well Screen	Thickness of Bentonite Seal	Thickness of Drill Cuttings Above Bentonite Seal	Cement Annular Seal?	Surface Seal?
M-14s	upper aquifer	28	No	16.5	4	0	Yes	Yes
M-14d	upper/un. Midl. Mbr.	70	No	19.7	22	1	No	Yes
M-15	upper aquifer	32.5	No	10.5	14	0	Yes	Yes
M-16	upper aquifer	28	No	15.5	4	0	Yes	Yes
M-17	upper aquifer	27.8	No	8	5	0	Yes	Yes
M-18d	upper aquifer	53.5	No	19.5	15	11	No	Yes
M-19	upper aquifer	20	No	8	4	0	Yes	Yes
M-20	upper aquifer	32	No	15.5	4.5	0	Yes	Yes
M-21	upper aquifer	52	No	24.5	11.5	0	Yes	Yes
M-22	upper aquifer	44.8	No	17.5	5	0	Yes	Yes
M-23	upper aquifer	27.5	No	6.3	4	0	Yes	Yes
M-24	upper aquifer	48	No	35	5.5	0	Yes	Yes
M-25	upper aquifer	36	No	20.5	3	0	Yes	Yes
M-26	upper aquifer	16	Yes	2.5	2	0	Yes	Yes
M-27	unnamed Midl. Mbr.	33	No	20.8	4	0	Yes	Yes
M-29	upper aquifer	27.5	No	8	5	0	Yes	Yes
M-30	upper aquifer	16	Yes	3.5	2	0	Yes	Yes
M-31s	upper aquifer	33.5	No	23.1	3	0	Yes	Yes
M-31m	upper aquifer	59	No	36.8	2.6	0	Yes	Yes
M-32	upper aquifer	14	No	0.5	0	N/A	Yes	Yes
M-33	upper/unm. Midl. Mbr.	23	No	4	4	0	Yes	Yes
M-34	upper aquifer	39.5	No	14.5	7	5	No	Yes
M-35	upper aquifer	29.5	No	10.8	4	0	Yes	Yes
M-36	upper aquifer	40	No	-17	*1	*3	No	No
M-37	upper aquifer	31.5	No	3.4	0	*3	Yes	Yes
M-49A	upper aquifer	25	No	-16	0	*3	Yes	Yes

*3 Bentonite seal to surface.

Table 8 (continued)

Well I.D.	Water Bearing Unit	Total Depth of Borehole	Bentonite Bottom Seal Implaced in Borehole?	Thickness of Filter Pack and/or Drill Cuttings Above Well Screen	Thickness of Bentonite Seal	Thickness of Drill Cuttings Above Bentonite Seal	Cement Annular Seal?	Surface Seal?
M-50As	upper aquifer	22	Yes	-15	0	* 3	Yes	Yes
M-50Ad	unnamed Midl. Mbr.	56	No	0	*1	- 2	No	Yes
M-51As	upper aquifer	15	No	-5	*1	- 2	No	Yes
M-51Am	unnamed Midl. Mbr.	45	No	3	7	-27	No	Yes
M-51Ad	unnamed Midl. Mbr.	70	No	1	10	-47	No	Yes
SP-1	upper aquifer	9	*2					
SP-2	unnamed Midl. Mbr.	8	*2					
SP-3	upper aquifer	5	*2					
SP-4	unnamed Midl. Mbr.	11	*2					
SP-4a	*4							
SP-5	alluv. aquifer	9	No	6.83	1	1	No	No
SP-7	alluv. aquifer	13.2	No	-4	2	1	No	No
SP-8	alluv. aquifer	11.2	No	4.92	3	1	No	No
SP-9	alluv. aquifer	9	No	2.33	2.5	0	No	No
SP-10	alluv. aquifer	14	Yes	2.5	2	2	No	No
SP-19	alluv. aquifer	8.5	No	4.5	0	N/A	No	No
SP-23	alluv. aquifer	9.3	No	4.6	0	N/A	No	No
SP-24	alluv. aquifer	13	No	6.6	3	*3	No	No
SP-25	*4							
SP-26	*4							
SP-27	*4							
SP-28	alluv. aquifer	10	No	*3	2	N/A	No	No
SP-29	alluv. aquifer	5.7	No	0	0	N/A	Yes	Yes
SP-30	alluv. aquifer	12.9	No	0.5	0	N/A	Yes	Yes
SP-31	alluv. aquifer	10	No	1	0	N/A	Yes	Yes
SP-32	alluv. aquifer	10.5	No	0.4	0	N/A	Yes	Yes

*4 Well log and well inventory data sheets unavailable.

Table 9
Drilling Fluid Utilized (North Area Wells)

<u>Hydro-gel</u>	<u>Baroid foam</u>
M-1	M-6a
M-2	M-6b
M-3	M-7s
M-4	
M-5	
M-7s	
M-7d	

According to the TEGD, Texaco should provide chemical data regarding any potential impacts on water quality the drilling fluid may have (EPA, 1986a).

According to Texaco, most of the wells in the system are designed and constructed in the colian sands and the Teapot Sandstone (upper aquifer). It should be noted that contrary to the various technical reports, the Teapot Sandstone is not being monitored directly except for possibly in one well (M-35).

Completion details show that many of the wells were drilled several feet deeper than the bottom of the screen was set (Appendix B). This interval was filled with drill cuttings and/or 12-20 frac sand, providing a potential pathway for downward migration of contaminants. Very few of these wells used a bentonite or equivalent bottom seal as depicted in Table 8. The TEGD recommends a bottom seal for the same reason as noted above (EPA, 1986a).

In virtually every well, the filter pack (consisting of drill cuttings and/or 12-20 frac sand) extended well above the well screen. As presented in Table 8, this interval ranged upwards to 36.8 feet. In order to ensure discrete sample horizons, the filter pack should extend no more than two feet above the well screen (EPA, 1986a). Completion details in some cases do not specify the thickness of the bentonite annular seal (Appendix B). From a qualitative standpoint, however, it appears that the thickness is adequate in most cases. Several of the wells, most notably the SP- series, do not utilize a bentonite annular seal. Most of these have a cement surface seal, however. The Task Force noted that two wells, SP-19 and SP-23, did not use either a (annular) bentonite or a cement (surface) seal.

Table 8 also indicates the thickness of drill cuttings above the bentonite seal and below the cement surface seal. The TEGD recommends this interval be filled with a cement-bentonite grout (EPA, 1986a). Finally, Table 8 indicates which wells used a cement based annular seal and a surface seal in their construction, as depicted from the completion details.

Completion details specify that all monitoring wells were constructed of either galvanized steel or PVC (Appendix B). According to the details, at least two wells were constructed using dissimilar metals. Wells M-20 and M-22 were constructed using a stainless steel screen and a galvanized steel casing. Additional wells may have been constructed using stainless steel

screens, but were not indicated in the well completion details. The TEGD (EPA, 1986a) recommends avoiding the use of dissimilar metals in the saturated zone unless a dielectric coupling is placed between the two metals.

Potential problems may exist when PVC is used in contact with aqueous organic mixtures. These organics may encourage leaching from or adsorption to the PVC polymer matrix. There has been recent concern over the potential of vinyl chloride monomer to leach from PVC casing, which in some cases may cause organic analytical interferences in situations where prolonged exposure to aqueous organic mixtures may occur (Barcelona and others, 1983). In certain situations under high organic concentrations, PVC may also adsorb organic constituents (Barcelona and others, 1983).

Furthermore, PVC in contact with organics, particularly benzene, is not recommended because of problems with long term structural integrity of the well. In the future Texaco should review all available data/information on casing materials carefully and make a selection accordingly before installing new wells. This would be important at wells which exhibit significant organic accumulations, especially since long term monitoring is probable.

In addition, the type, method and duration of well development have not been specified. Turbidity measurements during the Task Force evaluation indicate generally high values. Most wells exceeded the recommended limit of 5 N.T.U. (EPA, 1986a). Completion details often did not specify if a protective casing with a locking device was emplaced over the wells. The purpose of this is to prevent tampering with the well or entrance of foreign material (EPA, 1986a). Finally, decontamination of equipment and well casing were not specified.

Past Analytical Performance A ground-water pollution abatement plan was requested by EPA in November 1982, and the following month, the plan was implemented. As part of the plan, Texaco began treatment of the CEP water by mechanical aeration in December 1982 (WWC, 1984a). In November 1983, the treated water from the CEP was discharged to the Excess Service Water Effluent Ponds. Texaco stated that even though the resulting sludge contained up to 2.4 percent lead, EP toxicity tests indicated that the sludge was non-hazardous (WWC, 1984a). The sludge was removed from the CEP in 1986 and disposed of in the North Land Farm. As previously mentioned, approximately half of the monitoring wells located in the North Area are sampled quarterly as part of Texaco's assessment program. The purpose is to evaluate the rate, extent and concentration of contamination emanating from the CEP. The remainder of the wells are sampled semi-annually or annually. The specific well and the sampling frequency are presented in Table 10.

The parameters Texaco monitors pursuant to 40 CFR 265.93(d)(4)(ii) include: specific conductance, pH, TOC, total ammonia, total chloride, phenols, sulfide, total sodium, cyanide, nitrate, oil and grease, total sulfate, total arsenic, total barium, total cadmium, total chromium, total lead, total mercury, total selenium and total silver. Analytical results for the above parameters have been provided to the Task Force from March 1982 through December 1987 (WWC, 1984a, 1985, 1987a and 1988). Additional analyses were done between March 1982 and December 1984 on the following

Table 10 Monitoring Frequency of Wells on North Property for 1987.

Quarterly		Semi-Annually	Annually
<u>Uppermost Aquifer</u>			
M-7s	M-30	M-1	M-7d
M-8sa	M-32	M-2	M-15
M-9s	M-33	M-3	M-20
M-10s	M-36	M-4	M-21
M-10m	M-37	M-6b	M-22
M-11s	M-49A		M-23
M-13	M-51As		M-24
M-14s	SP-1		M-25
M-16	SP-3		M-29
M-17			M-31s
M-19			M-31m
M-26			M-34
			M-35
<u>Unnamed Middle Member</u>			
	M-9d		M-8d
	M-10d		M-11d
			M-14d
			M-18d
			M-27
			M-50Ad
			M-51Am
			M-51Ad
			SP-2
			SP-4A
<u>Alluvial Aquifer</u>			
	M-12s		SP-5
	SP-7		SP-9
	SP-23		SP-8
	SP-28		SP-10
	SP-29		SP-24
	SP-30		SP-26
	SP-31		
	SP-32		
<u>Surface Water</u>			
North Platte River		ESW-1a	
Recharge Pond		ESW-2a	
		ESW-5a	

Source: WWC, 1988.

parameters: DOC, TOX, alkalinity, aluminum, dissolved ammonia, dissolved arsenic, total barium, beryllium, boron, dissolved cadmium, calcium, dissolved chloride, dissolved chromium, cobalt, copper, coliform bacteria, fluoride, the herbicides 2,4-D and 2,4,5-TP Silvex, iron, dissolved lead, lithium, magnesium, manganese, dissolved mercury, nickel, nitrite, the pesticides endrin, lindane, methoxychlor and toxaphene, potassium, gross alpha, gross beta, Ra-226, Ra 228, Sr-90, uranium, dissolved selenium, dissolved silver, dissolved sodium, dissolved sulfate, total dissolved solids, vanadium and zinc.

In addition to the above "regular" analyses, four separate sampling events were held in the past. In March and September of 1984, Texaco monitored for the organic priority pollutants, and in June of 1986 for the modified Skinner list (TriHydro, 1987a). The Task Force evaluation was the fourth event. Twenty-three monitoring wells, two seeps and the alluvial pond were sampled during the first three events. The sampling locations and the results of the organic analyses are presented in Figure 10 and Table 11, respectively. The inorganic results are too massive to be included in the report or as an Appendix, but may be found in Volume III of the TriHydro (1987a) report.

The results of past organic analyses indicate that contamination exists in the North Area, primarily centered around the CEP and North Land Farm. The volatile organics benzene and toluene were detected at concentrations of less than 1000 ug/l near the regulated units during past sampling events. These two volatiles were not detected or were detected at extremely low concentrations in wells located along the western property boundary and the alluvial wells. Methyl ethyl ketone was also detected in wells M-32 and M-36 (Figure 10).

The base/neutral extractable organic bis(2-ethylhexyl)phthalate was detected at most sampling locations, including several wells along the western property boundary during the two events held in 1984. Because this constituent was not detected during the Task Force evaluation, it seems likely that these results may be due to laboratory or sampling related contaminants. Texaco has not presented any supporting information suggesting either of the above, however. Naphthalene was either not detected or not analyzed in the past.

Minor concentrations of the pesticides chlordane and heptachlor were detected in wells M-10s, M-10d and M-36 in 1986. Several acid extractable organics also were found in the ground water in the past. Again, these are generally confined to the wells surrounding the two regulated units. These constituents include benzenethiol, cresols, 2,4-dimethylphenol and phenol. Of importance, cresol was detected in concentrations up to 289,000 ug/l. It is interesting to note that this constituent may exist as a dense phase and that the highest concentrations of cresol were detected in wells screened at or near the upper aquifer/shale interface. From the above discussion and Table 11, wells M-10m and M-36 appear to be the most contaminated of all wells located in the North Area. Samples analyzed for a complete set of organic constituents in the wells near the Excess Service Water Effluent Ponds have not been collected prior to the Task Force evaluation. Two

Table 11 Organic Hazardous Constituents Detected In Ground Water, Casper Plant North Property.*

Well Number and Date Sampled	Volatile Organics			Base/Neutral Extractable Organics		Pesticides	
	Benzene	Methyl ethyl ketone	Toluene	Naphthalene	Bis(2-ethylhexyl)phthalate	Chlordane	Heptachlor
<u>M-7s (Background)</u>							
3-21-84	ND	ND	ND	ND	0.005	NA	NA
6 -86	ND	ND	ND	NA	NA	NA	NA
<u>M-10s</u>							
7 -86	0.012	ND	0.018	0.043/0.040J	ND	0.048	ND
<u>M-10m</u>							
3-21-84	0.330	ND	0.945	ND	0.171	NA	NA
6 -86	0.150	ND	0.800	NA	NA	NA	NA
<u>M-10d</u>							
7 -86	0.057	ND	0.012	ND	ND	ND	0.00026
<u>M-12s</u>							
9-21-84	ND	ND	ND	ND	0.066	NA	NA
6 -86	ND	ND	0.005	NA	NA	NA	NA
7 -86	0.0032J	ND	ND	ND	ND	ND	ND
<u>M-30</u>							
3-21-84	ND	ND	ND	ND	0.073	NA	NA
<u>M-32</u>							
3-21-84	ND	ND	ND	ND	0.10	NA	NA
9-21-84	ND	ND	ND	ND	0.10	NA	NA
6 -86	ND	0.011	ND	NA	NA	NA	NA
<u>M-33</u>							
3-21-84	ND	ND	ND	ND	0.132	NA	NA
7 -86	ND	ND	ND	ND	ND	ND	ND
<u>M-35</u>							
7 -86	ND	ND	ND	ND	ND	ND	ND

* All units are in mg/L.

NA - Not Analyzed

ND - Non Detectable

J - Indicates an estimated value where the measured value is less than the method detection limit but greater than 0.

Source: TriHydro 1987a

Table 11 Organic Hazardous Constituents Detected in Ground Water, Casper Plant North Property (continued).

Well Number and Date Sampled	Volatile Organics			Base/Neutral Extractable Organics		Pesticides	
	Benzene	Methyl ethyl ketone	Toluene	Naphthalene	Bis(2-ethylhexyl)phthalate	Chlordane	Heptachlor
<u>M-36</u>							
6 -86	0.230	0.520	0.330	NA	NA	NA	NA
7 -86	0.310	0.670	0.410	ND	ND	0.480	ND
7 -86 (duplicate)	0.270	0.570	0.360	ND	ND	0.300	ND
<u>M-49A</u>							
3-21-84	0.13	ND	0.10	ND	ND	ND	NA
6 -86	0.16	ND	0.410	NA	ND	NA	NA
<u>M-51A₂</u>							
7 -86	0.076	ND	0.034	ND	ND	ND	ND
<u>SP-1</u>							
3-21-84	0.058	ND	ND	ND	0.071	NA	NA
<u>SP-3</u>							
3-21-84	0.15	ND	0.22	ND	0.10	NA	NA
9-21-84	0.089	ND	0.12	ND	0.072	NA	NA
6 -86	0.080	ND	0.099	NA	NA	NA	NA
<u>SP-7</u>							
9-21-84	ND	ND	ND	ND	0.066	NA	NA
<u>SP-9</u>							
9-21-84	ND	ND	ND	ND	0.12	NA	NA
<u>SP-10</u>							
9-21-84	ND	ND	ND	ND	0.064	NA	NA
<u>SP-23</u>							
9-21-84	ND	ND	ND	ND	0.019	NA	NA
<u>SP-28</u>							
9-21-84	ND	ND	ND	ND	0.011	NA	NA
<u>SP-29</u>							
9-21-84	ND	ND	ND	ND	0.030	NA	NA

* All units are in mg/L.

NA - Not Analyzed

ND - Non Detectable

J - Indicates an estimated value where the measured value is less than the method detection limit but greater than 0.

Table 11 Organic Hazardous Constituents Detected In Ground Water, Casper Plant North Property (continued).

Well Number and Date Sampled	Volatile Organics			Base/Neutral Extractable Organics		Pesticides	
	Benzene	Methyl ethyl ketone	Toluene	Naphthalene	Bis(2-ethylhexyl)phthalate	Chlordane	Heptachlor
<u>SP-30</u> 9-21-84	ND	ND	ND	ND	0.010	NA	NA
<u>SP-31</u> 9-21-84	ND	ND	ND	ND	0.056	NA	NA
<u>SP-32</u> 9-21-84	ND	ND	ND	ND	0.028	NA	NA
<u>Seep #3</u> 9-21-84	ND	ND	ND	ND	0.024	NA	NA
<u>Seep #4</u> 9-21-84	ND	ND	ND	ND	0.052	NA	NA
<u>Alluvial Pond</u> 9-21-84	ND	ND	ND	ND	0.050	NA	NA

88

• All units are in mg/L.

NA - Not Analyzed

ND - Non Detectable

J - Indicates an estimated value where the measured value is less than the method detection limit but greater than 0.

Table 11 Organic Hazardous Constituents Detected In Ground Water, Casper Plant North Property.*

Well Number and Date Sampled	Acid-Extractable Organics					
	Benzenethiol	Cresols	2,4-Dimethylphenol	2,4-Dinitrophenol	4-Nitrophenol	Phenol
<u>M-7s (Background)</u>						
3-21-84	ND	ND	ND	ND	ND	ND
6 -86	ND	ND	ND	ND	ND	ND
<u>M-10s</u>						
7 -86	ND	0.048/0.060J	0.023/0.031J	0.000J	0.0665/0.380	0.008/0.010J
<u>M-10m</u>						
3-21-84	1.0	289	29	ND	ND	130
6 -86	0.12	32	5.0	ND	ND	8.4
<u>M-10d</u>						
7 -86	ND	ND	1.1	ND	ND	ND
<u>M-12s</u>						
9-21-84	ND	ND	ND	ND	ND	ND
6 -86	ND	ND	ND	ND	ND	ND
7 -86	0.014J	ND	ND	ND	ND	ND
<u>M-30</u>						
3-21-84	ND	ND	ND	ND	ND	ND
<u>M-32</u>						
3-21-84	ND	ND	ND	ND	ND	ND
9-21-84	ND	ND	ND	ND	ND	ND
6 -86	ND	ND	ND	ND	ND	ND
<u>M-33</u>						
3-21-84	ND	ND	ND	ND	ND	ND
7 -86	ND	ND	ND	ND	ND	ND
<u>M-35</u>						
7 -86	ND	0.0032J	ND	ND	ND	0.0038J

* All units are in mg/L.

NA - Not Analyzed

ND - Non Detectable

J - Indicates an estimated value where the measured value is less than the method detection limit but greater than 0.

Table 11 Organic Hazardous Constituents Detected In Ground Water, Casper Plant North Property (continued).

Well Number and Date Sampled	Acid-Extractable Organics					
	Benzenethiol	Cresols	2,4-Dimethylphenol	2,4-Dinitrophenol	4-Nitrophenol	Phenol
<u>M-36</u>						
6 -86	4.00	170	25	ND	ND	64
7 -86	ND	143	14	ND	ND	64
7 -86 (duplicate)	ND	136	13	ND	ND	62
<u>M-49A</u>						
3-21-84	ND	214	19	ND	ND	84
6 -86	ND	93	12	ND	ND	49
<u>M-51As</u>						
7 -86	ND	1.676J	2	ND	ND	ND
<u>SP-1</u>						
3-21-84	0.012	0.033	0.33	ND	ND	ND
<u>SP-3</u>						
3-21-84	0.11	30	7.9	ND	ND	0.14
9-21-84	ND	ND	6.5	ND	ND	0.23
6 -86	ND	49	15	ND	ND	ND
<u>SP-7</u>						
9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-9</u>						
9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-10</u>						
9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-23</u>						
9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-28</u>						
9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-29</u>						
9-21-84	ND	ND	ND	ND	ND	ND

* All units are in mg/L.

NA - Not Analyzed

ND - Non Detectable

J - Indicates an estimated value where the measured value is less than the method detection limit but greater than 0.

Table 11 Organic Hazardous Constituents Detected in Ground Water, Casper Plant North Property (continued).

Well Number and Date Sampled	Acid-Extractable Organics					
	Benzenethiol	Cresols	2,4-Dimethylphenol	2,4-Dinitrophenol	4-Nitrophenol	Phenol
<u>SP-30</u> 9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-31</u> 9-21-84	ND	ND	ND	ND	ND	ND
<u>SP-32</u> 9-21-84	ND	ND	ND	ND	ND	ND
<u>Seep #3</u> 9-21-84	ND	ND	ND	ND	ND	ND
<u>Seep #4</u> 9-21-84	ND	ND	ND	ND	ND	ND
<u>Alluvial Pond</u> 9-21-84	ND	ND	ND	ND	ND	ND

* All units are in mg/L.

NA - Not Analyzed

ND - Non Detectable

J - Indicates an estimated value where the measured value is less than the method detection limit but greater than 0.

wells, M-1 and M-6b, did not indicate organics present in the ground water during the evaluation, however. In addition, inorganics above applicable standards (to be discussed later) were not detected.

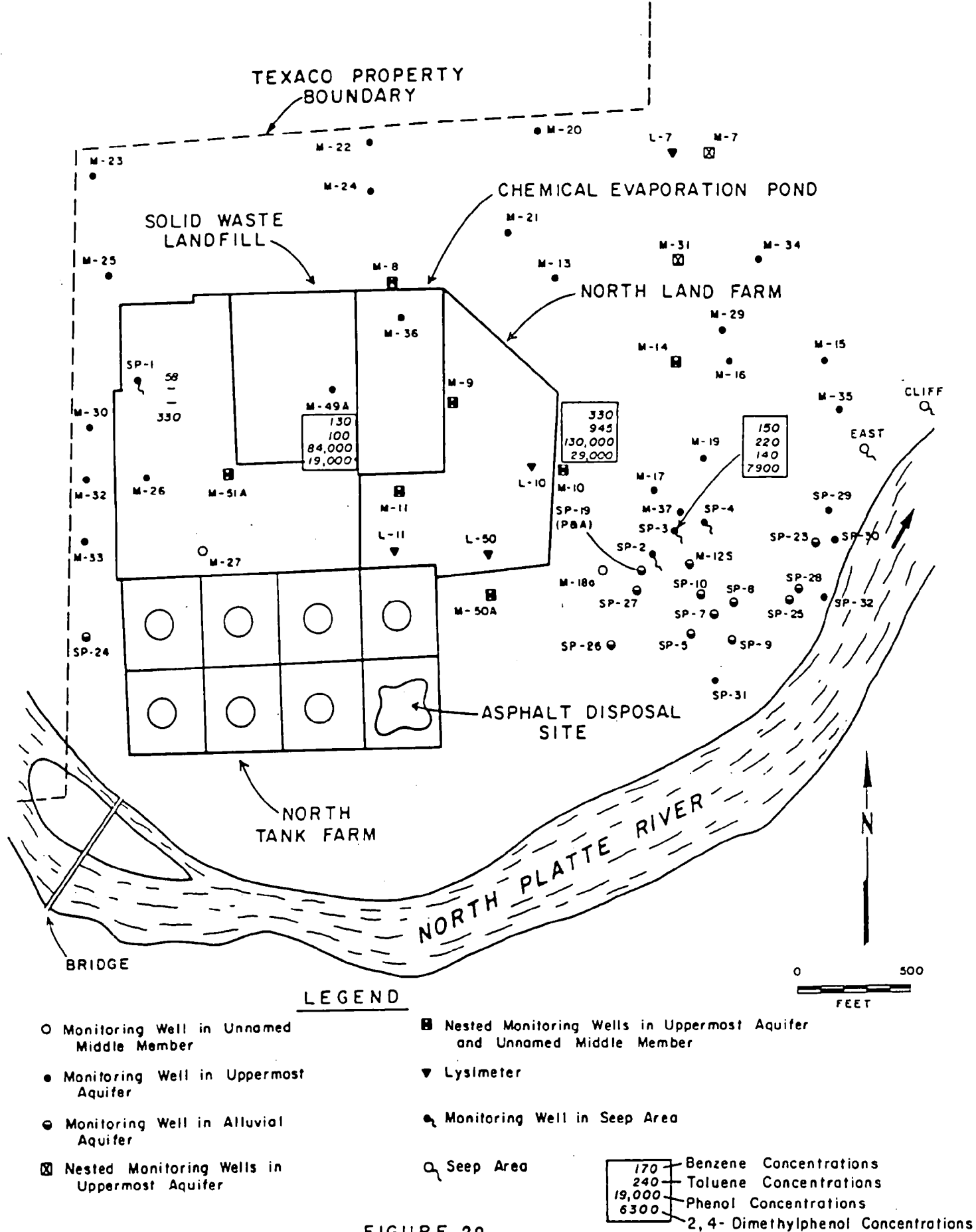
The extent of contamination has been defined by Texaco on a yearly basis for only a select group of parameters. These include TOC, phenol, sulfide and ammonia. Independent evaluations of these values and subsequent concentration maps prepared by the Task Force agree favorably with Texaco's presentations. Appendix F contains these concentration maps over a five year period for the above mentioned parameters. Additional contaminant concentrations have been posted for select organic species by the Task Force for further comparison purposes (Figures 20, 21, and 22). These parameters include benzene, phenol, toluene and 2,4-dimethylphenol. The above parameters were chosen because of their high rate of occurrence, relative to other parameters. It should be noted that because these figures are based on a limited number of data points (see Figure 10 and Table 11) the data cannot be contoured.

Other factors which may have had an effect on past analytical performance are summarized below. The system cannot generally detect light and dense phase immiscibles. Furthermore, it is unknown what influence some of the construction inadequacies may have on water quality. Texaco should consider installing new wells using current recommendations adjacent to some existing wells, and comparing analytical results of the paired wells to determine if construction inadequacies affect water quality. These paired wells will also aid in evaluating the effects of PVC casing material used in some wells. Finally, the depth at which the sample is taken in relation to the screened interval may affect past analytical results.

In summary, contamination has been documented in the past in the North Area. Strong evidence exists indicating that contamination may be migrating into the alluvial wells to the southeast. Organic contamination does not appear to have migrated past the western property boundary. Sufficient data do not exist to make a similar determination of the eastern property boundary, however. With the possible exception of light and/or dense phase constituents migrating off-site, the system as a whole seems capable of monitoring the rate and extent of contamination in the dissolved phase, assuming the appropriate analytes and wells are utilized.

Adequacy of System The assessment program, as it was designed and constructed, is adequate in some respects. Several potential and known problems exist with the system, however. This Subsection addresses the monitoring network as a whole, with major emphasis placed on the adequacy of the assessment program currently on-going at the facility.

The system is able to detect dissolved contaminants migrating from the HWMUs in most instances. An insufficient number of wells exist in the unnamed middle member south and southwest of the CEP and the North Land Farm. Because contamination has been documented in two wells in this unit, some degree of hydraulic communication may exist. In addition, the Teapot Sandstone subcrops just east of the North Land Farm. As indicated on Plate 1, this unit dips gently towards the northeast. Because



Concentrations of Select Organic Constituents (ug/l)
March, 1984 (Texaco)

Texaco Refinery, Casper, Wyoming

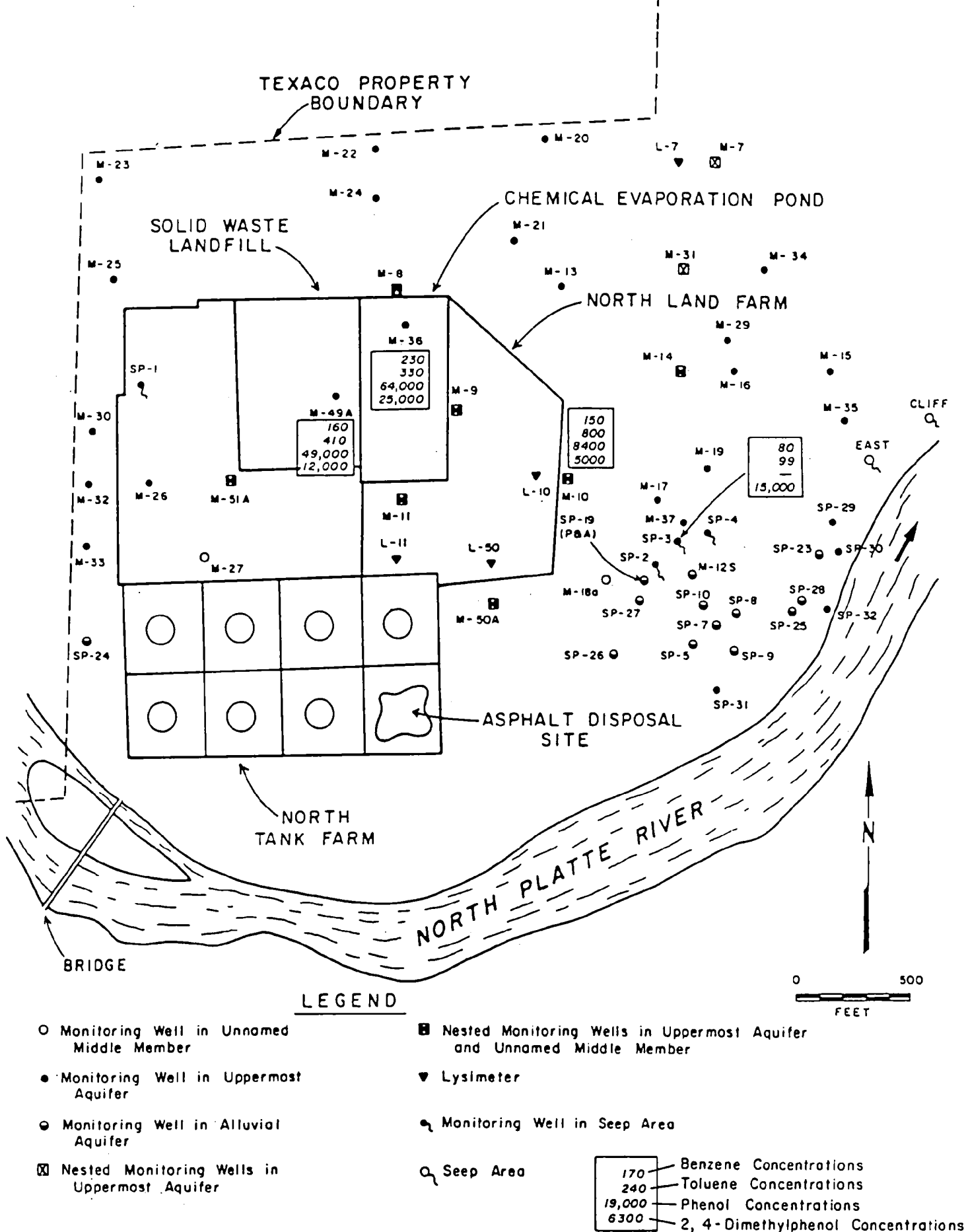


FIGURE 21

Concentrations of Select Organic Constituents (ug/l)
June, 1986 (Texaco)

Texaco Refinery, Casper, Wyoming

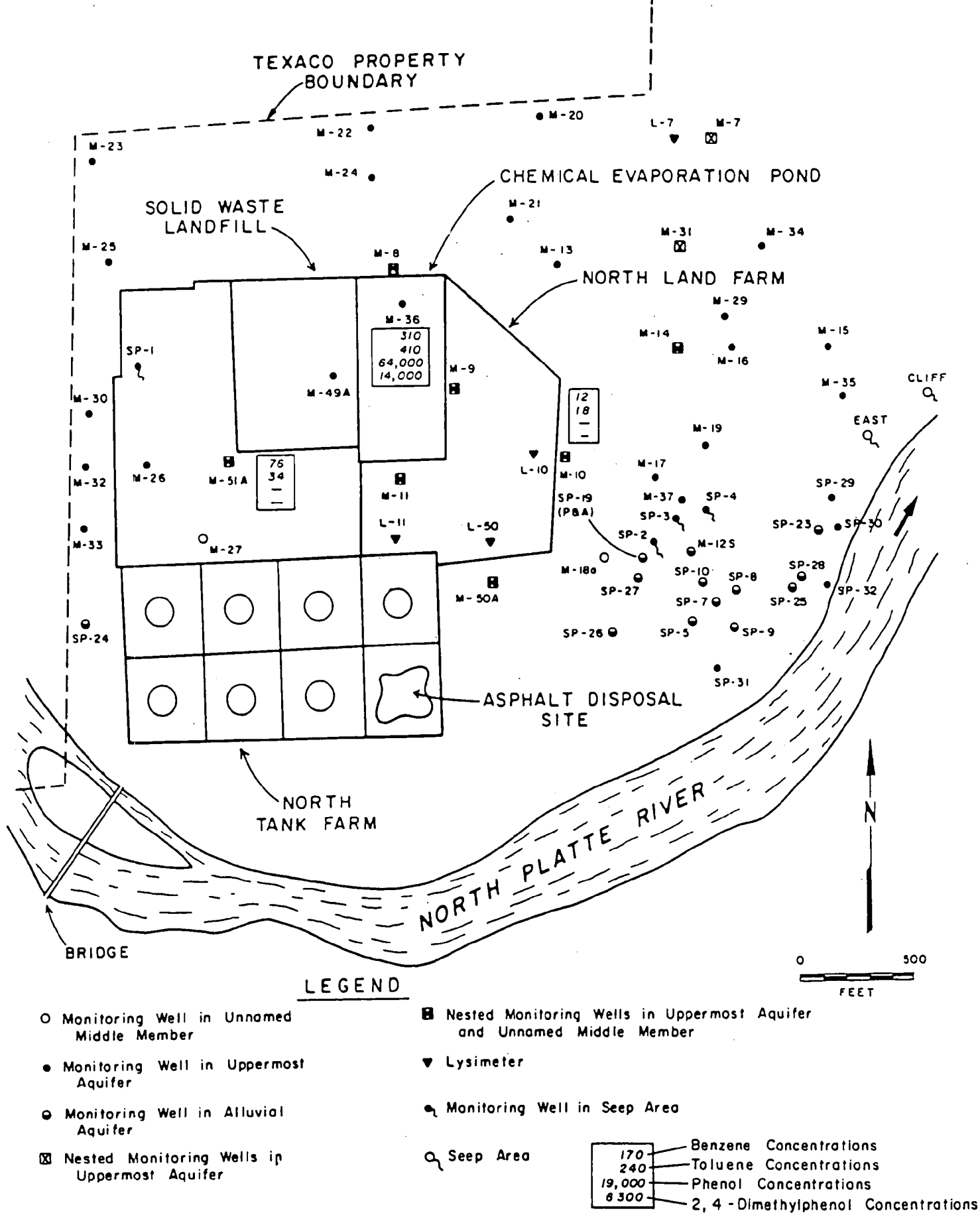


FIGURE 22
Concentrations of Select Organic Constituents (ug/l)
August, 1986 (Task Force)

Texaco Refinery, Casper, Wyoming

Texaco does not currently maintain any wells screened in this unit, a potential exists for contamination, especially dense phase immiscibles, to migrate off-site undetected.

It is apparent that the system cannot differentiate the source(s) of contamination between the CEP and/or possibly the North Land Farm. Because of the extent of contamination and the proximity of the HWMUs to each other (Figure 10), differentiating sources of contamination is probably not possible. Under the original assessment program, Texaco included both HWMUs as one single management unit under one assessment monitoring system. Following Texaco's admission that contamination was coming from the CEP and not the North Land Farm, an assessment monitoring program under 40 CFR 265.93(d) was continued for both units.

The majority of the wells as designed and constructed are only capable of monitoring dissolved constituents. As has been discussed in previous Subsections, relatively few wells have the capacity to detect light phase immiscibles during both historic high and low water levels. The same holds true for dense phase immiscibles, with the exception of the SP- series wells.

Several construction problems also exist with the monitoring system. Although it is difficult to assess the impact of these problems in relation to the adequacy of the system, they should be investigated by Texaco. As noted in the previous Subsection, Texaco should consider installing new wells next to existing wells and compare the results to determine what influence the construction flaws may have on the system.

In summary, the assessment program as a whole is able to detect the extent and rate of transport of dissolved species in the North Area. However, Texaco should re-evaluate their choice of parameters to be analyzed. The Task Force recommends that additional organic constituents be analyzed, plotted and contoured. Correlations between organic contaminants and organic indicators should be established, to demonstrate that the indicators (e.g., TOC, phenols) accurately depict contaminant concentrations and plume migration.

2. Proposed Ground-water Monitoring System under 40 CFR 264 (North Area)

Texaco has proposed in their Part B Permit Application that upon permit approval, the assessment program currently on-going under interim status for the North Land Farm would be dropped and that detection monitoring under 40 CFR 264 regulations would be implemented (Texaco, 1985). Texaco's logic is that unsaturated zone monitoring beneath the North Land Farm and the CEP in the past indicate that the CEP is the source of degraded ground water. Texaco has not designated detection wells specific to the land farm under interim status.

During the assessment monitoring of both HWMUs under interim status, Texaco determined that contamination was a result of the CEP and not the land farm. At this time an assessment program is on-going for the HWMUs as a whole, but the North Land Farm designate a detection program in order to monitor and detect an immediate release from this unit. As previously mentioned, differentiating the sources of contamination from the CEP and/or the landfill is probably not possible, but if a detection monitoring system was implemented for the land farm,

additional releases specifically from the land farm could have been monitored for, especially since wastes ceased to be disposed in the CEP after June 1982 but continued in the North Land Farm. Because of this, baseline and statistical data have not been provided for the North Land Farm area. In addition, Texaco must institute a corrective action program under 40 CFR 264.101 to protect and/or remediate the ground water from all releases from any SWMU, regardless of the time at which wastes were placed in such unit. This pertains specifically to the CEP pond as it is evident that some type of ground water restoration program should be implemented. In fact at the time of the Task Force Evaluation, Texaco had implemented a program involving the recharge of the CEP with river water in order to enhance biodegradation and reduce concentrations of contaminants.

a. **Detection Monitoring Program (North Land Farm)**

The detection monitoring program proposed by Texaco under 40 CFR 264.98 is assessed below. This includes an assessment of the design, placement and construction of the monitoring wells, past analytical performance and the adequacy of the system.

Monitoring Well System Design/Placement/Construction According to Texaco's Part B Permit Application, two existing and two proposed monitoring wells are specified to meet the requirements of 40 CFR 264 (Texaco, 1985). Texaco has designated monitoring well M-36 as the upgradient and M-10m as one of the downgradient wells. Although not explicitly stated in the application, the point of compliance appears to be the perimeter of the North Land Farm. The other two downgradient wells (M-38 and M-39) are to be installed upon application approval (Texaco, 1985). Figure 23 identifies the existing and proposed wells. A conflicting group of monitoring wells have also been presented by Texaco "to provide an environmental evaluation of the solid waste landfill and the North Land Farm" (TriHydro, 1987b). In this scenario, monitoring well M-7s is considered the upgradient well and M-10s, M-49A, M-50A and M-51As the downgradient. Information is not available stating with any certainty which group of wells has been and will continue to monitor ground water quality near the North Land Farm under the requirements of RCRA, 40 CFR 264. This Task Force evaluation will assess the monitoring system proposed in the Part B Permit Application. The other group of wells was previously discussed under the Interim Status assessment monitoring program for the North Area.

The current and proposed monitoring wells should be designed to monitor both light and dense phase immiscible constituents. Table 5 presents a list of constituents detected in the ground water in the vicinity of the North Land Farm and CEP. Following the recent land treatment demonstration, 17 hazardous waste constituents were identified in the soils under the North Land Farm at depths of up to seven feet. These were at statistically significant concentrations above background.

The potential for these constituents leaching and/or migrating into the aquifer is quite possible. Based on past water level elevations, approximately ten feet of soil are all that separate the extent of known contamination in the soil and the ground-water surface.

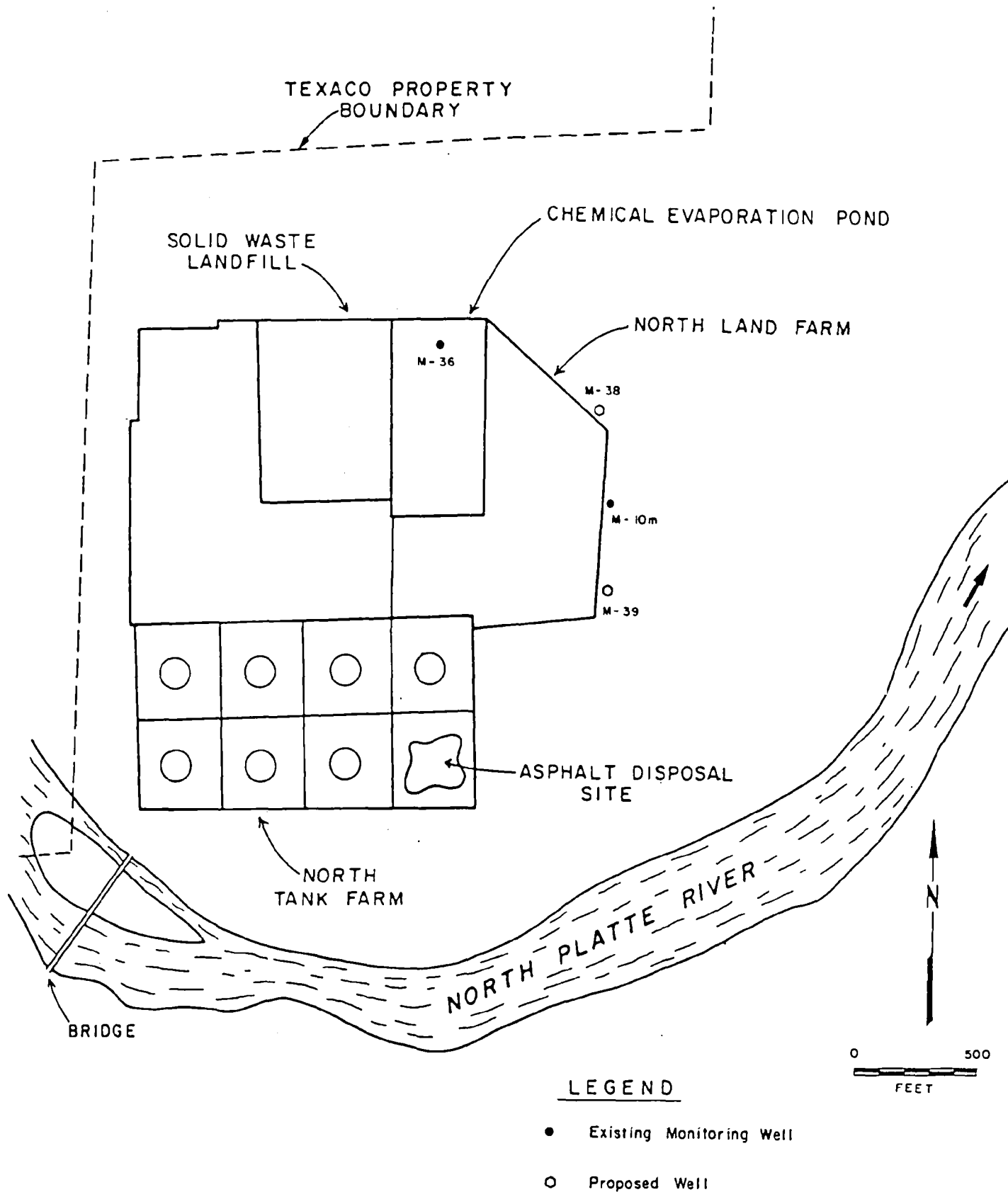


FIGURE 23

Location of North Land Farm Existing and Proposed Monitoring Wells

Texaco Refinery, Casper, Wyoming

According to the Part B Permit Application, Texaco only intends to monitor at the water table of the uppermost aquifer (Texaco, 1985). The Task Force has compiled Table 6 which demonstrates the ability of the North Land Farm wells to adequately monitor light phase immiscibles relative to historic high and low water table elevations. As indicated, monitoring wells M-36 and M-10m are not capable of detecting light phase immiscibles during high water table events because of screen placement. Historical high water level elevations will probably fluctuate as a result of Texaco artificially recharging the CEP. Complete water table elevations from wells in the North Area from December 1986 to December 1987 are located in Appendix E.

Monitoring wells M-36, M-10m and the proposed M-38 and M-39 wells are not designed to monitor dense phase immiscibles. This determination was based on well logs (Appendix B) and top of shale bedrock (unnamed middle member) (Figure 8). It should be noted that well M-10m could detect dense phases, based on well logs. As previously discussed, Plate 1 Section A-A' is a cross section of the North Area, and indicates a depression in the shale confining unit in the vicinity of the North Land Farm. The potential exists for dense phase constituents to pool or conglomerate in this depression. Currently, none of the existing and proposed wells could detect such a layer. Additional wells are required to monitor the lower depths of the aquifer for dense phase constituents, or designating different wells for such. The depth of the screened interval should intersect the upper aquifer/ confining unit interface.

The horizontal locations of monitoring wells (existing and proposed) are based on local ground-water flow. The three downgradient wells meet the regulatory and technical requirements for compliance point monitoring, although based on the lateral distance between wells, additional compliance point wells along the southern boundary are required. In this case, the limit of the waste management unit is the point of compliance. Background monitoring well (M-36) does not, however, comply with the required recommendations and regulations. Based on previously mentioned potentiometric surface maps constructed by Texaco and the Task Force (Figure 15), M-36 is generally not hydraulically upgradient. The fact that soil contamination exists below the treatment zone may indicate that contaminants are entering the ground water. Background wells must be designed/designated so that they are not affected by the unit they are monitoring. An anomalous potentiometric low has been noted in the past near M-36. It stands to reason that representative background water is not possible from M-36. The Task Force recommends that Texaco's choice of background well M-36 be removed from the permit application. This includes either designating an existing well as the background well, or replacing M-36 with a new well(s). The Task Force recommends that a new monitoring well be installed near M-36 to correct the previously mentioned deficiencies.

Construction details for monitoring wells M-36 and M-10m, in addition to a brief narrative for the construction of the proposed wells (M-38 and M-39), have been made available to the Task Force. Table 7 presents specification and design information and Appendix B contains well construction details (logs).

Monitoring well M-36 was drilled and completed on March 29, 1984 using a 6 1/4 inch hollow stem auger. Well M-10m was drilled and completed on January 25, 1982 using a rotary rig and a 6 1/2 inch bit. After drilling to the total depth (Table 7), the well screen and casing were emplaced into the borehole. A filter pack of known size and composition was not used in these wells, as collapsed formation sand and drill cuttings were used. A bentonite seal was emplaced immediately above the screened interval in M-10m. Well M-36 had approximately 17 feet of drill cuttings placed above the screened interval prior to placement of the bentonite seal. A cement surface seal was used in M-10m, but not in M-36, as the top of the bentonite seal was flush with the ground surface. Well development procedures were not indicated.

Sufficient detail to fully assess the technical merit of these wells is not available, although some deficiencies were noted. A bentonite bottom seal was not used prior to well installation to prevent vertical migration of constituents in M-36 and M-10m. Well completion details do not specify or indicate whether a bottom cap was used at the bottom of the screen. The filter pack consisted of collapsed formation sand in M-10m and drill cuttings in M-36. If surrounding formation material is used as a filter pack, the TEGD recommends that a sieve analysis to establish the appropriate well screen slot size and a determination of the chemical inertness of the formation material be performed (EPA, 1986a). This information was not provided. A bentonite seal was emplaced immediately above the well screen in M-10m, although the thickness of this seal is not specified. In M-36, approximately 17 feet of drill cuttings were emplaced above the screened interval, effectively acting as a conductor of water. The TEGD recommends a maximum of two feet of filter pack material above the well screen to ensure discrete sample horizons (EPA, 1986a). A bentonite seal of unknown thickness was emplaced above the drill cuttings (filter pack) to the ground surface. A cement surface seal was not used in M-36, according to completion details. In well M-10m, approximately 25 feet of drill cuttings were emplaced above the bentonite seal and below the cement surface seal. The annular space above the bentonite seal and below the surface seal should consist of a cement-bentonite mixture, as recommended by the TEGD (EPA, 1986a). Well casing stick-up was approximated for M-36, but not given for M-10m. Surveyed casing and/or reference point elevations are not specified on the construction details, as recommended by the TEGD (EPA, 1986a). The choice of the screened interval and construction material for M-36 may be inadequate. Completion details indicate that a 20 foot well screen was used (Appendix B).

Potential problems may occur when PVC is used in contact with aqueous organic mixtures. These organics may encourage leaching from or adsorption to the PVC polymer matrix. There has been recent concern over the potential of vinyl chloride monomer to leach from PVC casing, which in some cases may cause organic analytical interferences in situations where prolonged exposure to aqueous organic mixtures may occur (Barcelona and others, 1983). In certain situations under high organic concentrations, PVC may also adsorb organic constituents (Barcelona and others, 1983).

Furthermore, PVC in contact with organics, particularly benzene, is not recommended because of problems with long term structural integrity of the

well. In the future Texaco should review all available data/information on casing materials carefully and make a selection accordingly before installing new wells. This would be important at wells which exhibit significant organic accumulations, especially since long term monitoring is probable.

Well development techniques are unknown. Based on a turbidity value of 450 N.T.U. obtained during the Task Force evaluation in monitoring well M-36, development techniques or the choice of slot size appear inadequate. The TEGD recommends that if turbidity values in monitoring wells exceed 5 N.T.U.'s, then the well performance should be re-evaluated by further development or replaced as necessary (EPA, 1986a). Decontamination of the drill rig and well casing were not discussed as recommended by the TEGD (EPA, 1986a). Finally, the anomalous low water levels at well M-36 noted earlier in this report during the latter part of 1987 should be evaluated.

Proposed construction of monitoring wells M-38 and M-39 is discussed in Texaco's Part B Permit Application (Texaco, 1985). The following is taken verbatim from the application:

"Wells M-38 and M-39 will be installed in accordance with the RCRA regulations at 40 CFR 264.97(c). Test holes will be drilled by the hollow stem auger method. Total drilling depth is estimated to be 30 to 40 feet at each location. Boreholes will penetrate 10 to 15 feet into the uppermost aquifer.

"Soil samples will be taken from the ground surface to total depth. A lithologic log of the strata encountered will be recorded for each borehole. All drilling samples will be logged, recorded, bagged, and sealed in the field. Particular attention will focus on the identification of stained or discolored strata, odors, moisture content, and significant lithologic variations.

"After drilling and logging is completed, schedule 40, PVC casing will be installed to the total depth drilled. Casing diameter will be four inches. Factory-slotted PVC casing will be set from about 10 feet below the water table to about 5 feet above the water table. This range is desirable to ensure that the wells remain functional during the expected fluctuations in static water levels. Blank casing will extend from the top of the screen to the ground surface.

"A gravel pack consisting of sand or gravel will be emplaced in the annulus opposite the screen and up to about three feet above the screen. A bentonite seal will be emplaced above the gravel pack. A concrete grout will be emplaced in the annulus from the top of the bentonite seal to the ground surface. A protective steel shelter with locking lid will be set into the cement at each well.

"The drill stem and equipment will be cleaned with soap and water prior to drilling each borehole to prevent contamination of the sites." (Texaco, 1985)

A full technical evaluation of the two proposed monitoring wells would be pointless without actual construction details. However, the Task Force recommends the following changes: The well screen length should be re-

evaluated by Texaco. Fifteen feet of well screen may not provide water quality at discrete locations. The proposed wells are not capable of detecting dense phase immiscibles. Finally, the choice of material (PVC) in the construction of these wells should be re-evaluated in terms of leaching/adsorption and long term structural integrity.

Past Analytical Performance According to the Part B Permit Application, water quality data have been collected quarterly since March 1982 at 23 wells in the vicinity of the CEP and North Land Farm (Texaco, 1985). The two existing wells proposed under 40 CFR 264.98 are included in this sampling frequency (Table 10).

Existing water quality data, based on the horizontal location of well M-10m and past analytical data, are representative of water downgradient from the North Land Farm. It should be noted that well M-10m is screened towards the bottom of the saturated zone of the upper aquifer, thus prohibiting the detection of light phase immiscibles. Therefore, well M-10m is capable of detecting only dissolved and dense phase contaminants.

Texaco indicates in their Part B Permit Application that well M-36 is the background well for the North Land Farm. Past water quality data show that this is one of the most contaminated wells in the North Area. Potentiometric maps constructed by Texaco and the Task Force clearly indicate that this well is generally not upgradient. Furthermore, the ground water depression observed in this well should be explained (Figure 11). Also, because the contamination source cannot be currently delineated, the CEP is most likely affecting water quality in well M-36. The vertical placement of the screen in well M-36 is located to monitor the water table (for light phase immiscibles) during relatively low stages only.

According to well completion logs, M-36 has a 20 foot screened interval. A screen of this length may not provide discrete samples, as factors including dilution can affect water quality. Finally, it should be noted that well M-36 may be capable of detecting dense phase components based on Figure 8, Bedrock Surface Contours. However, the well log does not indicate that the unnamed middle member was encountered during drilling (Appendix B).

In summary, only well M-10m has provided adequate samples of ground water beneath the North Land Farm for dissolved species, but as previously stated, it cannot monitor for light and/or dense phase immiscibles at the point of compliance. To avoid redundancy, analytical data from these wells, in addition to others sampled by Texaco in the past, were previously presented in the Ground-Water Monitoring System under Interim Status (North Area) - Assessment Program section earlier in this report. Also, because a detection monitoring program under 40 CFR 265 was not implemented at the land farm, baseline data and/or statistical evaluations were not available.

Adequacy of Proposed Ground-Water Monitoring Program The ground-water system existing and proposed in Texaco's Part B Permit Application does not meet technical recommendations and regulatory requirements. The most serious problem is Texaco's choice of a background monitoring well. Well M-36 is neither hydraulically upgradient, nor able to provide water

quality unaffected by the North Land Farm. An apparent ground-water depression observed at well M-36 (Figure 14) should be explained. Texaco should evaluate this and designate other existing or new wells as the upgradient well(s). Regulation 40 CFR 264.97(g)(3)(i) states that background quality may be based on sampling of wells that are not upgradient from the waste management area where hydrogeologic conditions do not allow the owner or operator to determine what wells are upgradient. Downgradient wells M-10m (existing) and M-38 and M-39 (proposed) are located at the compliance point from a horizontal view. Additional wells designed to monitor the southern boundary of the North Land Farm are also warranted. Vertical placement of the existing and proposed downgradient wells are currently not capable of detecting dense phase immiscibles. Finally, construction details indicate that representative water quality samples may not be possible. Texaco should consider constructing new wells using current recommendations adjacent to existing wells, and compare analytical results to determine if construction flaws do in fact affect water quality.

Of importance for the North Land Farm unit is to design a ground-water monitoring system which meets the 40 CFR 264 Subpart F requirements, and is capable of detecting statistically significant releases over the long term. This includes ground-water monitoring specifically for the Land Farm, even during the corrective action program for the CEP or other SWMUs required under 40 CFR 264.101.

In summary the main purpose of the detection monitoring system should be to detect releases from the land farm given all of the other variable hydrogeologic and hydrogeochemical conditions in the immediate area surrounding the land farm.

b. Corrective Action Program under 40 CFR 264.101 (CEP)

This Subsection does not assess a corrective action program specified by Texaco, as the facility has not designated such a program under RCRA at this time. Rather, this Subsection reflects the view of the Task Force relative to the regulations under 40 CFR 264. Due to the serious nature of this deficiency in regards to permitting the North Land Farm, it merits discussion.

As a review, Texaco maintains that the ground-water monitoring program under 40 CFR 264 for the land farm would be detection monitoring (40 CFR 264.98). This is due to the fact that unsaturated zone monitoring at both the CEP and the land farm during interim status confirm that ground water degradation is due to the CEP. Quoting 40 CFR 264.101, "The owner or operator of a facility seeking a permit for the treatment, storage or disposal of hazardous waste must institute corrective action as necessary to protect human health and the environment for all releases of hazardous waste or constituents from any solid waste management unit at the facility, regardless of the time at which waste was placed in such unit."

Texaco readily admits to degraded ground water in the North Area, emanating from the CEP. This is evident by the assessment program currently on-going under interim status. Based on the above discussion, Texaco must operate a corrective action program under 40 CFR 264.101

because corrective action under 40 CFR 264.100 is not applicable as wastes were not received in the CEP after June, 1982 according to Texaco. As part of the program, Texaco must specify a ground water monitoring program capable of determining the effectiveness of the remedial action program in the form of recharge to the CEP, which at the time of the Task Force Evaluation had just begun. This would entail specifying the number and location of the wells, the parameters to be analyzed and the methods of evaluating data to show decreases in contaminant concentrations and the responsible hydrogeochemical mechanisms at work (e.g., dilution vs. biodegradation).

The Task Force recommends that Texaco submit a ground water remediation program pursuant to 40 CFR 264.101 which at a minimum specifies:

- o The number and locations of wells to be utilized, rationale for their selection and an evaluation of the construction details to permit assessment of the integrity of each well.
- o Designate those indicator parameters and waste constituents to be used to compare to a background well which can provide data that can accurately represent the conditions at the site. This is essential in order to show that all waste constituent concentrations of concern, the indicator parameters, are decreasing
- o Design a sampling and analysis program, which would complement data evaluation techniques, which can ultimately show the effectiveness of restoring the quality of ground water in the North Area.

A number of possible analytic procedures could be applied to existing data to assess the effects of recharge of river water on the attenuation of contaminant concentrations in ground water in the CEP area. These could include, but not necessary be limited to, the following kinds of data evaluation techniques:

- o Trend analyses of contaminant concentrations versus time in monitoring wells, in an effort to isolate the effects of river water recharge from attenuation effects occurring prior to recharge. Monitoring wells might be grouped according to their distances downgradient from the recharge pond in an effort to eliminate some variability in the data.
- o Reassessment of trends of maximum quarterly contaminant concentrations, to determine whether the data more probably suggest a stabilization of maximum concentrations, rather than a continuing decline. In addition, the wells at which maximum quarterly concentrations are detected should be identified, and an assessment made as to whether or not there is an identifiable trend of distance of maximum concentration from the CEP versus time.
- o Since Texaco has suggested that changes in sulfide and sulfate concentrations may correlate with aerobic or anaerobic biodegradation (Hamilton, 1988), an examination of temporal of

spatial trends in variations of sulfide/sulfate ratios might provide useful information. Similar geochemical studies might be possible using other chemical species.

- o Mathematical modeling of the hydraulic effects of river water recharge could provide useful information regarding relative rates of recharge versus ground-water underflow, rates of transport of recharged water within the uppermost aquifer, and the areal and temporal extent of the effects of river water recharge. Furthermore, by treating the recharged water as an ideal tracer within an appropriate mass-transport model, it should be possible to estimate the attenuation due solely to dilution and dispersion effects, and thus provide estimate, of the attenuation due to chemical and biological degradation phenomena.

3. Compliance with Applicable Regulations

This subsection addresses the regulatory deficiencies of the present interim status and proposed RCRA ground-water monitoring programs. At this time the CEP has been "clean closed" under RCRA and Texaco continues to monitor ground water under an assessment monitoring program. This program has been implemented to address ground-water contamination emanating from the CEP.

The North Land Farm is currently operating under the same interim status assessment monitoring program as the CEP (40 CFR 265.93(d)). A Part B application has been submitted for continued operation of this unit. A permit has been issued to Texaco for the Land Treatment Demonstration required prior to issuance of a permit. Because Texaco intends to continue operation of this unit, they will be required to operate their ground-water monitoring system in compliance with 40 CFR 264 Subpart F, and must provide permit information pursuant to 40 CFR 270.14(c).

a. Interim Status Program

The interim status ground-water monitoring system for the North Area has changed significantly since its inception in 1982. In 1982, as previously discussed, four wells were designated as RCRA wells under detection monitoring. Over the last 6 years changes in the designation of certain wells (detection vs. assessment), implementing a corrective action program (recharging the CEP), and the closure of the CEP have complicated the analysis of historical data from these wells. At this time Texaco considers the North Area to be operating under assessment monitoring.

Based on the above discussion, Texaco's assessment monitoring program must identify the extent and rate of migration of contamination, in addition to defining the concentrations of hazardous waste constituents within the plume. In addition, because a corrective action program (recharging CEP) will be on-going, the assessment monitoring program must be capable of demonstrating the effectiveness of the corrective action. The deficiencies noted in the interim status assessment monitoring system are as follows:

- o Texaco must determine the rate and extent of migration and concentration of hazardous waste in the groundwater (40 CFR 265.93(d)(4)). Currently, Texaco has made the above determination on only four parameters (TOC, phenol, sulfide and ammonia). The rate and extent of migration and concentration of all Appendix VII wastes must be established.
- o Because Texaco maintains that the CEP is the source of contamination in the North Area, the North Land Farm should not be included under an assessment program in conjunction with the CEP. Instead the North Land Farm should have a designated detection monitoring program which will allow for the immediate detection of releases from this unit (40 CFR 265.90). Data collected from this interim status program, which Texaco has not yet implemented, could be used as baseline data in evaluating the proposed detection system under 40 CFR 264.98.
- o Each well must be constructed in a manner that maintains the integrity of the well bore hole (40 CFR 265.91(c)). The casing must be screened to enable sample collection at depths where appropriate aquifer flow zones exist. The annular space must be sealed to prevent contamination of samples and the ground water.

Based on the refinery waste constituents, the monitoring system should be capable of evaluating the presence of both light and dense phase immiscibles. Only a few of the monitoring wells in this area are capable of detecting light phase constituents at both historic high and low water levels, in addition to detecting a dense phase component. Numerous wells also have construction deficiencies which may influence the quality of the samples and may provide a downward potential migration pathway for contaminants.

b. Proposed 40 CFR 264 Ground-Water Monitoring

Because Texaco is seeking a permit to continue the operation of the North Land Farm, the ground-water monitoring system, as previously stated, should be capable of detecting an immediate release at the point of compliance as outlined in 40 CFR 264 Subpart F. In operating the North Land Farm ground-water monitoring system, it is important to take into consideration how the recharging of the CEP will affect the ground-water flow in the vicinity of the land farm. The ground-water monitoring system must be capable at all times (during recharge and following completion of the CEP corrective action program) to detect immediate releases from the land farm. It is evident that this will require a detailed and continuous evaluation of the ground-water flow conditions and hydrodynamic effects from the CEP. Because ground water contamination is known to exist in the North Area, Texaco will also be required to implement a corrective action program under 40 CFR 264.101 for the CEP.

The following deficiencies for the proposed North Land Farm ground-water monitoring system are based on the ground-water monitoring requirements set forth by Texaco in their Part B application and those deficiencies found by the Task Force to be lacking for implementing a corrective action program under 40 CFR 264.101 for the CEP:

North Land Farm

- o Texaco should implement a monitoring system consisting of a sufficient number of wells to yield ground-water samples which are representative of background water quality unaffected by leakage from the regulated unit and which represents the quality of ground water passing the point of compliance (40 CFR 264.97(a)). Texaco designated well M-36 as the upgradient well designed to meet this requirement. This well is not always hydraulically upgradient from the North Land Farm. Due to its location, background water quality could likely be affected by the land farm. Furthermore, ground water flowing from well M-36 does not pass under the point of compliance. Finally, Texaco should evaluate the anomolous water levels and contaminant concentrations in well M-36. It appears that this well may be acting as a sink for contaminants and could introduce contamination into the lower portion of the uppermost aquifer. Therefore, Texaco's choice of M-36 as an upgradient well is inadequate.
- o Texaco must designate monitoring wells at the point of compliance which will detect an immediate release of hazardous waste constituents to the ground water (40 CFR 264.98). Based on the permit application, existing well M-10m and proposed wells M-38 and M-39 located at the point of compliance, an insufficient number of wells exist directly south of the North Land Farm.
- o All regulated monitoring wells must be constructed in a manner that maintains the integrity of the borehole. The casing must be screened to enable sample collection at depths where appropriate flow zones exist. The annular space must be sealed to prevent contamination of samples and the ground water (40 CFR 264.97(c)). Because constituents which may exist in both light and dense phases have been documented, the monitoring wells should be screened to detect these phases. Well M-10m is capable of detecting dense phase components, but not light phase components. Well M-36 is not constructed so as to detect light phase layers during relatively or historic high water levels, nor is it capable of monitoring the depths of the aquifer for dense phase constituents. Both monitoring wells M-10m and M-36 have construction deficiencies which may influence the quality of the samples and may provide a downward potential migration pathway for contaminants.
- o Texaco is required to monitor for indicator parameters, waste constituents or reaction products that provide a reliable indication of the presence of hazardous constituents in ground water (40 CFR 264.98(a) and 270.14(c)(6)(i)). The parameters chosen by Texaco include benzene, toluene, phenol, lead and chromium. These parameters are already present in the ground water and any leakage from the North Land Farm may not be detected. Texaco must provide a list of parameters unique to the land treatment wastes that would serve as reliable indicators of hazardous constituents migrating from the unit.

CEP

- o Texaco must implement a corrective action program which mitigates ground water contamination from any solid waste management unit (40 CFR

264.101). Texaco has stated that the degraded ground water in the North Area is from leakage of the CEP. Because a Part B permit has been applied for, the facility is required to initiate such a program. This should include specifying all pertinent information required to determine the effectiveness of the program. 40 CFR 264.101 lacks specific regulatory requirements for this corrective action program, therefore the following technical deficiencies are listed based on what the Task Force feels to be an appropriate corrective action program:

- Texaco should first establish a waste management boundary with a set of designated RCRA wells installed at this boundary. These wells should be continuously monitored in conjunction with those wells designated under the corrective action program for continued evaluation of the effectiveness of the corrective action program under 40 CFR 264.101.
- Texaco should establish a list of hazardous constituents and concentration limits for those hazardous waste constituents to be used in order to monitor the effectiveness of the corrective action program. These constituents should include not only indicator parameters, but those hazardous constituents detected in the ground water and which are unique to the CEP. In setting concentration limits, close scrutiny of the background well(s) should be performed.
- Texaco must designate those wells which will be utilized as part of a groundwater monitoring program to aid in evaluating the rate and extent of contamination. These wells may also be utilized as part of the corrective action ground-water monitoring program which will be used to determine the success of the corrective action. The data evaluation techniques used to determine the effectiveness of corrective action and the data collection schedule should be presented. Texaco should outline in detail those wells and data evaluation techniques which will be utilized as part of this corrective action ground-water monitoring program under 40 CFR 264.101.
- At this time, Texaco has only provided a description of the rate and extent of migration and concentrations of four indicator parameters: phenols, TOC, sulfide and ammonia. It appears that Texaco has only analyzed for organics four times, including the Task Force split samples, since 1982. Only during the Task Force Evaluation was an Appendix IX scan completed. An identification of organics on a continual basis is essential in order to relate those concentrations to the indicator parameters (e.g. TOC and phenols) that are currently being utilized to determine the effectiveness of the corrective action program. Texaco should not only evaluate indicator parameters over time for effectiveness of the corrective action program, but must also show that concentrations of specific hazardous waste constituents are also being addressed or treated as part of the program.

4. Ground-Water Monitoring System (South Area)

The area south of the North Platte River (South Area, Figure 15) currently maintains a network of ground-water monitoring wells, but is not subject to the

ground-water monitoring requirements of RCRA as outlined in 40 CFR 264 and 265 subparts F. As previously mentioned the South Area contains the process units of the refinery and several tankage units. RCRA-regulated or interim status land disposal units do not exist in this area. The South Area does, however, contain numerous solid waste management units which possess relatively high potential for contamination to the ground water. Such units include the service water return ditch; storm water surge ponds; PCS coke settling pond; precipitator and accelerator ponds; barometric separator and barometric lagoons; several tank farms; and the process area and associated piping and historical spills. In addition, the reports reviewed by the Task Force indicated that a waste oil dump, old ponds and dump sites located along the south bank of the river may also be contributing to releases to the ground water.

a. History

Investigations have been ongoing in the South Area since the 1940's to investigate and/or remediate the accumulation of large quantities of floating hydrocarbons in the central tank farm area (Figure 2). In addition a new study (1986/1987) is currently underway to investigate ground-water contamination beneath the southeastern corner of the site adjacent to the east tank farm and land farm area (Figure 2). This study was implemented as a result of the Task Force evaluation analytical results. A brief history of ground-water monitoring and hydrocarbon recovery activities for the South Area is as follows:

- o Between 1947 and 1958 Texaco drilled and installed approximately 74 wells which were used as monitoring wells, hydrocarbon recovery wells and for exploration of the local geology.
- o In July 1957, an east and west open interceptor ditch was installed to intercept the flow of hydrocarbons in the ground water before they seeped into the North Platte River. This open ditch system was replaced with a closed system in 1972/1973.
- o Sometime after 1957 a "clay barrier" was constructed east of the east end of the east interceptor ditch to halt hydrocarbon migration (WWC, 1982c).
- o In 1972 and 1973, the east and west interceptor ditches were replaced with a closed interceptor system which consisted of two 24-inch perforated culverts stacked one on top of the other and buried. A concrete sump was installed at the east and west end of the west and east interceptor ditches, respectively. Each sump contained a 300 gpm pump (WWC, 1982c).
- o From December 1981 to January 1982, 15 additional wells were drilled as part of the Phase I studies to better define the local geology, because detailed lithologic descriptions were not available (WWC, 1982b).
- o From June to July 1982, 27 additional monitoring wells were installed to further define the extent of hydrocarbon accumulation and the local hydrogeologic conditions (WWC, 1982c).

- o As a result of the June and July 1982 investigation, Texaco submitted an Application for Permit to Construct the Hydrocarbon (Oil) Recovery Project proposed at the Casper Texaco Refinery in March and June 1983 (WWC, 1983b).
- o In July and August 1983, Phase I of the Oil Recovery operations were implemented with the construction of four recovery wells, nine recharge wells and 11 additional monitoring wells. The system became operational (uninterrupted) in September 1983.
- o From April through June 1984, Phase II of the Oil Recovery system was undertaken. This phase included the installation of two additional recovery wells, 13 recharge wells, and four monitoring wells (April 1984). In April 1985, five additional recharge wells were installed.
- o In August 1986, EPA performed a Task Force Evaluation of the Texaco Refinery which included split sampling of six wells and the PCS Coke Settling Pond in the South Area.
- o As a result of the Task Force Evaluation ground-water analytical results, contamination was detected beneath the southeast corner of the Texaco Refinery. In December 1986 and January 1987, eight additional monitoring wells were installed to further investigate this contamination (WWC, 1987b). Because this investigation was undertaken after the Task Force Evaluation, it will not be discussed in detail.

A total of 139 ground-water monitoring wells were installed in the South Area from 1947 until January 1987. These wells were installed to monitor accumulations of floating hydrocarbons, oil recovery activities and characterization of the hydrogeologic conditions.

As part of the oil recovery system, a total of six recovery wells and 27 recharge wells have been installed.

Of the 139 ground-water monitoring wells and 33 oil recovery system wells, numerous wells either do not contain completion records or geologic logs, or they have been plugged, abandoned, or are no longer in use. An inventory of the monitoring wells as tabulated by Texaco as of 1982 is included as Appendix C. In evaluating the South Area, the Task Force only utilized wells where completion records and/or geologic logs were available. Fifty-nine ground-water monitoring wells which met this criterion are listed in Table 12 with their locations identified in Figure 15. This list of wells does not include those related to oil recovery operations, although their locations are included on Figure 15. The oil recovery system is discussed in further detail later in this section.

Those wells which were not utilized by the Task Force include the wells listed in Appendix C minus those presented in Table 12. Also wells SS-52 through SS-55 installed in April 1984 were not included, as no records were provided to the Task Force.

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Table 12

Well Specifications - Smith Area

<u>WELL</u>	<u>DATE INSTALLED</u>	<u>CASING TYPE</u>	<u>APPROX. GROUND SURFACE ELEVATION (MSL)</u>	<u>COMPLETION INTERVAL (SCREEN)</u>	<u>DEPTH TO BEDROCK</u>	<u>MONITORED INTERVAL</u>	<u>AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985</u>	<u>COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE</u>	<u>COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE</u>
SS-1	12-9-81	4" GALV	5086	27-32 (5059-5054)	35 (5051)	ALV	5080.3	YES	NO
SS-2	12-10-81	4" GALV	5085	7.5-12.5 (5077.5-5072.5)	37 (5048)	ALV	5080.5	NO	NO
SS-3	12-11-81	4" GALV	5085	25-30 (5060-5055)	36 (5049)	ALV	5080.6	NO	NO
SS-4	12-11-81	4" GALV	5085	8-13 (5077-5072)	19 (5066)	ALV	5081.8	NO	NO
SS-5	12-12-81	4" GALV	5085	15-18 (5070-5067)	20 (5065)	ALV	5076.5	POSSIBLE	NO
SS-6	12-13-81	4" GALV	5104	6-9 (5098-5095)	19 (5085)	ALV	5099.4	NO	POSSIBLE
SS-7	12-15-81	4" GALV	5116	42-45 (5074-5071)	60 (5056)	ALV	5084.9	NO	NO
SS-9	1-4-82	4" GALV	5108	42-45 (5066-5063)	54 (5054)	ALV	5085.6	NO	NO

Table 12

Well Specifications - South Area

<u>WELL</u>	<u>DATE INSTALLED</u>	<u>CASING TYPE</u>	<u>APPROX. GROUND SURFACE ELEVATION (MSL)</u>	<u>COMPLETION INTERVAL (SCREEN)</u>	<u>DEPTH TO BEDROCK</u>	<u>MONITORED INTERVAL</u>	<u>AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985</u>	<u>COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE</u>	<u>COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE</u>
SS-10	12-18-81	4" GALV	5098	18-21 (5080-5077)	23 (5075)	ALV	5085.1	POSSIBLE	NO
SS-11	12-20-81	4" GALV	5098	5-25 (5093-5073)	26 (5072)	ALV	5078.6	YES	YES
SS-12	12-7-81	4" GALV	5090	11-16 (5079-5074)	28 (5062)	ALV	5081.83	NO	NO
SS-13	6-23-82	4" PVC	5111	32.3-42.3 (5078.7-5068.7)	28.5 (5032.5)	BEDROCK	5085.9	NO	NO
SS-14	7-8-82	4" PVC	5116	31.7-41.7 (5084.3-5074.3)	68.5 (5047.5)	ALV	5085.1	NO	POSSIBLE
SS-15	7-11-82	2" PVC	5113	29.1-35.1 (5083.9-5077.9)	37.5 (5075.5)	ALV	5084.9	POSSIBLE	POSSIBLE
SS-16	7-11-82	2" PVC	5096	8.3-17.3 (5087.7-5078.7)	18.5 (5077.5)	ALV	NO	POSSIBLE	NO
SS-17	7-11-82	2" PVC	5089	3.7-12.7 (5085.3-5076.3)	12.5 (5076.5)	ALV	5083.2	YES	YES
SS-18a	7-14-82	2" PVC	5088	3.2-13.2 (5084.8-5074.8)	14.0 (5074)	ALV	5081.4	POSSIBLE	YES

t22-casp

Table 12

Well Specifications - South Area

WELL	DATE INSTALLED	CASING TYPE	APPROX. GROUND SURFACE ELEVATION (MSL)	COMPLETION INTERVAL (SCREWS)	DEPTH TO BEDROCK	MONITORED INTERVAL	AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985	COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE	COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE
SS-19	7-14-82	2" PVC	5087	7.5-17.5 (5079.5-5069.5)	18.0 (5069)	ALV	5080.4	POSSIBLE	YES
SS-20	7-14-82	2" PVC	5095	10.3-20.3 (5084.7-5074.7)	25.0 (5070)	ALV	5082.8	NO	YES
SS-21	7-16-82	4" GALV	5095	11.2-21.2 (5083.8-5073.8)	22.5 (5072.5)	ALV	5082.3	POSSIBLE	YES
SS-22	7-13-82	4" GALV	5099	19.2-29.2 (5079.8-5069.8)	17.5 (5081.5)	BEDROCK	5083.7	NO	NO
SS-23	7-14-82	2" PVC	5096	11.0-21.0 (5085-5075)	23.0 (5073)	ALV	5081.7	POSSIBLE	YES
SS-24	7-14-82	2" PVC	5091	9.5-19.5 (5081.5-5071.5)	22.0 (5069)	ALV	5081.5	POSSIBLE	YES
SS-25	7-15-82	2" PVC	5096	10.8-19.8 (5085.2-5076.2)	22.5 (5073.5)	ALV	5081.4	POSSIBLE	YES
SS-26	7-15-82	2" PVC	5092	11.8-20.8 (5080.2-5071.2)	22.5 (5069.5)	ALV	5081.4	POSSIBLE	POSSIBLE
SS-27	7-15-82	2" PVC	5093	10.3-19.3 (5082.7-5073.7)	22.5 (5070)	ALV	5081.7	POSSIBLE	YES

t22-cosp

Table 12

Well Specifications - South Area

<u>WELL</u>	<u>DATE INSTALLED</u>	<u>CASING TYPE</u>	<u>APPROX. GROUND SURFACE ELEVATION (MSL)</u>	<u>COMPLETION INTERVAL (SCREEN)</u>	<u>DEPTH TO BEDROCK</u>	<u>MONITORED INTERVAL</u>	<u>AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985</u>	<u>COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE</u>	<u>COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE</u>
SS-28	7-15-82	2" PVC	5095.5	14.3-23.3 (5081.2-5072.2)	27.5 (5068)	ALV	5081.7	NO	YES
SS-29	7-15-82	2" PVC	5090	7.0-16.0 (5083-5074)	22.5 (5067.5)	ALV	5081.9	NO	YES
SS-30	7-16-82	2" PVC	5088	5.1-15.1 (5082.9-5072.9)	15.1 (5072.9)	ALV	5082.2	YES	YES
SS-32	7-16-82	2" PVC	5088	13.0-23.0 (5075-5065)	24.0 (5064)	ALV	5082.2	YES	NO
SS-33	6-26-82	2" PVC	5084	2.5-8.5 (5081.5-5075.5)	8.0 (5076)	ALV	5078.9	YES	YES
SS-34	6-26-82	2" PVC	5084	4.4-14.4 (5079.6-5069.6)	23.7 (5060.3)	ALV	5080.1	NO	POSSIBLE
SS-35	6-27-82	2" PVC	5086	3.6-13.2 (5082.4-5072.8)	25.5 (5060.5)	ALV	5079.9	NO	YES
SS-36	6-27-82	2" PVC	5085	4.8-14.4 (5080.2-5070.6)	32.8 (5052.2)	ALV	5080.4	NO	YES
SS-37	6-27-82	2" PVC	5088	4.9-14.5 (5083.1-5073)	31.4 (5056.6)	ALV	5080.6	NO	YES

t22-casp

Table 12

Well Specifications - South Area

<u>WELL</u>	<u>DATE INSTALLED</u>	<u>CASING TYPE</u>	<u>APPROX. GROUND SURFACE ELEVATION (MSL)</u>	<u>COMPLETION INTERVAL (SCREEN)</u>	<u>DEPTH TO BEDROCK</u>	<u>MONITORED INTERVAL</u>	<u>AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985</u>	<u>COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE</u>	<u>COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE</u>
SS-39	7-12-82	2" PVC	-5098	1.7-10.7 (5096.3-5087.3)	11.0 (5087)	ALV	ND	POSSIBLE	ND
SS-40	1983	2" PVC	5093.13 ^{1"}	8.0-18.0 (5085.1-5075.1)	NA	ALV	5081.1	ND	YES
SS-41	1983	2" PVC	5097.18 ^{1"}	11.0-21.0 (5086.2-5076.2)	NA	ALV	ND	ND	ND
SS-42	1983	2" PVC	5092.68 ^{1"}	6.8-16.8 (5085.9-5075.9)	NA	ALV	5081.1	ND	YES
SS-43	1983	4" PVC	5093.29 ^{1"}	4.3-14.3 (5088.9-5078.9)	NA	ALV	5080.9	ND	YES
SS-44	1983	4" PVC	5092.97 ^{1"}	7.0-17.0 (5085.9-5075.9)	NA	ALV	5080.9	ND	YES
SS-45	1983	4" PVC	5097.29 ^{1"}	9.0-19.0 (5088.3-5078.3)	NA	ALV	5081.2	ND	YES
SS-47	1983	4" PVC	5096.77 ^{1"}	10.0-20.0 (5086.8-5076.8)	NA	ALV	5082.2	ND	YES
SS-48	1983	4" PVC	5099.77 ^{1"}	12.0-22.0 (5087.8-5077.8)	NA	ALV	5082.5	ND	YES

t22-casp

Table 12

Well Specifications - South Area

<u>WELL</u>	<u>DATE INSTALLED</u>	<u>CASING TYPE</u>	<u>APPROX. GROUND SURFACE ELEVATION (MSL)</u>	<u>COMPLETION INTERVAL (SCREEN)</u>	<u>DEPTH TO BEDROCK</u>	<u>MONITORED INTERVAL</u>	<u>AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985</u>	<u>COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE</u>	<u>COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE</u>
SS-49	1983	4" PVC	5093.24 ^{1*}	5.3-15.3 (5087.9-5077.9)	NA	ALV	5082.3	NO	YES
SS-50	1983	4" PVC	5095.20 ^{1*}	8.7-18.4 (5086.5-5076.8)	NA	ALV	5081.3	NO	YES
SS-51	1983	4" PVC	5098.51 ^{1*}	9.7-19.7 (5088.8-5078.8)	NA	ALV	5081.9	NO	YES
SS-56	12-29-86	2" PVC	5106.9	16.2-25.9 (5090.7-5081)	30' (5076.9)	ALV	5085.7 ^{2*}	NO	YES
SS-57	12-30-86	2" PVC	5112.1	21.6-31.4 (5090.5-5080.7)	NE	ALV	5085.7 ^{2*}	NO	YES
SS-58	12-30-86	2" PVC	5114.0	24.2-33.8 (5089.8-5080.2)	NE	ALV	5085.77 ^{2*}	NO	YES
SS-59	12-31-86	2" PVC	5114.4	23.8-33.6 (5090.6-5080.8)	NE	ALV	5085.8 ^{2*}	NO	YES
SS-60	1-5-87	2" PVC	5110.3	19.8-29.6 (5090.5-5080.7)	NE	ALV	5085.7 ^{2*}	NO	YES
SS-61	1-6-87	2" PVC	5106.0	15.5-25.3 (5090.5-5080.7)	NE	ALV	5085.8 ^{2*}	NO	YES

t22-casp

Table 12

Well Specifications - South Area

WELL	DATE INSTALLED	CASING TYPE	APPROX. GROUND SURFACE ELEVATION (MSL)	COMPLETION INTERVAL (SCREEN)	DEPTH TO BEDROCK	MONITORED INTERVAL	AVERAGE WATER LEVELS CORRECTED MAY, AUG., OCT. 1985	COULD DETECT HEAVY IMMISCIBLES YES/NO/POSSIBLE	COULD DETECT LIGHT IMMISCIBLES YES/NO/POSSIBLE
SS-62	1-7-87	2" PVC	5114.6	24.5-34.4 (5090.1-5080.2)	NE	ALV	5085.6 ^{2*}	NO	YES
SS-63	1-7-87	2" PVC	5114.8	28.8-35.6 (5086-5079.2)	NE	ALV	5085.28 ^{2*}	NO	YES
M-41	2-7-82	4" GAL	5123	46-49 (5077-5074)	49 (5074)	ALV	ND	YES	ND
M-41a	6-21-82	2" PVC	~5114	49-55 (5065-5059)	55 (5059)	ALV	ND	YES	ND
OB-1	12-19-81	4" ?	~5097	3-25 (5094-5072)	37 (5060)	ALV	5083.06	NO	YES
OB-2	1-7-82	4" ?	~5096	19-39 (5077-5057)	39 (5057)	ALV	5082.1	YES	NO

1* TOP OF CASING ELEVATION (MSL)
 2* WATER LEVELS (NOT CORRECTED), SEPTEMBER 1987
 ND NO DATA
 NE NOT ENCOUNTERED
 GALV GALVANIZED STEEL
 NA NOT AVAILABLE

Completion records and geologic logs for the South Area wells utilized by the Task Force are also presented in Appendix C.

b. Monitoring Well System Design/Placement/Construction (South Area)

The facility-wide ground-water monitoring system in the South Area was installed to define the extent of accumulation of floating hydrocarbons and local hydrogeologic conditions. Subsequently, the system has not been utilized to define the water quality which would include dissolved constituents and also dense phase immiscible components of refinery wastes. This does not include the southeast area of the refinery, where ongoing investigations are evaluating both dissolved and light immiscible contamination.

The horizontal placements of the South Area wells were based on previous data on hydrocarbon accumulations and also local ground-water flow conditions. This resulted in almost all of the wells being completed to define the extent of floating hydrocarbons. For the remaining discussion, the central South Area and the southeast corner will be discussed separately.

Central South Area The vertical placement of the screened intervals of most wells are completed in the alluvium with emphasis placed on screening the water table to detect floating hydrocarbons. Only two wells in the South Area, SS-13 and SS-22, had screened intervals within the unnamed middle member. Well SS-13 is discussed under the Southeastern Corner Area.

Based on the refinery waste constituents (Table 5), the ground-water monitoring system should be capable of monitoring the water table for light immiscibles, dense immiscibles and also dissolved organic and inorganic constituents. According to Texaco, oil samples from ten wells showed virgin to cracked contaminated products with the cracked content increasing eastward, and distillation tests indicated contaminated refined product mixtures ranging from nearly heavy straight run naphtha to gas oil (WWC, 1982b).

To evaluate the monitoring well network's capability of detecting light immiscibles, Table 12 presents data for average water levels, corrected for hydrocarbon accumulations taken from most wells in May, August and October 1985 corrected water levels, except as noted on the Table. These averaged water levels were compared to screened interval depths to evaluate which wells would be capable of detecting light immiscibles. Table 12 lists those wells capable of detecting light immiscibles with a "Yes." The term "Possible" was used as screen and water levels may vary from 1 to 2.0 feet, and these wells may be capable of detecting floaters during fluctuations in water levels. These wells have also been plotted on Figure 24, which shows the apparent petroleum thickness as calculated by Texaco on November 5, 1985. This was the most recent petroleum thickness map available to the Task Force.

It should be noted that numerous wells measured on November 5, 1985 displayed the presence of light immiscibles at less than 0.5 feet. These wells include: SS-24, 0.48'; SS-11, 0.44'; SS-23, 0.15'; SS-45, 0.41'; SS-47, 0.49'; SS-52,

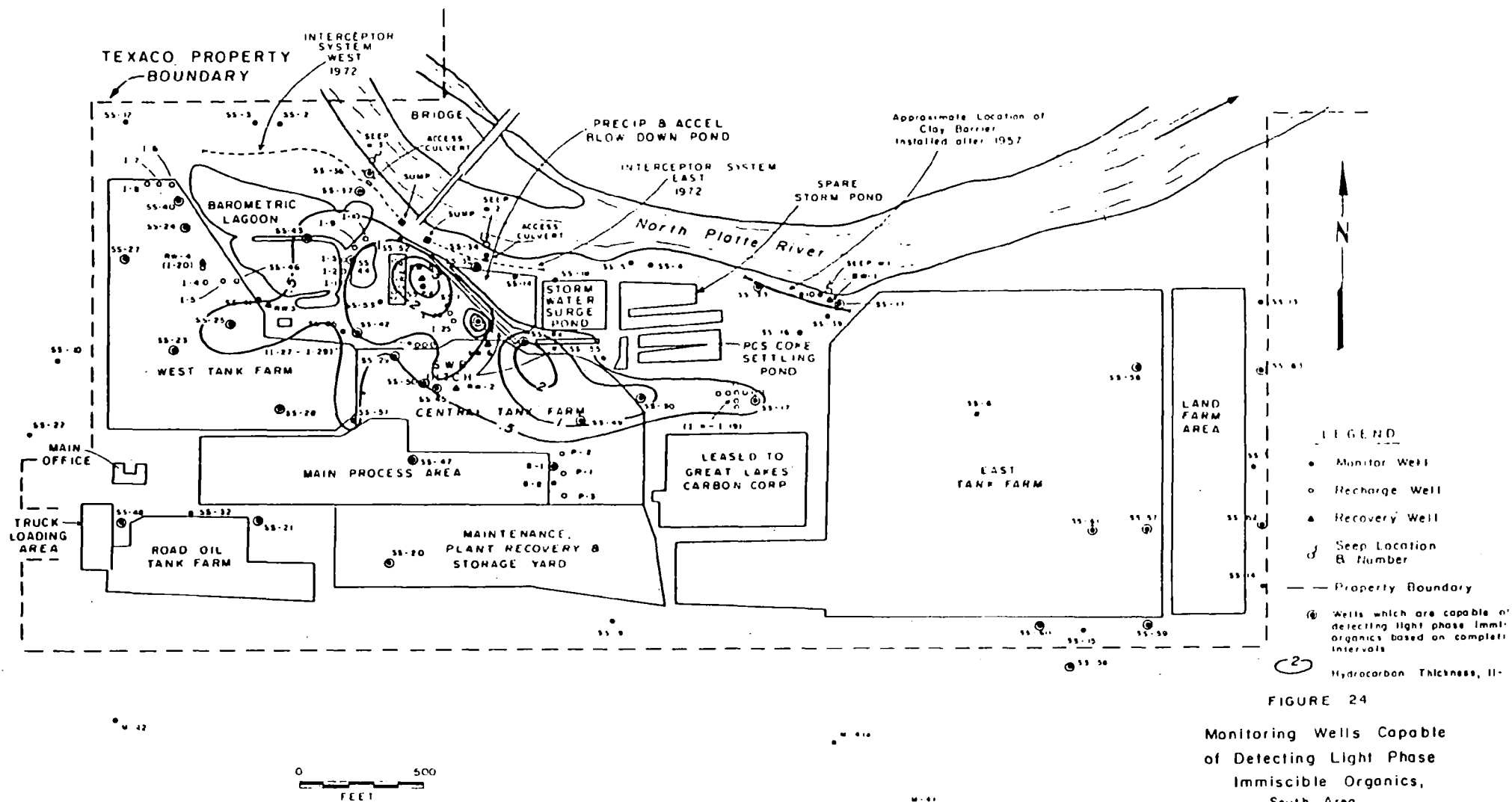


FIGURE 24

Monitoring Wells Capable
of Detecting Light Phase
Immiscible Organics,
South Area
Texaco Refinery, Casper, Wyoming

Source: Modified from Ground-water Technology,
1983 - 1985

0.15'; SS-5, 0.23'; SS-37, 0.26'; and SS-55, 0.14' (Groundwater Technology, 1983-1985). These wells and other wells often show fluctuations in oil thickness with water level increase/decreases. This is discussed later in this Section, under the Hydrocarbon Recovery System.

Figure 24 points out that wells do not exist north/northeast of the storm surge ponds to detect light immiscibles. It is interesting to note that wells SS-4 and SS-5 have historically shown hydrocarbon accumulation up to 2.0 feet, even though their screened intervals do not intersect the average water table. During the Task Force evaluation, 5.02 feet of hydrocarbon accumulation was measured in well SS-4 (see Task Force Field Data Sheets, Appendix D). Oil was measured from 9.83 to 14.85 feet (screen at 8-13 feet and measured total depth of 15.4' below ground surface), thus explaining that this hydrocarbon accumulation may be attributed to a dense immiscible phase rather than light. Regardless, the potentiometric map previously presented (Figure 17) would indicate that this area may be seeping into the North Platte River. The lack of wells adjacent to SS-4 and SS-5 screened at the water table or deeper precludes an evaluation of hydrocarbon accumulation in this area. Additional areas which may lack wells to evaluate accumulations of hydrocarbons include the areas north of SS-30 and SS-17, adjacent to SS-51 and between the east and west interceptor ditches north of SS-52 (Figure 24).

Table 12 also presents those wells in the South Area which may be capable of detecting a dense phase immiscible component. Criteria for these wells included those whose screened interval was completed at approximately the alluvium/unnamed middle member contact. The potential for dense phase immiscibles has not been investigated by Texaco, as their efforts have been directed to the floating phase. As previously mentioned, the Task Force's detection of hydrocarbons in well SS-4 indicates the presence of a dense phase (i.e. 5.02 foot of hydrocarbons from 9.83 to 14.85' with a screened interval from 8 to 13 feet and a total depth of 15.4 feet). The Task Force also detected a dense phase at well SS-19, where 1.0 foot of hydrocarbons were measured on the bottom of the well (see field data sheet for SS-19, Appendix D). No other dense phases were detected by the Task Force in the South Area. To date, no measurements or documentation exists from Texaco for dense immiscible components. Those wells which may be capable of detecting a dense phase are plotted on Figure 25. Based on the hydrogeologic conditions in the South Area previously discussed, there are two areas where the potential for an accumulation of dense immiscibles could exist. They include a bedrock erosional low presented previously in Figure 7 and confirmed in Figure 16, and also a potentially abandoned meander loop identified on those figures. The low and abandoned meander loop are presented on Figure 25 for comparison to well locations. Although these areas may be potentially conducive to dense immiscible accumulation, other variables such as ground water flow directions and the alluvium/unnamed middle member interface surface (i.e. local features) may also be conducive.

For detecting dissolved constituents, it appears that numerous wells would be suitable, although Texaco has not implemented such a ground-water program at this time.

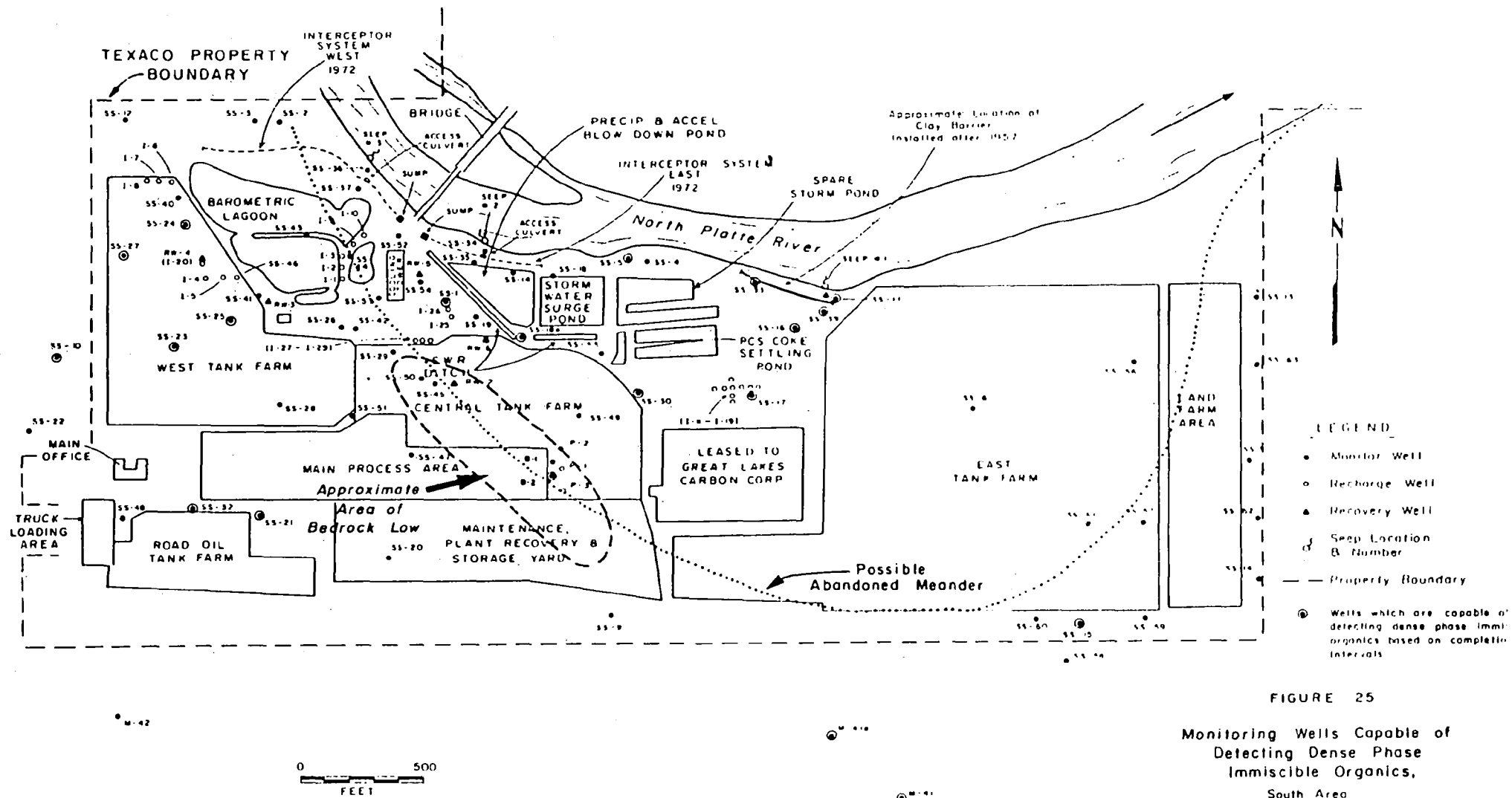


FIGURE 25

Monitoring Wells Capable of
Detecting Dense Phase
Immiscible Organics,
South Area

Texaco Refinery, Casper, Wyoming

Only two wells, SS-13 and SS-22, have a screened interval within the bedrock, although at this time no analytical data have been collected. Both wells appear to have been completed in a sandy siltstone or silty sandstone lens in the unnamed middle member. It should be noted that construction details indicate that only well SS-13 may be completed to allow for a discrete sample from the bedrock unit and this well is located in the southeastern area far removed from the areas of hydrocarbon accumulation (Appendix C). Further evaluation of the bedrock unit is recommended in order to evaluate the potential for contaminant pathways and/or contamination in this unit.

The horizontal locations of wells M-41, M-41a, M-42 and SS-9 all appear to be appropriate for them to serve as background wells for the South Area, based on ground-water flow (Figure 17). Although M-42 is presented on this Figure, no completion records or geologic logs were provided to the Task Force.

Design specifications of the wells located within the South Area and evaluated by the Task Force are presented briefly in Table 12 and are detailed on completion logs in Appendix C. Because of the large number of wells in the South Area, only general construction practices and inadequacies will be mentioned.

All wells were drilled with either rotary or hollow stem augers to the total depth of the boring. The rotary drilling included the use of either Hydrogel, air, water, or Johnson Revert (Appendix C). No details were provided by Texaco on the chemical composition of the drilling fluids.

As indicated on Table 12, many of the wells were drilled to a total depth (top of bedrock) which was several feet deeper than where the bottom of the well was actually completed. In most cases the bottom of the boring was either backfilled or gravel packed, and then the well was completed. As was previously stated for the North Area, the backfilled or gravel packed interval below the bottom of the well may act as a pathway for potential migration of contaminants deeper in the aquifer. At least one well (SS-6) contained a bentonite seal at the bottom of the hole to avoid vertical migration of contamination (Appendix C).

As presented in Table 12, well construction materials vary from 2" and 4" PVC to 4" Schedule 40 galvanized steel. The screen and in many cases the perforated interval was constructed of saw, pre-cut galvanized (0.10 perforations) slots or stainless steel Johnson screen (0.02 to 0.1 slot) for the 4" galvanized wells or factory slotted PVC screen with variable slot size from 0.02, 0.08, to 0.18 inches for the PVC wells. Screen lengths varied from 3.0 to 22 feet (Table 12, Appendix C). The TEGD (EPA, 1986a) states that the use of galvanized in conjunction with stainless steel may lead to accelerated corrosion of the galvanized steel, which could cause failure of wells during long term monitoring. The TEGD recommends that an electrically isolating (dielectric) coupling be used when two dissimilar metals are in direct contact.

Also, the use of PVC as a monitoring well material may present problems when in contact with aqueous organic mixtures. Please refer to the discussion on the adequacy of PVC well casing material for the North Area.

In all wells, the filter pack consisted primarily of a gravel pack material (pea-gravel, 8-16 or 12-20 free silica sand), or in many cases, collapsed formation material or backfill from drill cuttings. Texaco did not provide a grain size analysis of the formation material which could have been used to evaluate the adequacy of the screen slot size with either the natural gravel pack or the introduced filter pack.

In most cases the gravel pack and/or backfill extended well beyond the recommended 2.0 feet above the top of the screen. This recommended interval ensures collection of discrete samples (TEGD, EPA, 1986a) (Appendix C).

The use of bentonite as an annular sealant above the screen was noted in numerous wells, although it was also common practice to backfill the annular space above the gravel pack and/or top of screen with drill cuttings to about 2-3 feet below ground surface. Overlying the gravel pack, a cement surface seal (2:1 cement to water ratio) was installed. The use of drill cuttings as backfill material may not be appropriate as contaminants from the soils could migrate into the open interval. In addition, where a bentonite annular seal is non-existent, the backfill and/or gravel pack could provide a contaminant pathway from shallow to deep aquifer flow paths.

There were no data presented by Texaco on the type of well development procedures which may have been utilized following well construction.

Data collected by the Task Force for turbidity from several South Area wells indicate values exceeding those recommended by the TEGD (5 N.T.U.) (EPA, 1986a). The values recorded by the Task Force include: SS-19, 90 N.T.U.; SS-7, 85 N.T.U.; and SS-49, 247 N.T.U. These high turbidity values may be a result of screen slot size vs. gravel pack vs. formation material, or may be a result of the natural introduction of silts and clays to the well. The impact of such turbidity values should be evaluated by Texaco if a ground-water quality sampling program is implemented in the future.

As a check on the construction diagrams and the measured vertical placement of the screened intervals, the Task Force measured total depth for comparison. A brief comparison showed that the Texaco boring logs for wells SS-49, SS-4, SS-7, SS-34 and M-41A compared favorably with only slight variances of 1 to 2 feet. These variances may be a result of accumulations of sediment in the bottom of the well or errors in measurements during well completion.

Past Analytical Performance (Central South Area) Studies of the water quality in the South Area are limited to those performed by Texaco in conjunction with the oil recovery project. Specifically, only an evaluation of the excess water produced from the recovery wells exists. The first set of ground-water analyses were collected in September 1982 at monitoring wells M-41a (upgradient), SS-9 (upgradient), Ob-2, SS-1, SS-5 and #10 (not utilized or presented on Table 12 by the Task Force). These wells are for the most part completed with screens below the oil-water interface to evaluate concentrations of dissolved constituents. As part of Texaco's permit conditions to operate the oil recovery system, samples were collected

at the recovery wells on November 27, 1984 and again on May 14, 1985 (Groundwater Technology, 1983-1985). During these sampling events, indicator parameters, inorganics and some metals were sampled for. The only organic analysis for the alluvial aquifer in the South Area was for effluent from the interceptor system flowing to the effluent ponds (WWC, 1983b). The next sampling event was performed by the Task Force in August 1986, where five wells (SS-19, SS-49, SS-34, SS-4, and M-41a) in the central portion of the South Area were analyzed. Results verify the presence of organics in the ground water. This does not include the present investigation currently ongoing in the southeastern portion of the property, which is discussed later in this section.

The inorganic and indicator parameter analytical results for samples collected from wells M-41a, well SS-9, well Ob-2, well SS-1, well SS-5 and well #10 are presented in Table 13 and their locations can be found on Figure 15.

These data show elevated TOC and chlorides when compared to background. The metals analysis did not show any elevated constituents. As was previously mentioned, Texaco maintains that the organic data listed in Table 14 for the inflow to Excess Effluent Ponds is representative of the alluvial ground water as it originates in the interceptor ditches. These data show several organics detected which may exist in light and/or dense immiscible phases (dependent upon concentrations) and/or dissolved in ground water when compared to the physical characteristics of refinery wastes outlined previously in Table 5.

The ground-water data collected in November 1984 was for effluent being pumped from recovery wells RW-1, RW-2, RW-3, RW-5 and RW-6 (Groundwater Technology, 1983-1985). These data were evaluated to characterize the quality of the water being discharged to recharge wells as part of the oil recovery system. These wells (RW-1, RW-2, RW-3, RW-5 and RW-6) were again sampled in May 1985 for similar constituents which include indicator parameters, some inorganics and several heavy metals. As previously mentioned, no organics were sampled for. Analytical results are presented in the Fifth and Seventh Quarterly Reports for the Oil Recovery System (Groundwater Technology, 1983-1985). Table 15 lists those parameters which either appear to be elevated or have been identified as indicator parameters at the facility. These results indicate variable water quality with sulfate and chromium concentrations being consistently elevated and above the applicable criteria. It should be noted that sulfates may be a function of variable ground-water quality in the shallow aquifer and/or biodegradation of sulfides, as background sample results in Table 13 show elevated sulfates. It is probable that the waste constituents of concern in the South Area are organics, for which there is a lack of data.

The Task Force samples collected in August 1986 were analyzed for organics at wells SS-19, SS-49, SS-34, SS-4 and M-41A. These results are discussed in detail later in this report. In summary, numerous organics including benzene, ethylbenzene, naphthalene, toluene, total xylenes and other base/neutral organics were detected in various concentrations. The upgradient well M-41A did not contain any organics. It is worth noting that at well SS-4, adjacent to SS-5, several other organics were detected which

Table 13 Water Quality Data, Casper Texaco Refinery (September 1982).

Constituent	Well N-41A	Well SS-9	Well Ob-2	Well SS-1	Well SS-5	Well #10
<u>Organic Species</u>						
Biochemical Oxygen Demand (mg/l)	20	23	26	14	23	32
Chemical Oxygen Demand (mg/l)	43	2	75	3	199	127
Oil and Grease (mg/l)	2.1	1.0	1.9	1.2	54.2	8.4
Phenols (mg/l)	-0.01	-0.01	-0.01	-0.01	0.10	0.10
Total Organic Carbon (mg/l)	29.2	21.0	61.9	34.6	50.5	46.2
<u>Field Parameters</u>						
pH (std. units)	7.1	7.3	7.2	7.5	6.9	--
Spec. Cond. (umhos @ 25°C)	2030	1380	1490	2110	1490	--
Temperature (°C)	10	19	21	23	22	--
<u>Major Inorganic Species</u>						
Total Dissolved Solids (mg/l)	2526	1400	1323	1817	1145	963
Sodium (mg/l)	210	128	122	373	202	65
Potassium (mg/l)	27	10	87	49	39	64
Calcium (mg/l)	261	132	172	116	120	164
Magnesium (mg/l)	185	105	105	105	63	81
Bicarbonate (mg/l)	540	400	880	700	880	1020
Sulfate (mg/l)	1430	650	363	315	8	12
Chloride (mg/l)	32	17	72	445	255	56
<u>Minor Inorganic Species</u>						
Arsenic, Total (mg/l)	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Barium, Total (mg/l)	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10
Boron, Total (mg/l)	0.92	0.51	0.74	0.51	0.42	0.54
Cadmium, Total (mg/l)	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
Chromium, Total (mg/l)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Chromium, Dissolved (mg/l)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Copper, Total (mg/l)	0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Cyanide, Total (mg/l)	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02
Fluoride, Total (mg/l)	0.27	0.40	0.30	0.45	0.27	0.40
Iron, Total (mg/l)	0.04	0.03	0.04	0.04	0.29	0.09
Lead, Total (mg/l)	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Manganese, Total (mg/l)	0.18	0.05	1.06	0.70	2.46	1.08
Mercury, Total (mg/l)	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
Nitrogen, Ammonia (mg/l as N)	-0.05	-0.05	0.85	0.27	3.3	4.0
Nitrogen, Nitrate (mg/l as N)	0.48	0.22	0.10	0.15	0.24	0.47
Nitrogen, Nitrite (mg/l as N)	0.035	0.002	0.001	-0.001	0.005	0.040
Selenium, Total (mg/l)	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Silver, Total (mg/l)	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Sulfide (mg/l)	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10
Uranium, Total (mg/l)	0.028	0.007	0.004	0.002	0.001	0.001
Zinc, Total (mg/l)	1.043	1.191	1.329	0.603	1.550	-0.005

Note: -- means less than value shown

Source: wwc. 1983b

Table 14 TOX and Priority Pollutant Data for the Excess Service Water Effluent Ponds, Casper Texaco Refinery (October 1982).

Constituent	Inflow to Excess Effluent Ponds	Excess Effluent Pond #1	Excess Effluent Pond #2	Excess Effluent Pond #5
<u>Chlorinated Hydrocarbons</u> ^(a)				
TOX (ug/l as Cl)	--	41	63	49
∞ - BHC (Benzene Hexachloride) (ug/l)	-0.001	-0.001	-0.001	0.12
Endosulfan Sulfate (ug/l)	3.5	-0.03	-0.03	-0.03
1,1,1 - Trichloroethane (ug/l)	3	-2	-2	-2
<u>Unchlorinated Hydrocarbons</u> ^(a)				
Methyl Phenol (2 isomers) (ug/l)	-50	-50	-50	-50
Dimethyl Phenol (2 isomers) (ug/l)	-50	-50	-50	-50
Methyl Ethyl Phenol (2 isomers) (ug/l)	-50	-50	-50	-50
Acetone (ug/l)	25	-5	-5	88
2,2,5 - Trimethylhexane (ug/l)	20	-5	-5	-5
Dimethyl Hexane (ug/l)	24	-5	-5	-5
Methyl Octene (ug/l)	34	-5	-5	-5
Methyl Cyclohexane (ug/l)	53	-5	-5	-5
Trimethyl Cyclopentane (ug/l)	9	-5	-5	-5
Ethyl Methyl Cyclopentane (ug/l)	6	-5	-5	-5
Methyl Naphthalene (ug/l)	150	-10	-10	-10
Dimethyl Naphthalene (ug/l)	630	-10	-10	-10
Trimethyl Naphthalene (ug/l)	370	-10	-10	-10
Methyl Phenanthrene (ug/l)	97	-10	-10	-10
Hydrocarbons C ₁₆ - C ₁₈ (ug/l)	180	-10	-10	-10
Naphthalene (ug/l)	-10	-10	-10	-10
Toluene (ug/l)	-2	-2	-2	-2
Chrysene (ug/l)	27	-10	-10	-10
Fluorene (ug/l)	41	-10	-10	-10
Phenanthrene (ug/l)	67	-10	-10	-10
Pyrene (ug/l)	61	-10	-10	-10

(a) Priority pollutants not listed on the table were not detected in the samples.

Source: WWC 1983b

Table 15

Summary of Refinery- Related Constituents
Recovery Well Samples - South Area

<u>Parameters</u>	<u>Applicable Criteria</u>	<u>RW-1 11/27/84</u>	<u>RW-1 5/14/85</u>	<u>RW-2 11/27/84</u>	<u>RW-2 5/14/85</u>	<u>RW-3 11/27/84</u>	<u>RW-3 5/14/85</u>	<u>RW-5 11/27/84</u>	<u>RW-5 5/14/85</u>	<u>RW-6 11/27/84</u>	<u>RW-6 5/14/85</u>
Sulfate	250 ^{*1}	8	24	1020	1030	2840	1960	440	550	760	900
Chloride	250 ^{*1}	24	24	26	31	110	84	38	57	32	30
Phenol	NA	0.16	0.11	0.04	0.10	1.5	0.99	0.08	0.11	0.10	0.11
Chromium(T)	0.05 ^{*2}	0.10	0.08	0.17	0.20	0.21	0.23	0.08	0.12	0.14	0.19
Lead (T)	0.05 ^{*2}	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)	0.17	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)	ND(0.05)
TOC	NA	32	23	9	7	62	29	18	19	129	10
Oil & Grease	NA	365(oil)	0.7	4.0	ND(1.0)	1091.0	1.4	22.8	77.8	3.58	0.4
pH (su)	NA	7.1	7.0	8.4	7.65	7.5	7.2	7.0	7.35	7.2	7.0
Conductivity (umhos/cm)	NA	936	1090	1600	2180	4360	3750	1260	1660	1710	1920

*1 Secondary Drinking Water Standards 40 CFR 143.3.

*2 Primary Drinking Water Standards 40 CFR 265 App III.

Sources: Groundwater Technology, 1983-1985

are indicative of a dense immiscible organic phase. These constituents include chrysene, fluorene, fluoranthene, pyrene and phenanthrene. This supports the previous statement that dense immiscible organics are of concern at wells SS-4, SS-5, and possibly in other areas at the site.

Based on the past analytical performance for the South Area, it is apparent that Texaco has only been evaluating the extent of floating product, as a ground-water quality evaluation for both dissolved constituents and dense phase organics has not been undertaken.

Southeast Corner As previously mentioned, the southeastern corner of the refinery property is currently subject to an investigation of the extent of ground-water contamination in this area (WWC, 1987b). Approximately 13 monitoring wells have been included in this investigation (Figure 15). Of the 13 wells, 8 were installed in late 1986 and 1987 as a result of the Task Force evaluation and will not be discussed in detail. These eight wells include SS-56 through SS-63 (see Figure 15). The subsequent discussion refers to the five original wells.

The vertical placement of the screened interval in most wells is completed in the alluvium with emphasis on detecting light immiscible phases. In the past, floating phases have been detected in well SS-15. Monitoring well SS-13 has been screened within the unnamed middle member.

Based on the refinery waste constituents (Table 5), the monitoring wells in this area should be capable of detecting light and dense immiscibles and also dissolved constituents. Based on Table 12 and Figure 24, none of the five wells have screened intervals capable of detecting light phases (SS-6 and 7, SS-13 - 15). As was previously presented in Figure 18, the ground-water flow direction appears to be northeast to east, although in the vicinity of well SS-15, the gradient appears to be fairly flat and probably to the east. According to Table 12, SS-14 does not have a screened interval which intersects the water table. At this time no wells exist at the southeastern property boundary (Figure 24) capable of monitoring for light immiscibles potentially migrating off the Texaco property. The presence of light immiscibles detected in well SS-15 (0.1 feet) indicates the need for additional wells located to the east/southeast to evaluate the presence of a floating phase.

Table 12 also presents those wells which could detect a dense immiscible component. As previously mentioned, these wells would have to contain a screened interval completed at the alluvium/unnamed middle member interface.

Based on these criteria, only one well, SS-15, may be capable of detecting a dense immiscible phase if measured and/or sampled for (Figure 25). Well SS-13, completed in the unnamed middle member, may be capable of detecting a dense phase, if migration from the alluvium to the top of the unnamed member has occurred. It is interesting to note in this area, especially at well SS-7 and SS-14, that the erosional subsurface of the bedrock is deep, compared to adjacent wells. This feature can be seen on the bedrock surface map presented as Figure 16. It is possible that the

bedrock surface could control contaminant migration and ground-water flow. The potentiometric map constructed by the Task Force (Figure 18) appears to mimic the bedrock surface, especially near well SS-13.

For detecting dissolved constituents, it appears that several of the wells would be capable, as several dissolved contaminants were detected in the wells, unrelated to light phase immiscibles (i.e., SS-7 and SS-14). At this time, the monitoring wells completed at the eastern boundary (SS-7 and SS-14) and along the southern boundary (SS-13) have shown some organics contamination. No wells have been installed outside of the Texaco property to evaluate the extent and/or contaminant concentrations. Analytical results are discussed in further detail later in this section, under past analytical performance.

Wells SS-6 and M-41A would appear to be located appropriately to act as upgradient wells. However, the ground-water flow conditions as they relate to well M-41A and the southeastern corner should be investigated further, possibly by the installation of additional piezometers.

Design specifications of the wells located within the southeastern area are presented in Table 12 and are detailed on completion logs presented in Appendix C. The new wells SS-56 through SS-63 are included in this Table and Appendix as information on well specifications was available to the Task Force at the time of this writing.

The construction of wells SS-6, SS-7, SS-13, SS-14 and SS-15 is similar to the design specifications previously discussed for the wells in the central portion of the South Area (see previous discussion). Therefore the deficiencies in construction previously presented also pertain here.

Past Analytical Performance (Southeast Corner) The sampling of monitoring wells in this area began with the detection of benzene, ethylbenzene, total xylenes and naphthalene at well SS-7 by the Task Force evaluation performed in August 1986. Since August 1986, Texaco collected samples in October 1986 for verification of the Task Force results, and in December initiated a drilling program and sampling schedule to investigate this contamination.

Potential sources as identified by Texaco may include "the storage tanks and pipe lines in the East Tank Farm, numerous other (non Texaco) hydrocarbon pipelines in the area and other (non Texaco) storage tanks near the area of investigation" (WWC, 1987b). No further details were provided.

It appears that Texaco has only analyzed for selected organic compounds (benzene, ethylbenzene, toluene, xylene, and naphthalene) in the southeastern area. Texaco has plotted concentrations for the October 1986 sampling event, which are presented in Figure 26.

As can be seen from Figure 26, contamination has been detected consistently along the eastern property boundary (SS-7 and SS-14) and southeastern corner (SS-15), with the highest concentrations found in SS-15 (note that this well has contained accumulations of hydrocarbon in the past).

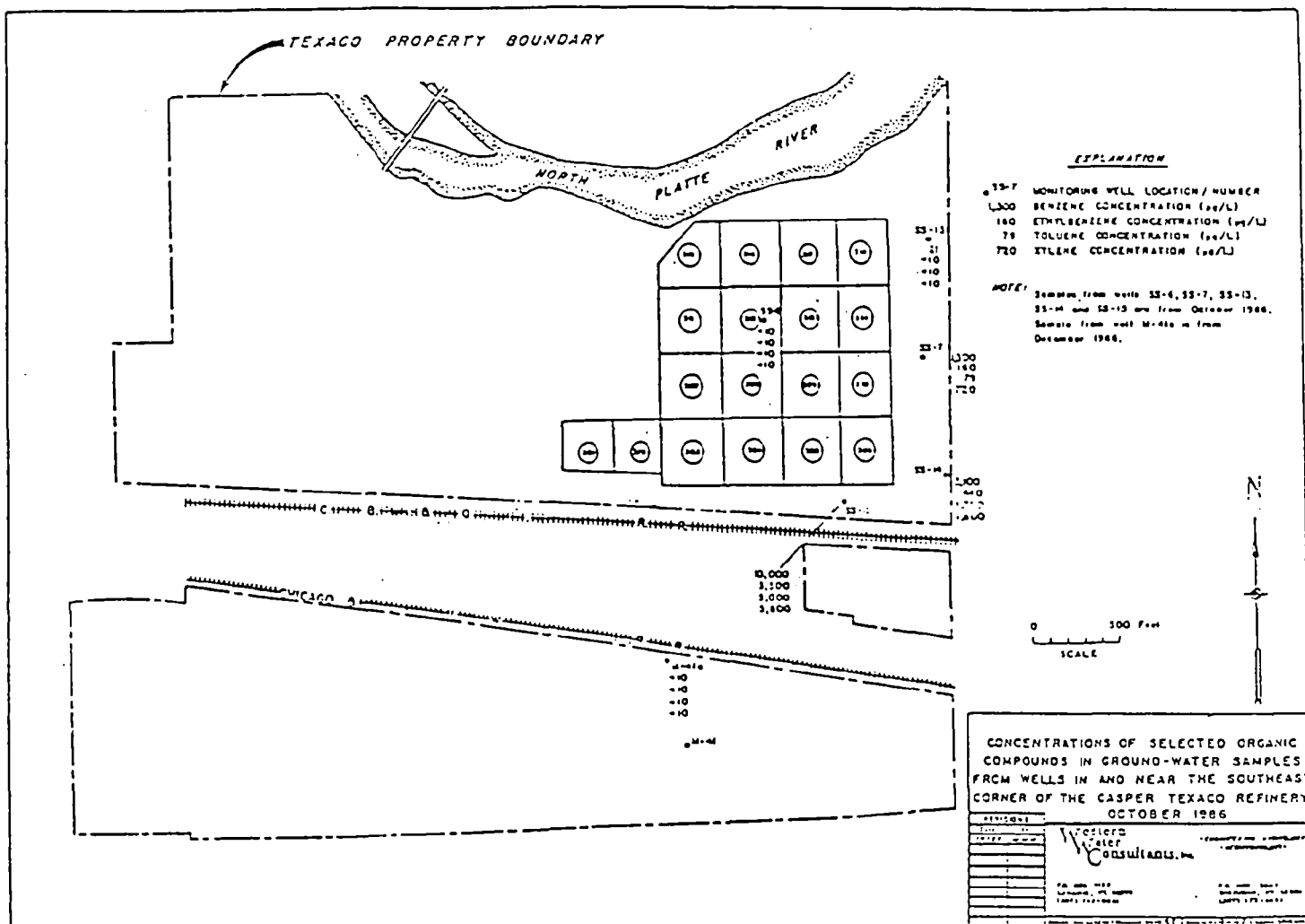


Figure 26

In summary, it appears that the potential for migration of contamination off-site to the east is high, as wells along the property boundary have elevated concentrations of several organics and the potentiometric map (Figure 18) indicates an eastern/northeastern component of flow. It should be noted that the ground-water flow is not completely understood at this time. As previously mentioned, additional data is required to completely understand the conditions in this area.

c. Adequacy of Ground-water Monitoring System (South Area)

The facility-wide monitoring system was designed and constructed to detect and evaluate the extent of accumulations of floating hydrocarbons throughout the south property. As a result, the full extent of contamination in the South Area has not been defined, specifically the presence of dissolved and/or dense phase immiscible organics. It appears that a detailed evaluation of the rate and extent of contamination and oversight of the ground water corrective action system will fall under RCRA as the potential for releases from SWMUs has been documented in an RFI (A.T. Kearney, 1986).

Of importance is the identification and abatement of all potential sources of ground-water contamination in the South Area which may be continuing to release contaminants into the ground water in the form of light and dense phase immiscibles and other dissolved organic and inorganic contaminants.

The monitoring well network overall appears adequate to detect and evaluate the presence of the floating hydrocarbons in the South Area, although as was pointed out previously, several areas north of the identified plume (Figure 24) appear to lack wells constructed to monitor for light immiscibles. These wells would aid in detecting floating hydrocarbons migrating towards the river prior to any actual seepage along the south bank of the North Platte River.

Although numerous wells may be adequate to detect dense phase immiscible components, Texaco has not initiated a program to evaluate the potential for such accumulations. It was documented during the Task Force investigation that dense phase immiscible do exist at the site as was evidenced by a one foot sinking oil phase at the bottom of well SS-19. As was previously mentioned, several areas at the site appear to be conducive for the accumulation of dense phase immiscibles (e.g., Figure 25 presents approximate locations of bedrock lows and abandoned meander loop channels of the North Platte River).

The significance of dissolved organic contamination in the ground water has not been addressed except in the southeastern corner of the South Area. Wells in this area have detected benzene, ethyl benzene, toluene, total xylenes and naphthalene.

The southeastern area lacks the number of wells required to define the full extent of contamination. This is apparent as wells located along the eastern and southern boundary have detected organic contaminants, and based on ground-water flow directions, appear to be migrating off-site to the east/northeast.

Several construction problems also exist with the monitoring well network as previously mentioned. It is difficult to assess the impact of these problems at present as Texaco has concentrated only on monitoring accumulations of floating hydrocarbons. When a ground-water quality assessment of the South Area is undertaken, the adequacy of each well must be evaluated prior to collecting and analyzing ground-water samples. It may be appropriate, through process of elimination, to choose wells in the South Area which meet the technical requirements of RCRA monitoring wells as set forth in the TEGD (EPA, 1986a) and at the same time are placed vertically and horizontally such that the full extent of contaminant migration can be evaluated.

d. Hydrocarbon Recovery System

In response to the problem of floating hydrocarbons, two remedial action technologies have been employed at the site. The first remedial action includes the interception of ground water along the south bank of the North Platte River via two interceptor ditches, and the second, involves the recovery of floating hydrocarbons by pumping the aquifer. The following is a discussion of each remedial action technology.

Interceptor Ditch System The original interceptor ditch was installed in 1957 to address oil seepage into the North Platte River (i.e. seeps #2 and #3, Figure 15). In addition to these open ditches, several pits were installed to intercept floating hydrocarbons. Both the trenches and pits reportedly recovered high volumes of hydrocarbon wastes (WWC, 1982c). There are no data on the maintenance and/or performance of these trenches from 1957 to 1972, when they were replaced. According to Texaco, a "Clay Barrier" was also constructed in 1957 (Figure 15). No construction details were provided, except that the clay was locally derived material with hydraulic conductivities ranging from 10^{-4} to 10^{-5} cm/sec (WWC, 1982a). Based on the potentiometric map for the South Area (Figure 17), it appears that this clay barrier may still exist (i.e., flow of ground water around clay barrier and east trench).

The present interceptor system (east and west, Figure 15) was constructed in 1972 and 1973 to replace the original open trenches. This new system consisted of a closed system. The east and west trenches were constructed using two 24-inch perforated culverts, stacked on top of each other, approximately 495 and 643 feet long, respectively. Each ditch, following insertion of culverts, was backfilled with one inch gravel, a minimum of 2 feet on each side of the culvert (WWC, 1982c). Based on the regulatory definition of a SWMU, both trenches meet this definition as previously discussed.

At the east end of the west trench and the west end of the east trench, a 17-foot deep concrete sump was installed with a 300 gpm pump located in each. Water levels in the trench were controlled by an adjustable weir located in each sump. Water levels in the trench were maintained approximately 0.6' below the river in order to reverse flow and have the trenches act as a ground-water sink. From the sumps, the hydrocarbons and ground water are

diverted through a series of tanks used to separate the oil phase and store water prior to discharge to the service water ditch system (Figure 15) (WWC, 1982c).

In 1982, Texaco performed a spot check on the velocity of flow and also installed 4 wells, SS-36 and SS-37 (West System) and SS-34 and SS-35 (East System) to evaluate the cone of depression caused by the trenches. The flow tests performed by Texaco indicated that there was flow in the western system, but little to no flow in the eastern system. This would indicate that the eastern system may not operate properly during certain times of the year. The water level measurements taken in 1982 at the wells adjacent to the trenches (SS-34, SS-35, SS-36, SS-37) show that the trench systems are in fact acting as ground-water sinks (WWC, 1982c). Since 1982, no data exist on maintenance or performance monitoring of the interceptor system. Based on the location of the east and west system, and the approximate location of the "clay barrier" (Figure 15), it appears that approximately 950 feet of the south bank of the North Platte River could be subject to undetected seepage. This seems highly likely as substantial accumulations of hydrocarbons were detected over time by Texaco in wells SS-4 and SS-5 and by the Task Force in August 1986 in well SS-4 (5.02 feet). This suggests that floating hydrocarbons and possibly dense phase immiscibles may be migrating to the north and towards the river in this area.

The analytical results collected by the Task Force in August 1986 at well SS-34 showed concentrations of benzene at 38 ug/l, indicating that a dissolved organic fraction may be migrating past the east interceptor trench. In addition the Task Force results for well SS-4 indicate that organic contamination exists in this well in elevated concentrations, thus increasing the potential for discharge to the river as a trench or barrier does not exist in this area. As previously mentioned, the results seem to indicate that contamination in wells SS-4 and SS-34 may be in the form of a dense immiscible phase (i.e. presence of chrysene, fluorene, fluoranthene etc.) or dissolved organics respectively. This indicates the trench system may not be capable of intercepting dense phase organics.

Because detailed construction design specifications were not available, it could not be determined whether the interceptor trenches would in fact intercept dense immiscibles migrating towards the river. If in fact the trenches could intercept dense phases, the sumps (based on details provided by Texaco) do not appear capable of pumping dense phase hydrocarbons collected at the bottom of the sump (WWC, 1982c). Although the interceptor system may drain dissolved organic constituents within the ground water to the sump, the treatment process (oil/water separation) would not adequately treat dissolved constituents. The water routed through the separation tanks would in fact end up in the service water system ditch, and would be returned to the ground water through seepage from the bottom of the ponds (i.e. service water ditches and ponds) (A.T. Kearney, 1986).

Oil Recovery System Texaco installed a series of hydrocarbon recovery wells in August, 1983 (RW-1 through RW-4). In June 1984, two additional recovery wells (RW-5 and RW-6) were installed. The approximate locations of these recovery wells is presented on Figure 15.

Each recovery well is fitted with two pumps, one which is situated at the ground-water interface to pump product, and the other pump utilized to depress the water table and induce flow of floating hydrocarbons toward the recovery well(s). The water produced from the pump which lowers the water table is injected without treatment down a series of recharge wells assigned specifically for each recovery well, except for RW-1 which discharges to the PCS coke settling pond. These recharge wells are also presented on Figure 15.

The design of the oil recovery system was based on the identified extent of floating phase, and the characteristics of the aquifer (WWC, 1983c). Figure 27 presents the theory originally used for the installation of the first four recovery wells in 1983. Figures 28 and 29 present as-built drawings for recovery wells RW-1 through RW-4. Design specifications for RW-5 and RW-6 installed in 1984 were unavailable. An as-built diagram for the recharge wells installed in 1983 is presented as Figure 30.

The design and operation of the oil recovery system as of January 1986, which includes all new components (recovery and recharge wells), is discussed below. Table 16 presents specifications for the recovery system in operation as of January 1986.

The operation of the recovery system has been somewhat intermittent since August of 1983 due to 1) severe weather during the winter months which forced shutdown of all recovery wells, except RW-1; and 2) in September, 1986, when the price of oil dropped, so did the reason for operating the recovery system, except RW-1. This was because the contractor operating the system derived their profits from the sale of recovered product (A.T. Kearney, 1986).

The reason for continued operation of RW-1 was that sometimes during the shutdown of this recovery well, oil seeps were noted along the river, beyond the interceptor system (probably the clay barrier). Since the system's operations from August 1983 to November 30, 1985, approximately 25,007 barrels of hydrocarbon have been recovered from this system (Groundwater Technology, 1983-1985). The breakdown for each individual well is as follows:

RW-1	9.0 barrels (no product removed since 1983; RW-1 still operating)
RW-2	11,307.68 barrels
RW-3	9,663.35 barrels
RW-4	587.58 barrels (shutdown April 1984)
RW-5	1,569.36 barrels
<u>RW-6</u>	<u>1,870.85 barrels</u>
Total	25,007.82 barrels

The Task Force reviewed nine quarterly reports from the period August 1983 to November 1985 (Groundwater Technology, 1983-1985) in order to evaluate the effectiveness of the oil recovery program in reducing the accumulations of hydrocarbons across the central portion of the South Area. During each quarter, Texaco constructed apparent petroleum thickness maps and ground-water contour maps to evaluate the effects of pumping. Figures 31 through 40 present apparent petroleum thicknesses for each quarter. As

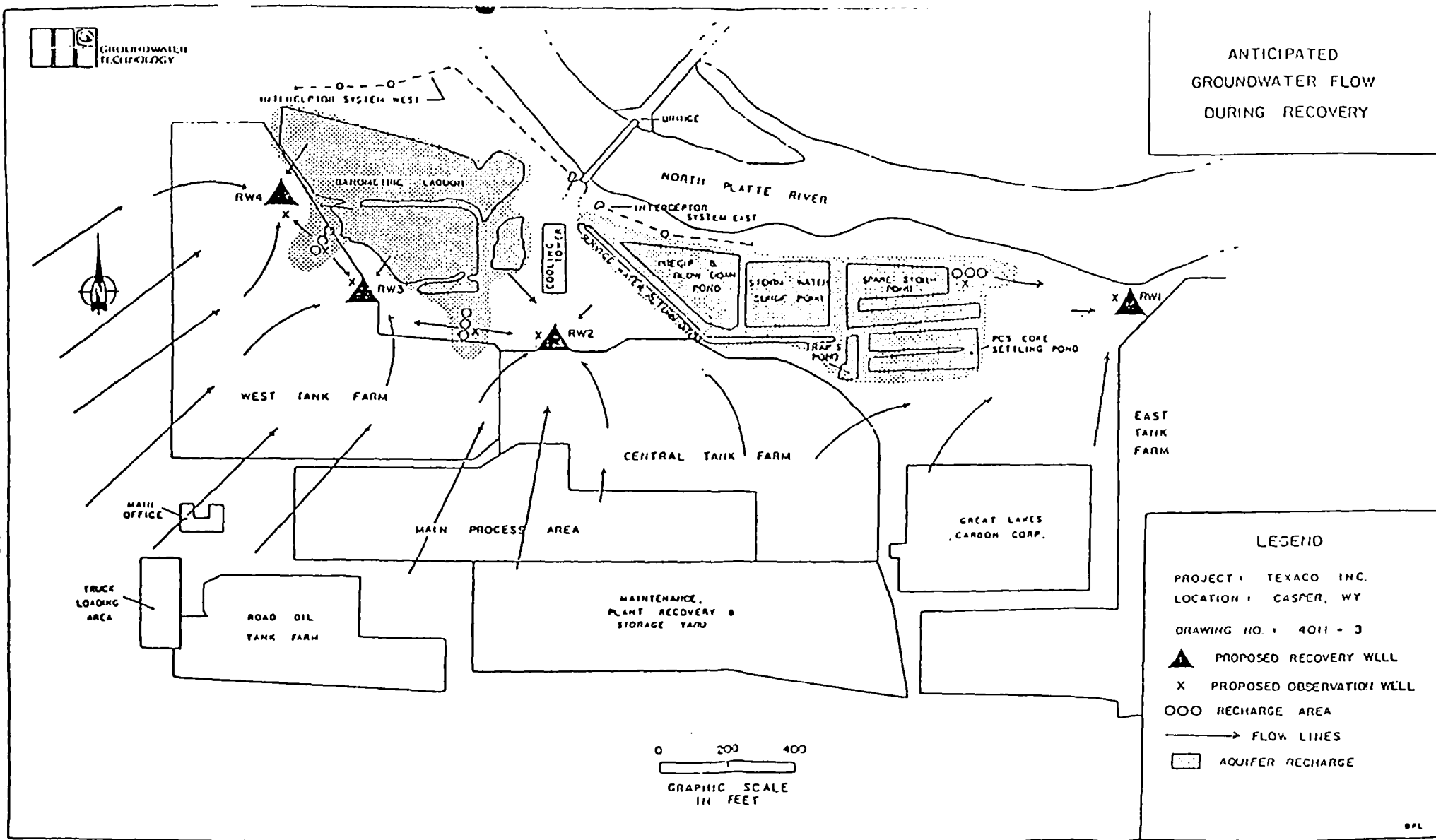


Figure 27

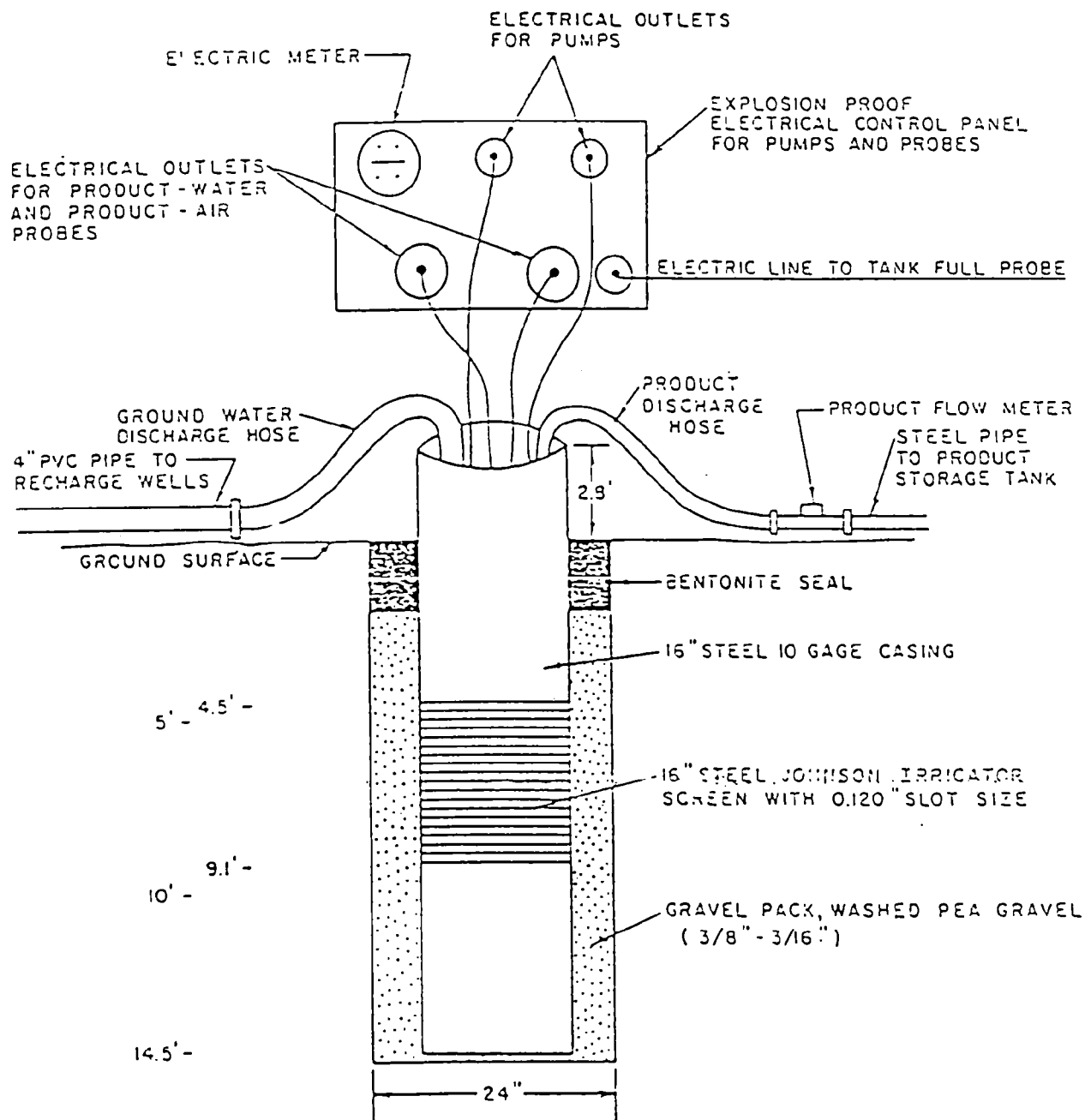


Figure 28

AS-BUILT DIAGRAM OF RECOVERY WELL RW-1
CASPER TEXACO REFINERY

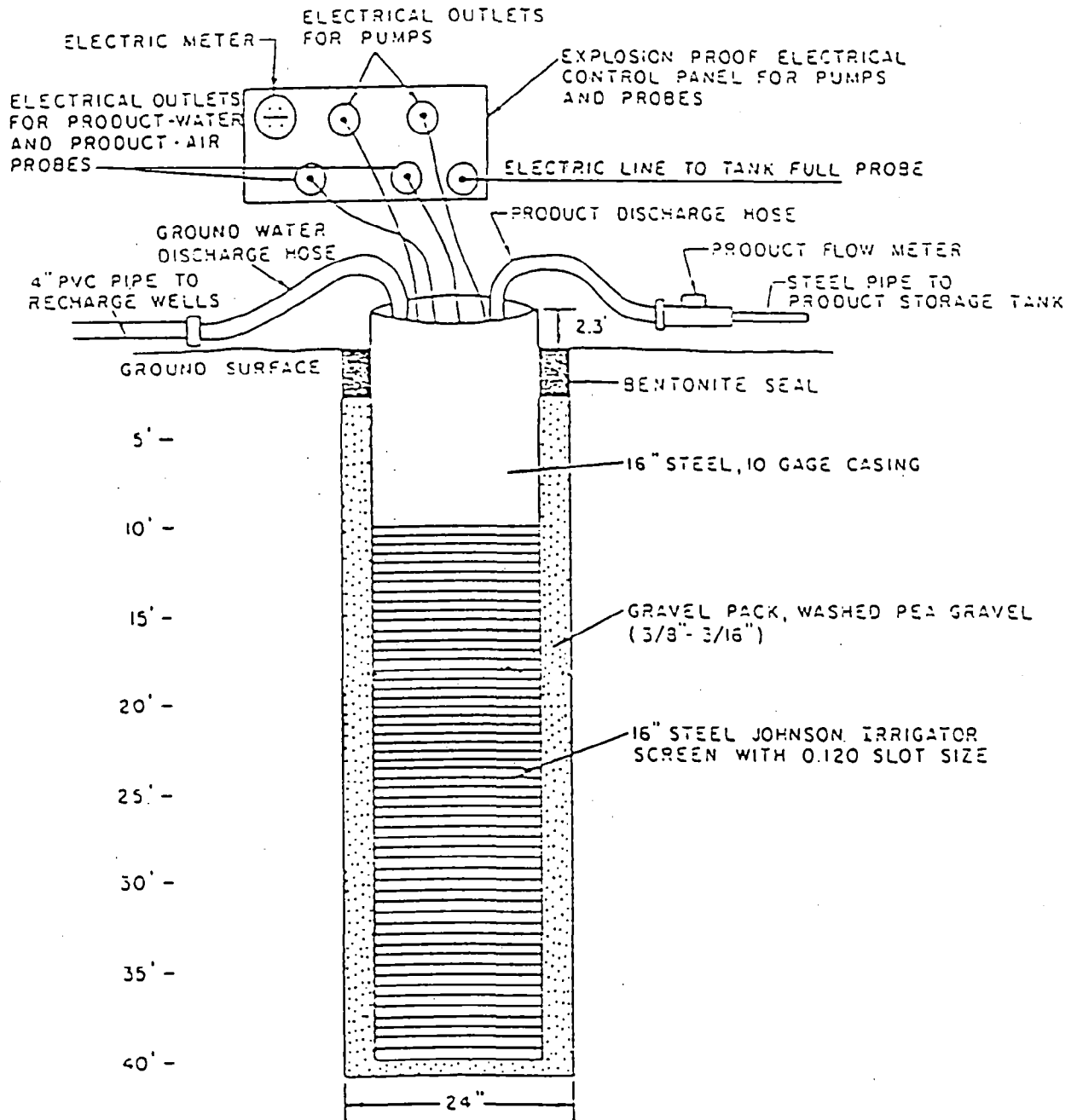


Figure 29

AS-BUILT DIAGRAM OF RECOVERY WELLS
RW-2, RW-3, AND RW-4, CASPER TEXACO
REFINERY

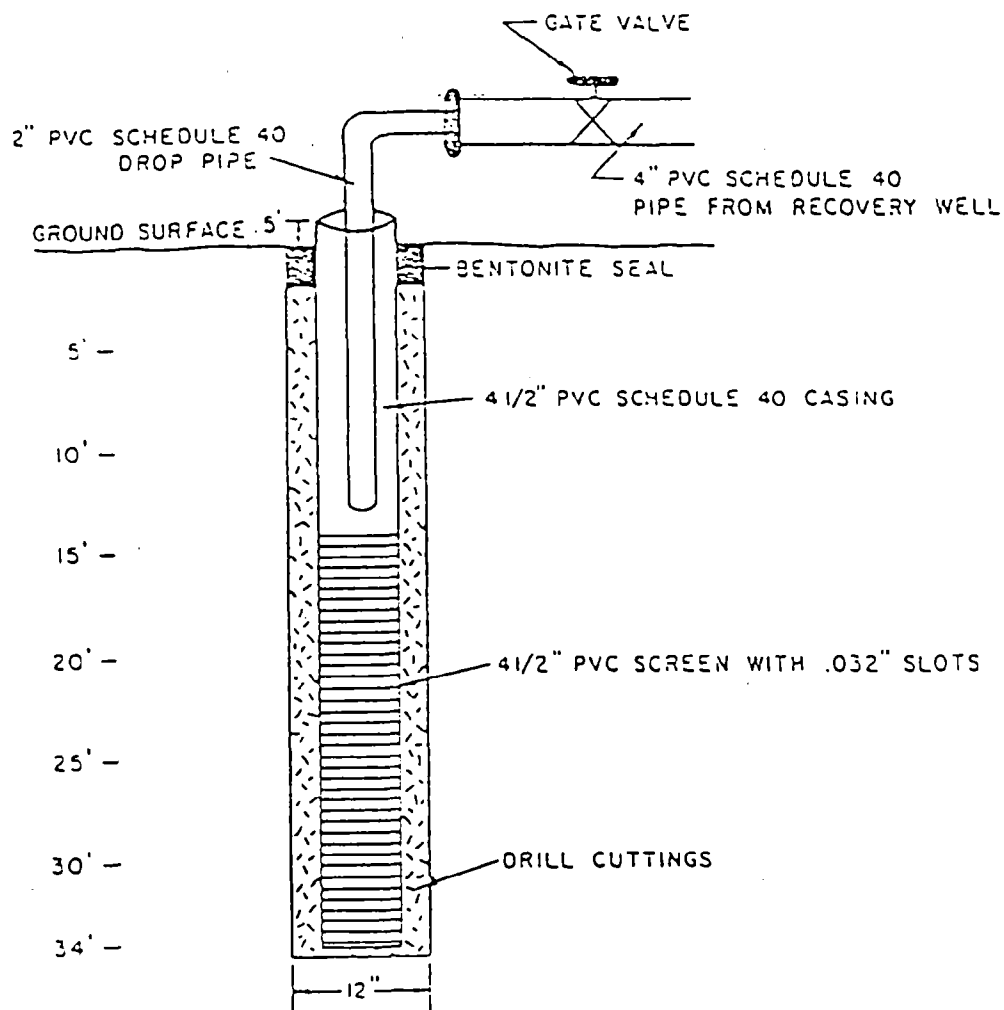


Figure 30

AS-BUILT DIAGRAM OF RECHARGE WELLS SS-46,
I-1, I-2, I-3, I-4, I-5, I-6, I-7, I-8 CASPER
TEXACO REFINERY

Table 16
Oil Recovery System Design Specifications

Recovery Well - Injection (Recharge) Well Series

<u>Recovery Well</u>	<u>Receiving Injection Wells</u>
RW-1	PCS Coke Settling Pond
RW-2	I-1, I-2, I-3, I-9 and I-10
RW-3	I-4, I-5 and SS-46
RW-5, RW-6	I-11 through I-19 and P-1

- Note:
- 1) RW-4 was removed from service in April 1984.
 - 2) Documentation as to what recovery well discharged to recharge wells P-2, P-3, I-20 and I-25 through I-29 was not available.
 - 3) Recharge Gallery I-11 through I-19 abandoned in May 1985.

Operational Pumping Rates

<u>Recovery Well</u>	<u>Maximum Pumping Rate (gpd)</u>	<u>Average Pumping Rate (gpd)</u>
RW-1	14,400	7,200
RW-2	259,200	216,000
RW-3	259,200	216,000
RW-5	230,400	64,800
RW-6	230,400	129,600

Recharge Wells/Capacity to Receive

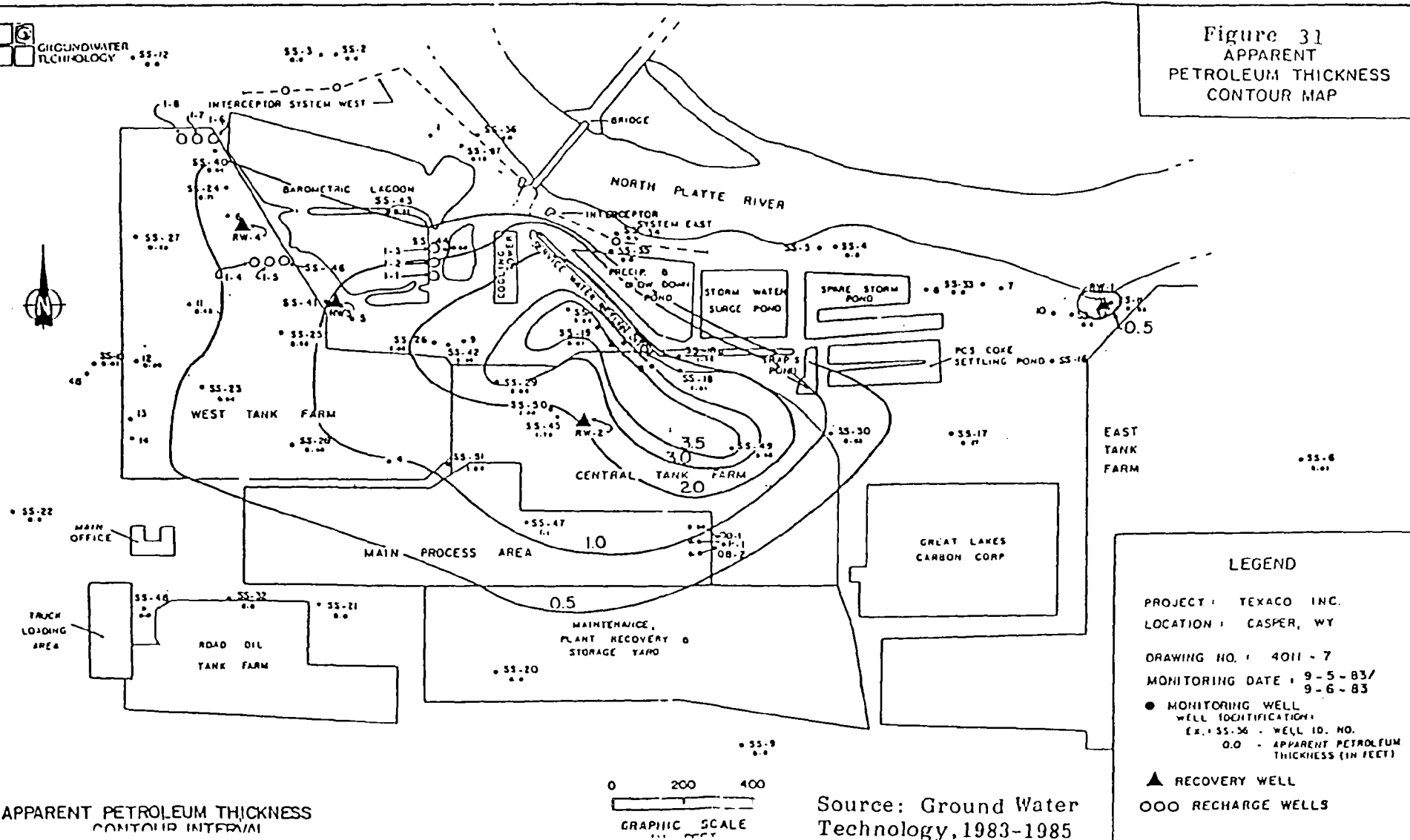
<u>Recharge Well</u>	<u>Maximum Receiving Rate (gpd)</u>	<u>Average Receiving Rate (gpd)</u>
I-1, I-2, I-3, I-9, I-10	51,840	43,200
I-4, I-5, SS-46	86,400	72,000
I-11 through I-19 and P-2	46,080	19,440

Source: A.T. Kearney, 1986



GROUNDWATER
TECHNOLOGY

Figure 31
APPARENT
PETROLEUM THICKNESS
CONTOUR MAP

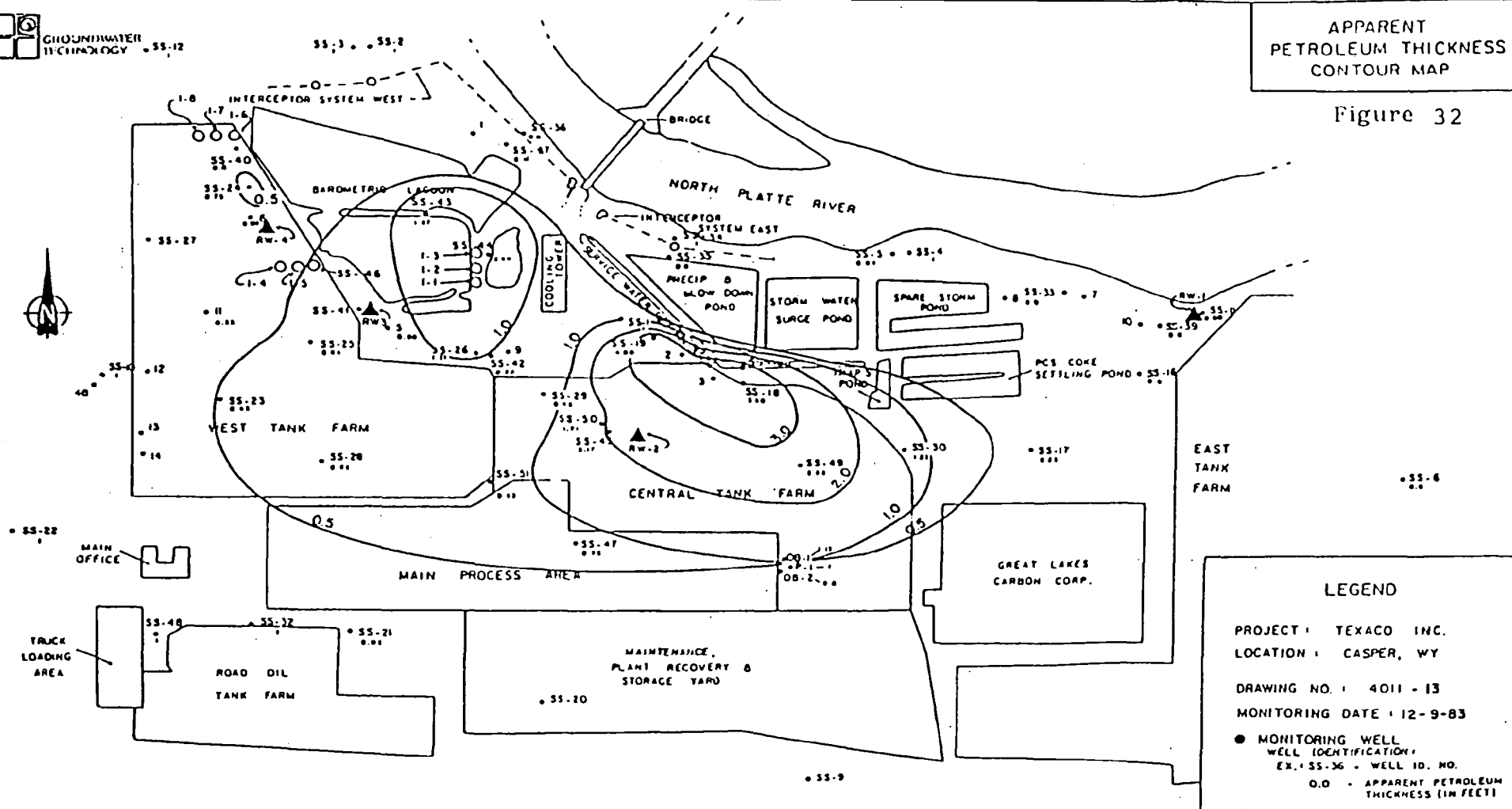




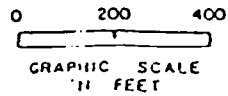
GROUNDWATER
TECHNOLOGY • SS-12

APPARENT
PETROLEUM THICKNESS
CONTOUR MAP

Figure 32



APPARENT PETROLEUM THICKNESS
CONTOUR INTERVAL
AS SHOWN — IN FEET

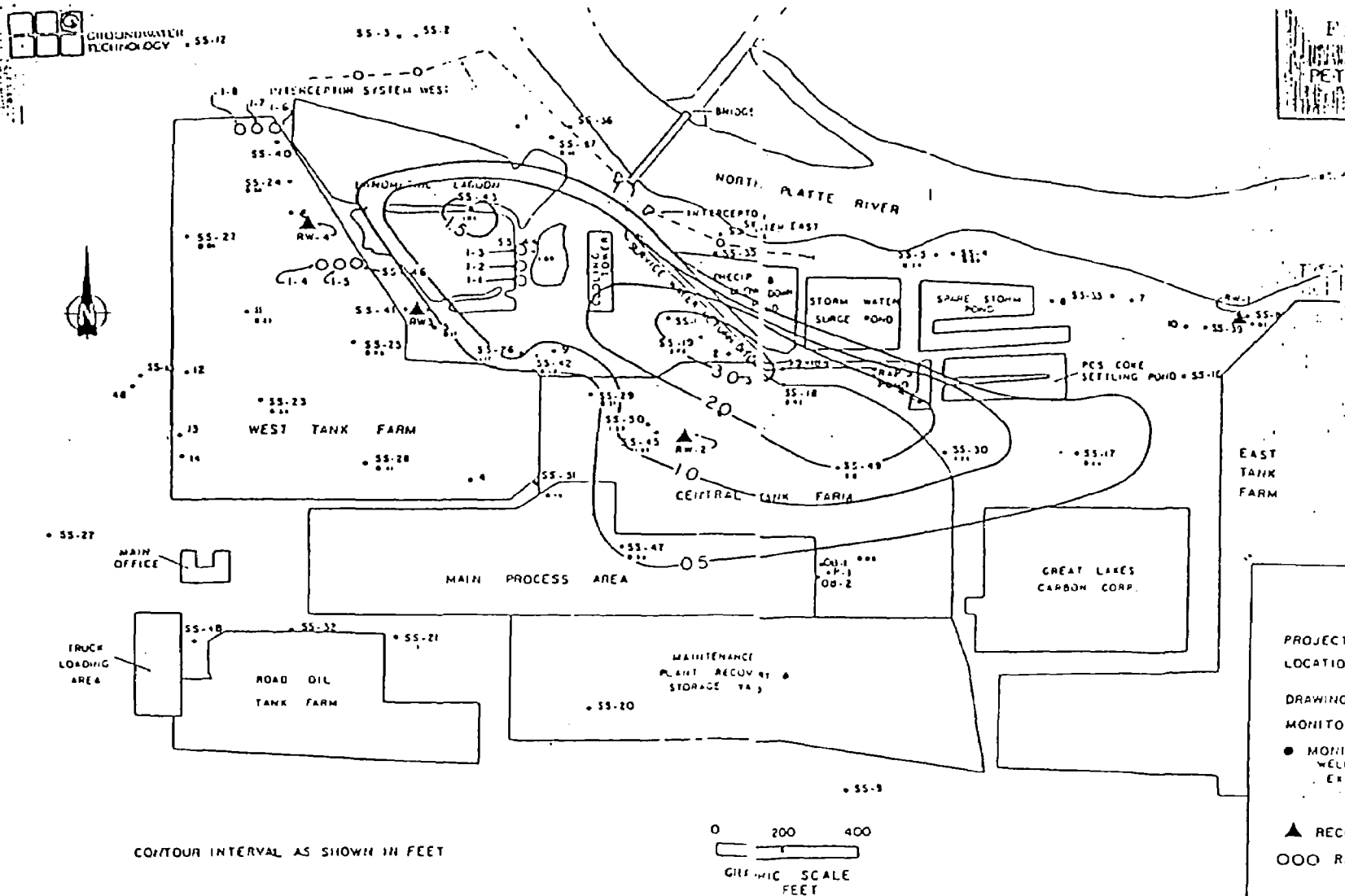


Source: Ground Water
Technology, 1983-1985

- LEGEND
- PROJECT : TEXACO INC.
LOCATION : CASPER, WY
- DRAWING NO. : 4011 - 13
MONITORING DATE : 12-9-83
- MONITORING WELL
WELL IDENTIFICATION:
EX. SS-36 - WELL ID. NO.
0.0 - APPARENT PETROLEUM
THICKNESS (IN FEET)
- ▲ RECOVERY WELL
OOO RECHARGE WELLS

Figure 33

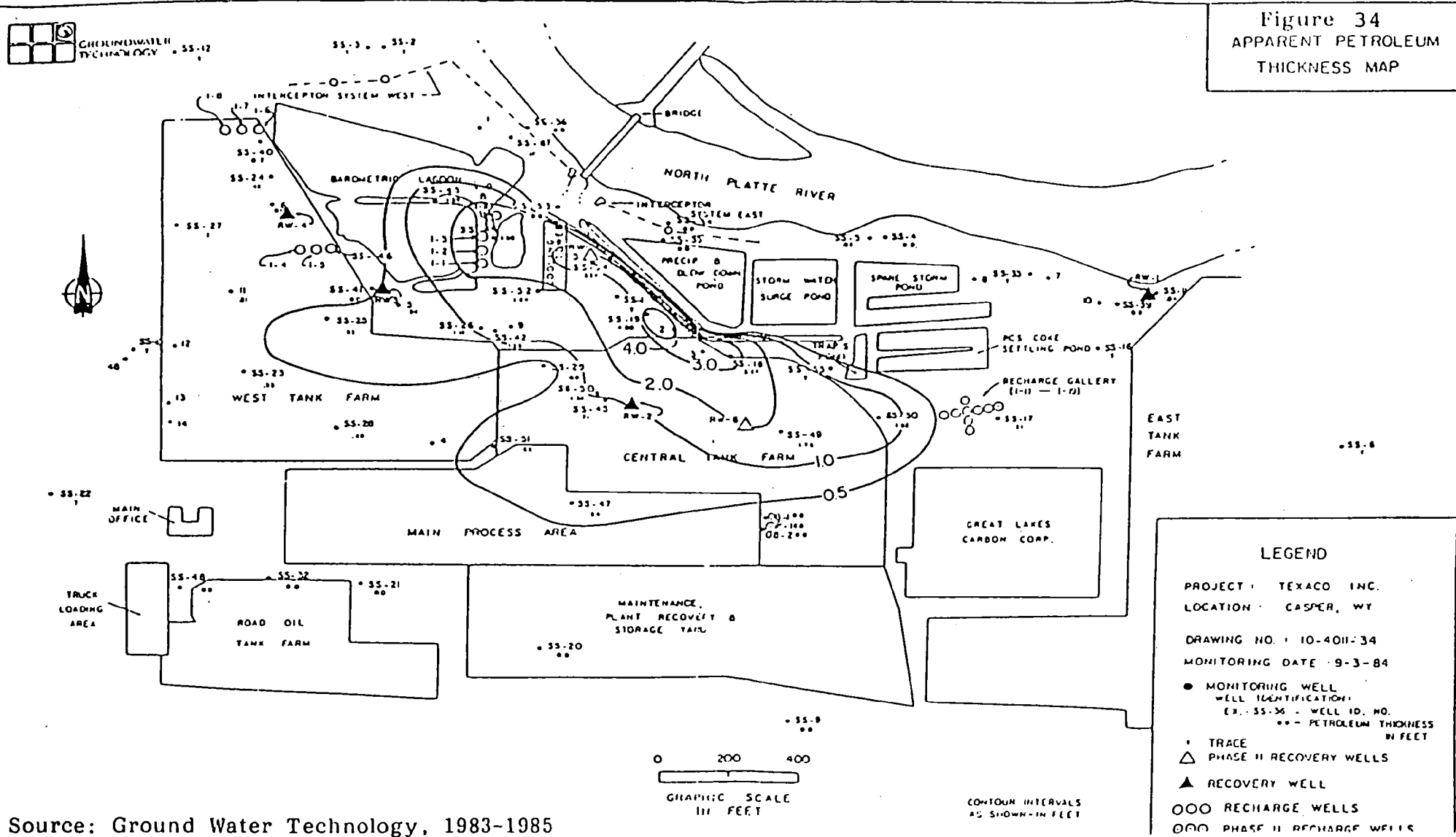
APPARENT
PETROLEUM THICKNESS
CONTOUR MAP

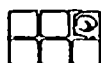
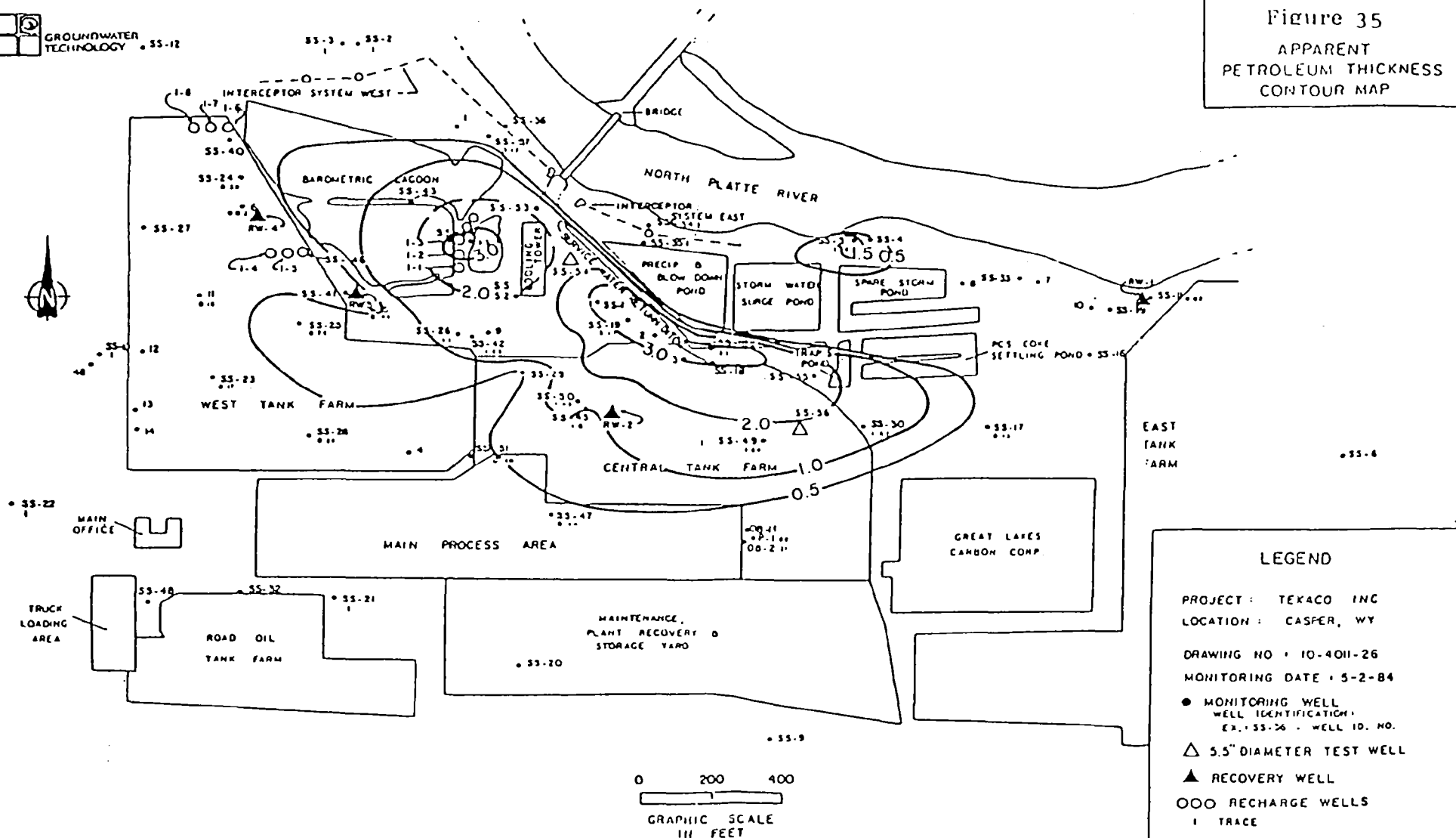


LEGEND

PROJECT : TEXACO INC.
LOCATION : CASPER, WY
DRAWING NO : 4011 - 20
MONITORING DATE : 3-12-84
● MONITORING WELL
WELL IDENTIFICATION
EX. SS-34 WELL ID. NO.
00 APPARENT PETRO-
THICKNESS (IN FEET)
▲ RECOVERY WELL
○○○ RECHARGE WELLS

Figure 34
APPARENT PETROLEUM
THICKNESS MAP



GROUNDWATER
TECHNOLOGY • SS-12

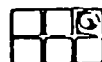
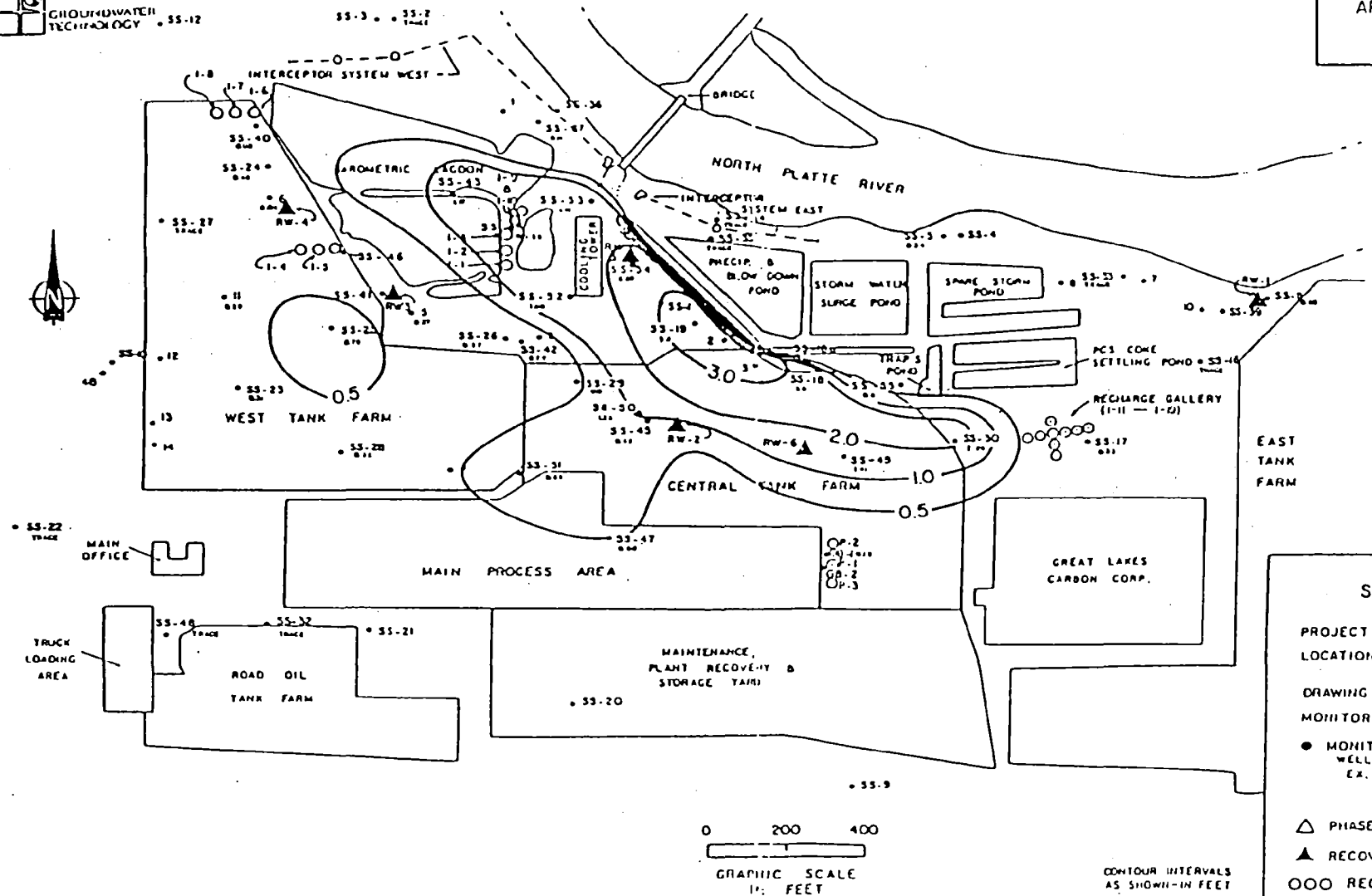
GROUNDWATER
TECHNOLOGY • SS-12

Figure 36
APPARENT PETROLEUM
THICKNESS MAP



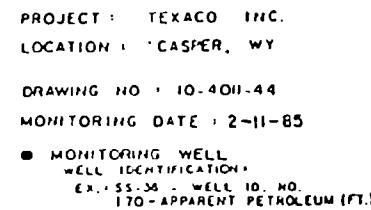
SITE MAP

PROJECT : TEXACO INC.
LOCATION : CASPER, WY

DRAWING NO. : 10-4011-38
MONITORING DATE : 11-1-84

● MONITORING WELL
WELL IDENTIFICATION:
EX: SS-12 - WELL ID. NO.
033 - PETRO THICKNESS IN FEET

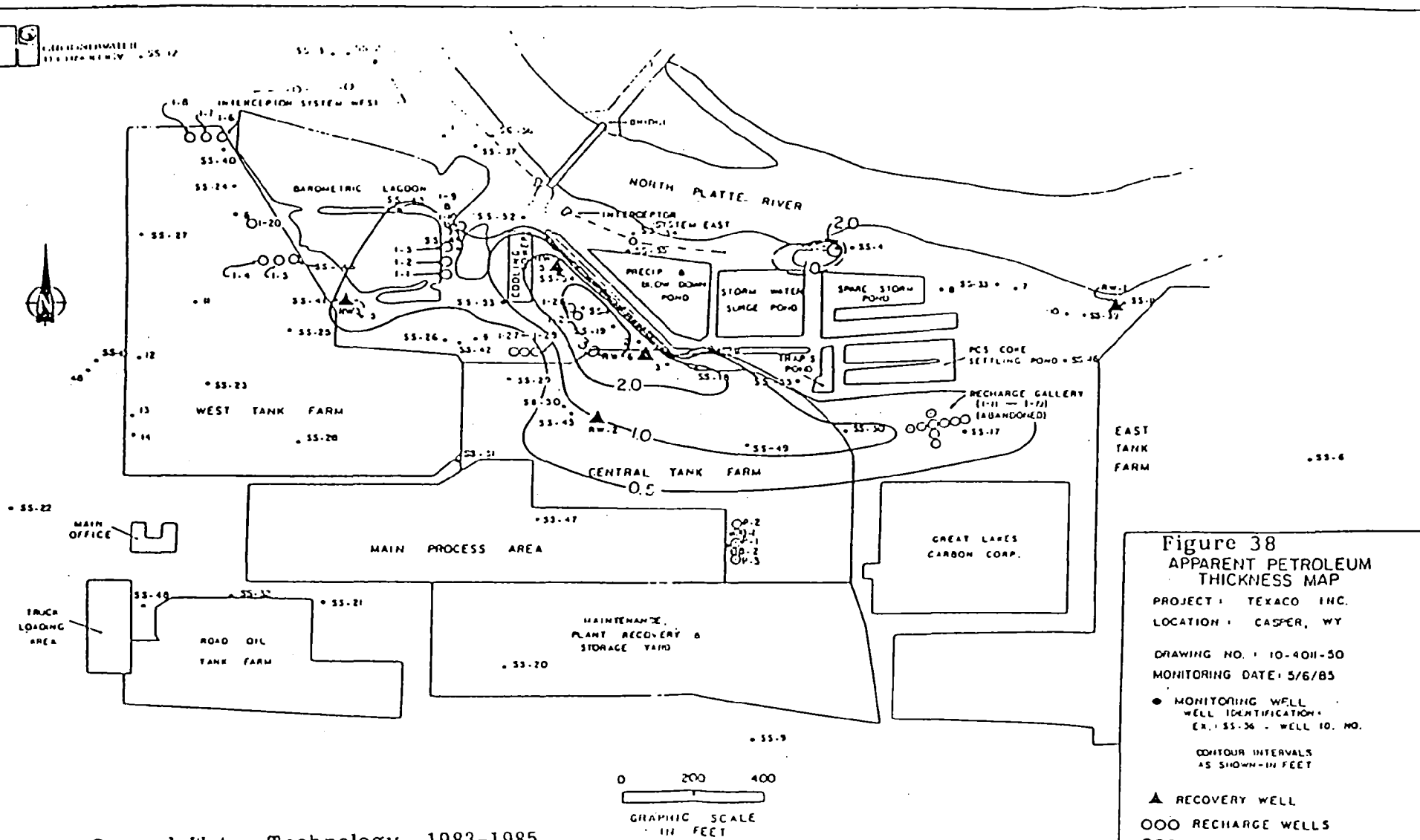
△ PHASE II RECOVERY WELLS
▲ RECOVERY WELL
○○○ RECHARGE WELLS
○○○ PHASE II RECHARGE WELLS

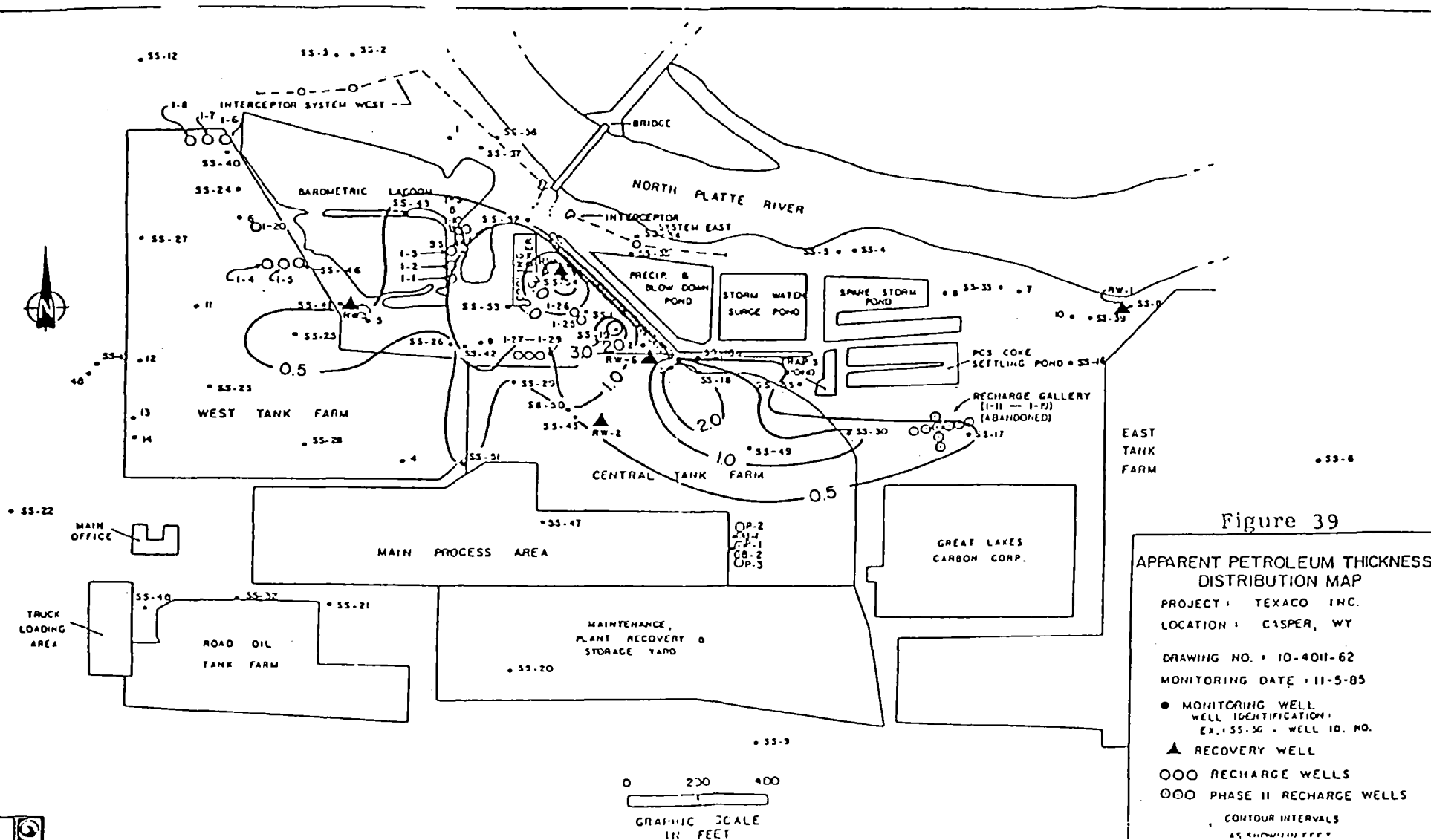


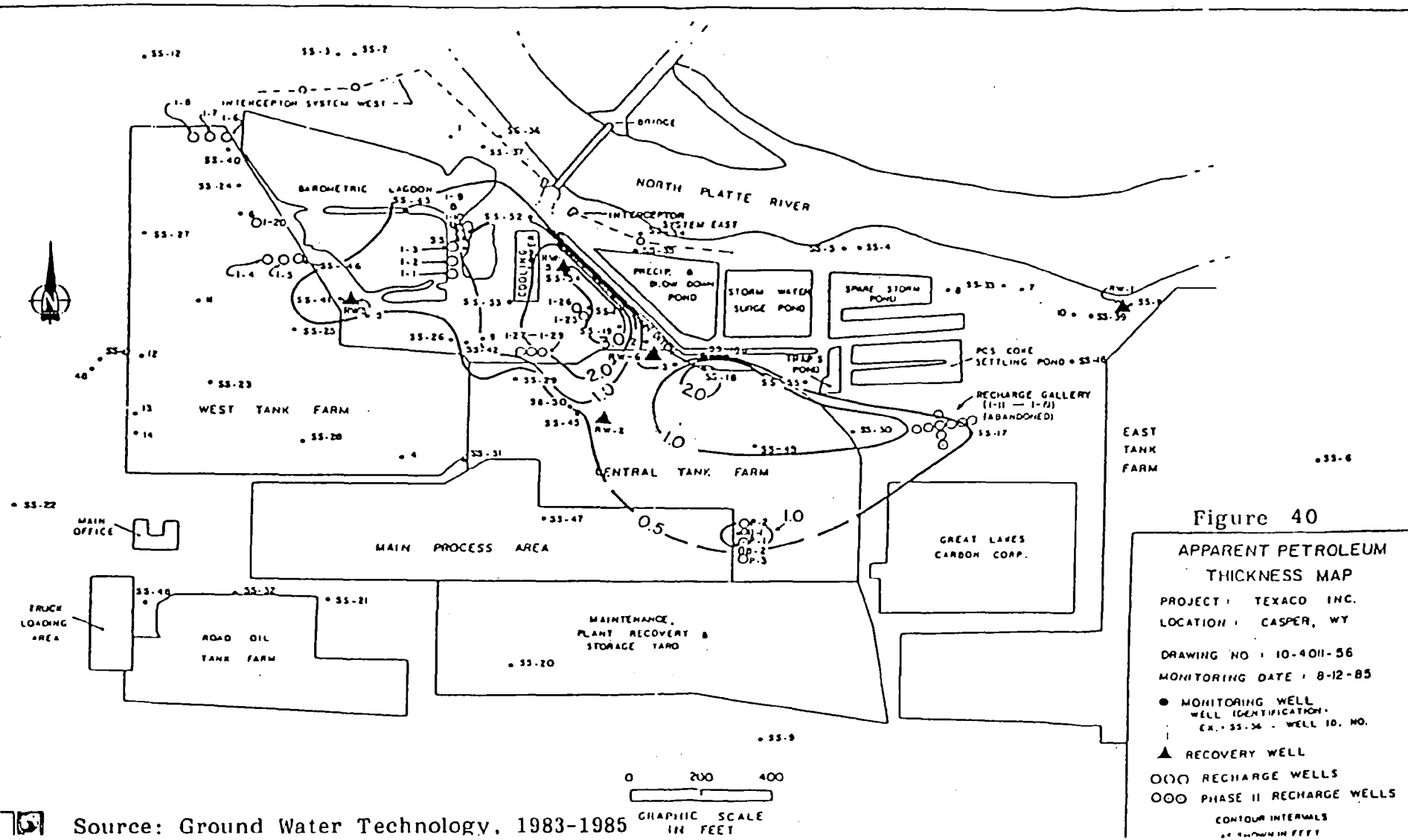
▲ RECOVERY WELL
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○○○ PHASE II RECHARGE WELLS



U.S. ENVIRONMENTAL PROTECTION AGENCY
EPA/600/R-85/011







can be seen from these figures, it appears that a reduction in the hydrocarbon plume is occurring as a result of pumping, although the plume dimensions seem to vary through time. This is evidenced by the presence of hydrocarbon accumulation isolated at wells SS-4 and SS-5 during the May quarterly measurement periods (Figures 35 and 38). This accumulation does not appear to be within the influence of either the interceptor trenches or recovery wells currently in place. Other isolated accumulations are also evident through time.

It is also interesting to observe the influence that the recharge wells/galleries are having on the shape of the plume. For example, it appears that recharge wells I-1, I-2 and I-3 and later I-9 and I-10 could be pushing accumulations of hydrocarbons farther north towards well SS-37 and the northern bank of the Barometric Lagoon (Figures 35 and 37). In addition, the recharge gallery I-11 through I-19 activated in September of 1984 (Figure 34) appeared to have controlled some lateral migration of hydrocarbons by hydraulic control (reversal in gradients). When this gallery was abandoned in May 1985 (Figure 38), the plume appears to have migrated farther eastward. Without further monitoring, the effects of adding and/or abandoning recharge wells on plume migration cannot be evaluated.

An evaluation of decreasing accumulations in any one given well across the site would be difficult, as the fluctuations appear to be sporadic and controlled by several variables including but not limited to, seasonal fluctuations in water levels which may be attributed to rise and fall of the North Platte River and operation and shutdown of both the recovery and recharge wells.

Task Force conclusions on the oil recovery system are that after three years of operation, there still appears to be an area trending northwest/southeast adjacent to the cooling towers and service water ditch where substantial accumulations of hydrocarbons are present (2.0 - 3.0') (Figures 31 through 40). The overall dimensions of the plume appear to have decreased since 1983.

The treatment of the floating hydrocarbons in a series of tanks cannot be evaluated as no data have been presented by Texaco on the effectiveness of this process.

The ground water collected from the recovery wells (i.e. pumps used to depress water table) is injected down a series of recharge wells. The quality of this water, re-injected into the uppermost aquifer, has been sampled twice, but only included an analysis of indicator parameters and several water quality constituents. These data were previously discussed and presented in past analytical performance for the central South Area. Table 15 previously presented a summary of analytical results collected from the recovery wells. No analysis for organics has ever been performed on the ground water being re-injected into the aquifer. The only analysis for organics in the alluvium was collected by the Task Force in August 1986 for wells SS-4, SS-19, SS-49 and SS-34. The results may be indicative of the ground-water quality being extracted from the recovery wells and re-injected into the uppermost aquifer due to their locations in relation to the

recovery wells. The organics detected are presented here for information on the recharge water quality. A detailed discussion of the Task Force data is included later in this report.

Table 17 presents the Task Force organic data which may be most representative of the ground-water quality being re-injected into the aquifer through the recharge wells. Wells SS-19 and SS-49 are probably the most indicative of recharge water as they are located closest to the recovery wells. Wells SS-34, located north of the interceptor trench, and SS-4 (which appeared to contain dense immiscible components) may be less representative. The data (Table 17) show considerable concentrations of benzene, ethyl benzene, toluene, naphthalene, and total xylenes. In addition, as previously discussed and presented in Table 15, other inorganic constituents may be present in the recharge ground water, such as total chromium above the Interim Primary Drinking Water Standard (40 CFR 265 App III).

In addition to the recharge wells, the PCS coke settling pond and service water return ditch are the receptors for skimmed water from recovery well RW-1 and also from the interceptor trench system. As can be seen from Table 17, the PCS Pond results indicate that contaminants were detected and may be seeping back into the aquifer.

These data suggest that re-injection of this ground water from recovery wells may not be appropriate without prior treatment. In addition, both the dissolved organic fraction and dense immiscible phases are not addressed by the current oil recovery system.

Evaluation of Hydrocarbon Recovery System The hydrocarbon recovery system currently in place at the Texaco south property can only be expected to reduce the floating hydrocarbon phase but not entirely eliminate it. According to Texaco, up to 50 percent of the hydrocarbons will remain bound to sediments and will not flow to either the interceptor trenches or recovery wells (WWC, 1982c).

The existing data indicate that a dissolved organic fraction and probably a dense immiscible organic phase exist at the site. The extent of these types of hydrocarbon contamination has not been defined and the current recovery system (trenches and recovery wells) is not capable of extracting or treating these contaminant plumes. In fact, with the re-injection of dissolved organic contamination into the recharge wells, the recovery system may be contributing more to the dissolved organic contamination.

It is possible that the recovery wells will increase contamination of ground water by mixing of floating hydrocarbons with ground water (i.e. change in gradients and pumping of product within the recovery well), thus causing more contaminants to dissolve into the ground water and possibly migrate and/or discharge to the North Platte River.

Specific conclusions and recommendations for the hydrocarbon recovery system are as follows:

Table 17

Ground-Water Quality/Dissolved Fraction
Indicative of Recharge Water Quality

Ground Water Task Force, August 1986 (ug/l)

	<u>SS-19</u>	<u>SS-49</u>	<u>SS-34</u>	<u>SS-4</u>	<u>PCS Pond</u>
Benzene	2000	6000	38	900	7.7
Acetone	ND	ND	ND	ND	12
Ethylbenzene	170	310	ND	41	ND
Toluene	290	620	ND	44	ND
Total Xylenes	890	3000	ND	140	27
Anthracene	ND	ND	ND	480	ND
Benzo(a)anthracene	ND	ND	ND	860	33
Chrysene	ND	ND	ND	1200	68
Fluorene	ND	ND	ND	700	ND
Fluoranthene	ND	ND	ND	560	ND
Naphthalene	770	2800	ND	610	ND
2-Methyl-naphthalene	1800	3200	ND	960	ND
4-Methylphenol	ND	210	ND	ND	ND
2-4-Dimethylphenol	ND	500	ND	ND	ND
Pyrene	ND	ND	ND	2100	120
Phenanthrene	340	240	ND	6000	59

- o The oil recovery system (recovery and recharge wells) and the interceptor trench system should work in conjunction with each other. Texaco only reports quarterly on the operation of the oil recovery system. Continued operation of these components should be maintained.
 - Texaco should implement a performance monitoring program for the interceptor trenches, which at a minimum should include 1) an evaluation of grade control (Wagner, et al., 1986) to ensure that ponding in the trenches is not occurring; 2) continued monitoring of water levels in wells SS-34, SS-35, the east interceptor trench, wells SS-36, SS-37, the west interceptor trench and the North Platte River to ensure the trench is continuing to act as a ground-water sink. This is important as it is probable that the oil recovery system (recovery and recharge wells) plus seasonal variations in water levels will alter the performance of the trench. In order for the trenches to be effective, they must operate to account for these variations. Texaco should consider additional wells south and north of the trenches to evaluate gradients; 3) the implementation of a monitoring program of wells installed between the trenches and the North Platte River to ensure that no contamination is migrating past the trenches. The wells should be completed to monitor for floating hydrocarbons, dissolved organics and dense immiscible phases; 4) A maintenance and operation program to inspect the trenches to ensure proper operation. Inspections should include an evaluation of the drains for chemical clogging (biological slimes), excess siltation due to introduction of fines and other mechanical failures associated with the pumps and skimming devices in each sump.
- o At this time, there is approximately 950 feet of shoreline along the North Platte River where a trench or barrier does not exist (Figure 15). This area is evidenced by the potentiometric contours plotted by the Task Force in Figure 17 and appears to be a prominent contaminant pathway for the discharge of hydrocarbons to the North Platte River. This is further supported by the presence of contamination in wells SS-4 and SS-5 in the form of a floating and/or sinking phases. Based on the location of wells SS-4 and SS-5, it appears that discharge of contaminants to the North Platte River may be occurring, possibly on a seasonal basis.
 - It is recommended that Texaco evaluate the potential for releases in this area to the North Platte River. This may include the installation of additional wells between SS-4 and recovery well RW-1 (Figure 15). As part of this evaluation, the structural integrity of the clay barrier installed in 1957 (Figure 15) should be investigated in order to determine the efficiency of this structure to control contaminant migration (i.e. floating, dissolved and/or dense immiscibles). If the potential for migration is high, which it appears to be in this area, Texaco should consider the installation of a ground-

water control system in this area which may include French drains or barrier walls, or possible expansion of the oil recovery system (recovery wells). As part of this monitoring and performance evaluation for the trenches, inspection for seeps along the south bank of the North Platte River (entire Texaco property) should be implemented so that immediate detection of releases can be made. The inspection schedule for seeps should take into account seasonal fluctuations in water levels and river stages and operation and shutdown of the hydrocarbon recovery system.

- o It is apparent that the oil recovery system (recovery and recharge wells) may be increasing contamination of the aquifer by injecting untreated ground water back into the aquifer. As part of performance monitoring, Texaco should sample the water being recharged to the aquifer for organics. Based on these analyses, Texaco should present a treatment method (if required) such as air stripping to remove the dissolved hydrocarbons to an acceptable level (Wagner, et al., 1986). The use of the PCS coke settling pond and the service water ditch for discharged skimmed water from RW-1 and the interceptor trenches, respectively, should be evaluated as this may also be re-introducing contaminants into the ground water through seepage as was previously discussed and presented in Table 17. An enclosed treatment system as opposed to open ponds would be more appropriate. In conclusion, the treatment technologies currently in place should be re-evaluated to determine further impacts to the ground water and/or surface water bodies.
- o The oil recovery system installed to treat the floating hydrocarbons appears to have significantly reduced accumulations of hydrocarbons across the site. As part of the performance monitoring of this recovery system, Texaco should continually monitor the existence of intersecting capture zones (overlapping cones of depression) to assure that the plume is being contained and captured. This evaluation program should include the identification of dead zones where contamination is not being influenced by the recovery system. Also, the influence of the recharge wells should be evaluated as to their impact to the shape of the floating hydrocarbon plume. As was previously mentioned, the impact from the recovery and recharge wells on the interceptor system should be evaluated.

E. SAMPLING AND ANALYSIS

This section of the report assesses Texaco's Sampling and Analysis Plan for compliance with the applicable technical recommendations and regulatory requirements of 40 CFR 265.92 and proposed for 40 CFR 264. Texaco's field implementation is also assessed for compliance with accepted methodologies and adherence to their sampling and analysis plan. Following the above assessment, the analytical results of the Task Force inspection are presented and discussed. Also, an analytic comparison between the split samples (Task Force and Texaco) are provided. Finally, this section compares the analytical results from the Task Force to past results from Texaco.

1. Texaco

a. Sampling and Analysis Plan Review

Two sampling and analysis plans and one addendum have been submitted by Texaco in their Part B Permit Application. The report entitled Casper Texaco Refinery Sampling and Analysis Plan was prepared by Western Water Consultants, Inc. on November 19, 1981 (WWC, 1981). An addendum to this plan was prepared by the same author on May 5, 1982. Interestingly, this addendum contained an undated Ground-Water Monitoring Manual prepared by TriHydro Corporation, which is for the most part a sampling and analysis plan. The Part B Permit Application does not specify how these reports are related. Because all were submitted within the application, the Task Force will consider them as a single document and review them as such.

The sampling and analysis plan addresses the following topics: presampling procedures, sample collection, sample preservation and shipment, analytical procedures and chain-of-custody control. Most of the above topics are not addressed in any appreciable detail. A brief discussion of the above topics follows:

Presampling Procedures All wells will be monitored for water levels prior to water quality sampling. At least three saturated well column volumes will be evacuated prior to sampling. Field parameters will include specific conductance, temperature, and pH.

Sample Collection A submersible pump or bailer will be used to obtain water samples. The pump or bailer will be constructed out of materials resistant to leaching or sorbing when placed in contact with ground water. To reduce possible interpretation errors on the vertical segregation of water quality at the nested well site, the shallow wells will be pumped and sampled first. The pump and bailer will be thoroughly cleaned after sampling each well. Samples to be analyzed for volatile organics will be transferred directly to a VOA bottle.

Sample Preservation and Shipment The plan states that all sample bottles will be cleaned with the acid used in the preservation procedure if required and distilled water. In addition, two distilled water blanks preserved with concentrated nitric acid will be analyzed for the heavy metals. Preserved samples will be refrigerated and transported to the laboratory for analysis. Samples will reach the laboratory within 24 hours of collection.

Analytical Procedures The plan states that analytical procedures will be selected from "Standard Methods (APHA, 1975), Manual of Methods for Chemical Analysis of Water and Wastes (EPA, 1979), and the Annual Book of ASTM Standards (ASTM, 1980)" wherever possible (WWC, 1981).

Chain-of-Custody According to the plan, a chain-of-custody record will be maintained for every sample in order to document sample possession from the time of collection through the time of analysis.

In accordance with the TEGD (EPA, 1986), the following technical deficiencies of the written sampling and analysis plan were noted by the Task Force:

- o The air in the well head should be sampled for organic vapors using either a photoionization analyzer or an organic vapor analyzer.
- o A discussion of how static water levels will be obtained is not included.
- o The plan does not specify how light and/or dense phase immiscibles will be detected. A discussion on how Texaco will determine the thicknesses of such layers should also be included.
- o A step by step procedure for well evacuation was not included in the plan. Specifically, the procedures used by the facility when an appropriate volume of water cannot be evacuated, should be discussed.
- o Texaco should further discuss sample withdrawal procedures. The plan does state the choice of materials used during sampling withdrawal, but does not indicate how samples will be obtained for light and/or dense phase immiscibles.
- o Texaco indicates in the addendum to the sampling and analysis plan that ground water samples that are organically contaminated should be filtered. This is in direct opposition of current protocols.
- o A detailed QA/QC program that will be used in the field and laboratory was not specified in the plan.

The above deficiencies in the plan indicate that the sampling and analysis plan lacks the detail required as set forth in 40 CFR 265.92(a) and also the technical recommendations in the TEGD (EPA, 1986a) due to a lack of detail.

The only other regulatory deficiency noted by the Task Force in the written plan specifically for the 40 CFR 264 ground water program was that a statistical procedure for determining whether a statistically significant change has occurred was not proposed [40 CFR 264.97(h)(2)].

b. Field Implementation (Sampling Audit)

Two months prior to the actual Task Force evaluation, members of the Task Force scheduled a sampling audit coinciding with Texaco's scheduled round of sampling at all wells in the North Area (EPA, 1986b). The purpose of this audit was to evaluate Texaco's field procedures relative to their sampling and analysis plan and accepted methodologies. Samples were collected by Western Water Consultants, Inc. on behalf of Texaco.

Western Water Consultants stated that all the wells had three casing volumes of water removed. Also, some of the wells had gone dry before three casing volumes could be removed, and it was necessary to revisit some of the well

sites to remove the three casing volumes. It should be noted that evacuation of the wells took place before the Task Force arrived in the field. An independent evaluation of the methods used to calculate the three casing volumes and how the quantity was measured could not be performed.

The sampling procedures were the same at all wells. Western Water Consultants stated it followed the procedures listed in the document entitled Casper Texaco Refinery Sampling and Analysis Plan, written by the same. The Task Force observed that a 1 1/2 inch I.D. stainless steel bottom-filling bailer was used for sampling the wells. A braided white rope was present in each well. It was stated that this rope was also used on the bailers which were used to purge the wells. According to Western Water Consultants, new ropes are used during each sampling event. Plastic drop cloths were present around each well to minimize the contact of the bailer rope with potential contaminants on the ground surface.

Prior to sampling, the stainless steel bailer was cleaned in the field by first rinsing with a small amount of acetone, and then with deionized water. The rope was then attached and the bailer was lowered into the well. The first bail of water was used to rinse the device used for filtering samples obtained for the analysis of metals. The filtering device was then filled and placed into a positive pressure nitrogen drive filtering apparatus. A 0.45 micrometer filter was used. One liter plastic bottles, with preservatives already emplaced, were then filled for analysis of metals.

The subsequent sample bottles were filled by pouring the ground water directly from the top of the bailer into the appropriate sampling container. Labels on the sampling containers were filled out prior to filling the bottles. The pH, temperature, and specific conductance of the well samples were measured in the field by filling a glass beaker with ground water from the bailers. The field instruments were calibrated in the field, at the beginning of each day, and immediately prior to use. All the filled sample bottles were placed into a cooler with "blue ice." Preparation of chain-of-custody records was not observed. It was stated by Western Water Consultants that the appropriate forms are filled out in the office prior to shipping the samples. Western Water Consultants also stated that the samples are shipped by bus to Accu-Labs, which is located in the Denver metropolitan area.

The parameters to be analyzed varied depending on which well was sampled. At most of the wells, samples were taken for the analysis of:

- o dissolved metals
- o phenols
- o anions
- o oil and grease
- o cyanide
- o nutrients
- o sulfide
- o TOC

The sampling for the above parameters was done on the majority of wells sampled during this event (RCRA semi-annual). On ten of the wells, Texaco changed the analysis to include sampling for organic constituents. The parameters sampled on the ten wells were the same as the list given above with the following changes:

- o volatile organic analysis
- o base-neutral organic analysis
- o no oil and grease analysis
- o no cyanide analysis

The following deficiencies in sampling methodologies were noted:

- o The air in the well head was not sampled for organic vapors.
- o Texaco did not sample for light and/or dense phase immiscibles, nor determine the thickness of any such layer.
- o The first bail of water was used to rinse the filter used for dissolved metal analysis. Samples taken for volatile organic analysis should be taken first to minimize disturbance of the well water by the bailer.
- o The composition of the bailer rope was not specified.

The above discussion noted the technical deficiencies as observed by the Task Force. In general, Texaco's sampling procedures appear adequate. The sampling audit verified that Texaco's current sampling procedures are more up to date than the sampling and analysis plan. The Task Force recommends that Texaco update its November, 1981 plan and addendum to incorporate current recommendations of the TEGD (EPA, 1986a).

2. Task Force

a. Techniques of Sampling

The Ground Water Task Force conducted an evaluation of the Casper Texaco facility from August 11 to 15, 1986. This evaluation included conferences with facility representatives and an independent sampling of 16 ground-water monitoring wells and three surface water locations. In addition, five QC samples were taken including a field blank, three equipment blanks and a trip blank. The sampling procedures listed below were detailed by the Ground Water Task Force in a Project Plan dated August, 1986 (EPA, 1986c).

Well Purging Table 18 presents the list of parameters analyzed by the CLP laboratory during the Task Force evaluation. Field analysis included pH, specific conductance, temperature, turbidity and static water level measurements. All field analysis and sample collection were performed by Versar Inc., on behalf of the Task Force. The field analyses may be found in Appendix D.

Prior to sampling, depth to water measurements were obtained. Standing water in all wells sampled by the Task Force (Versar Inc.) was removed

TABLE 18 Analytical Parameters

VOLATILES

chloromethane	1,1,2,2-tetrachloroethane
bromomethane	1,2-dichloropropane
vinyl chloride	trans-1,3-dichloropropane
chloroethane	trichloroethane
methylene chloride	dibromochloromethane
acetone	1,1,2-trichloroethane
carbon disulfide	benzene
1,1-dichloroethene	cis-1,3-dichloropropene
1,1-dichloroethane	2-chloroethylvinylether
trans-1,2-dichloroethene	bromoform
chloroform	2-hexanone
1,2-dichloroethane	4-methyl-2-pentanone
2-butanone	tetrachloroethene
1,1,1-trichloroethane	toluene
carbon tetrachloride	chlorobenzene
vinyl acetate	ethylbenzene
bromodichloromethane	styrene

SEMIVOLATILE COMPOUNDS

acenaphthene	phenol
2,4-dinitrophenol	4-nitrophenol
bis (2-chloroethyl) ether	dibenzofuran
2-chlorophenol	2,4-dinitrotoluene
1,3-dichlorobenzene	2,6-dinitrotoluene
1,4-dichlorobenzene	diethylphthalate
benzyl alcohol	4-chlorophenyl-phenylether
1,2-dichlorobenzene	fluorene
2-methylphenol	4-nitroaniline
bis(2-chloroisopropyl) ether	4,6-dinitro-2-methylphenol
4-methylphenol	n-nitrosodiphenylamine(l)
n-nitroso-di-n-propylamine	4-bromophenyl-phenylether
hexachloroethane	hexachlorobenzene
nitrobenzene	pentachlorophenol
leophorone	phenanthrene
2-nitrophenol	anthracene
2,4-dimethylphenol	di-n-butylphthalate
benzoic acid	fluoranthene
bis (2-chloroethoxy) methane	benzidine
2,4-dichlorophenol	pyrene
1,2,4-trichlorobenzene	butylbenzylphthalate
naphthalene	3,3-dichlorobenzidine
4-chloroaniline	benzo (a) anthracene
hexachlorobutadiene	bis (2-ethylhexyl) phthalate
4-chloro-3-methylphenol	chrysene

Source: Project Plan Ground-Water Monitoring Compliance Evaluation
Hazardous Waste Ground Water Task Force, Texaco Inc.,
Casper, Wyoming, August 1986.

Table 18 (continued)

2-methylnaphthalene	di-n-octyl phthalate
hexachlorocyclopentadine	benzo (b) fluoranthene
2,4,6-trichlorophenol	benzo (k) flupranthene
2,4,5-trichlorophenol	benzo (a) pyrene
2-chloronaphthalene	indeno (1,2,3-cd) pyrene
2-nitroaniline	dibenz (a,h) anthracene
dimethyl phthalate	benzo (g,h,t) perylene
acenaphthylene	3-nitroaniline

PESTICIDES/PCB'S

alpha-BHC	beta-BHC
delta-BHC	gamma-BHC (lindane)
heptachlor	aldrin
heptachlor epoxide	endosulfan I
dieldrin	4,4,-DDE
endrin	endosulfan II
4,4-DDD	endrin aldehyde
endosulfan sulfate	4,4-DDT
methoxychlor	endrin ketone
chlordane	toxaphene
aroclor-1016	aroclor-1221
aroclor-1232	aroclor-1242
aroclor-1248	aroclor-1254
aroclor-1260	

METALS AND OTHERS

aluminum	magnesium
antimony	manganese
arsenic	mercury
barium	nickel
beryllium	potassium
cadmium	selenium
calcium	silver
chromium	sodium
cobalt	thallium
copper	tin
iron	vanadium
lead	zinc
cyanide	percent solids (%)
ammonia	sulfates
chloride	total organic carbon
nitrate	total organic halides
purgeable organic carbon	total phenols
purgeable organic carbon	

Sulfides

Total Sulfides

Tds

prior to sampling. Removal of three casing volumes was attempted using a Teflon bailer or bladder pump. When the recovery rate of the well was sufficient, three well volumes were purged and sampling instituted. The order of collection, beginning with volatile organics, is presented in Table 19, along with the bottle type and preservation method. The amount of water removed was determined by collecting it in a container of known volume during purging.

Where slow-recharging wells were encountered, the three casing volume minimum evacuation requirement was waived. In these situations, the volatile organic samples were collected as soon as possible. The other samples were collected after a sufficient volume had accumulated. The purged water was treated as a hazardous waste and shipped off-site for disposal. For wells in which historical or field information did not indicate contamination, the purged water was disposed of at the well.

The following information was recorded during purging of the well (note that Western Water Consultants did the actual purging of the wells prior to the arrival of the Task Force):

- 1) Type of purging equipment used and types of materials used in well construction, including lines used to lower equipment into the well. This was recorded for each well. Also noted was if facility-dedicated equipment was used.
- 2) Physical properties of evacuated water:
 - o Color,
 - o Odor,
 - o Turbidity,
 - o Presence of oil/grease or heavy-phase organic compounds.
- 3) Intake depth in wells not completely evacuated.
- 4) Volumes purged from all wells.
- 5) Time interval necessary for each purge sequence.
- 6) Methods used to determine volumes evacuated.
- 7) Procedures for collection, management and disposal of evacuated water.
- 8) Decontamination and cleaning procedures for equipment used to sample more than one well.

Sample Collection In wells in which an immiscible phase was not encountered, dedicated Teflon bailers with double check valves that are bottom emptying were used for sample collection. These bailers were used for the collection of all sample parameters. The Teflon bailers were lowered into the wells using a Teflon and stainless steel cable. The sampling proceeded as follows:

TABLE 19 Sampling Order, Bottle Type and Preservation Method

<u>Sampling Order</u>	<u>Parameter</u>	<u>Bottle Type</u>	<u>Preservatives</u>
1.	Volatile organics	4 - 40 ml VOA vials	Cool 40
2.	Purgeable organic carbon (POC)	1 - 40 mL VOA vials	Cool 40
3.	Purgeable organic halogens (POX)	1 - 40mL VOA vials	Cool 40
4.	Extractable organics	4 - 1 L. amber glass	Cool 40
5.	Pesticides/herbicides	2 - 1 L. amber glass	Cool 40
6.	Dioxin	2 - 1 L. amber glass	Cool 40
7.	Total metals	1 L. plastic HNO ₃ -5 mL	
8.	Dissolved metals	1 L. plastic HNO ₃ -5 mL	
9.	Total organic carbon (TOC)	1 - 50 mL glass CO ₂ 40C	H ₂ SO ₄ -5 mL
10.	Total organic halogens (TOX)	1 L. amber glass no headspace	Cool 40C
11.	Phenols	1 L. amber Cool 40	H ₂ SO ₄ -5 mL
12.	Cyanide	1 L. plastic Cool 40	NaOH-5 mL
13.	Sulfate and chlorine	1 L. plastic	Cool 40
14.	Nitrate and ammonia	1 L. plastic	h ₂ SO ₄ -5 mL Cool 40

Source: Project Plan Ground-Water Monitoring Compliance Evaluation
Hazardous Waste Ground Water Task Force, Texaco Inc.
Casper, Wyoming, August 1986.

- 1) Selection of a new or cleaned Teflon bailer.
- 2) Attached bailer to a Teflon-coated stainless steel cable.
- 3) Lowered the bailer slowly until it contacted the water surface.
- 4) Allowed the bailer to sink to the bottom of the screened interval and then filled with minimal surface disturbance.
- 5) Slowly raised the bailer to surface. Efforts were made not to allow the bailer line to contact the ground surface by placing the bailer line on a protective liner.
- 6) Opened the bottom emptying device to allow slow discharge down the side of the sample bottle with minimal entry turbulence. Intermediate sample containers were not used.
- 7) Repeated the above steps as needed to acquire a sufficient sample volume to fill all containers. The sample bottles were filled by parameter sets.

In wells in which an immiscible phase was encountered, a bladder pump constructed of Teflon was employed. The bladder pump was operated by compressed air from air cylinders. The bladder pump intake was lowered slowly through the immiscible oil phase to the bottom of the well, and then moved up approximately one foot to minimize the introduction of sediments. After three casing volumes were removed, sampling began. The pumping rate was adjusted to minimize the velocity at which water exits the sample orifice to minimize turbulence.

Pond Sampling Samples of the liquids contained in one waste pond in the South Area and two ponds on the North Area were obtained. The samples obtained were also analyzed for the parameter listed in Table 18.

Sampling of the three ponds was performed using an intermediate collection container attached to a pole. The container was constructed of Teflon, and was rinsed before filling with the desired pond liquid twice before taking a sample. Care was taken to avoid leaves, stones, sediments and other debris that was present. The appropriate sample container was filled in a manner that minimized sample agitation/aeration.

The same in-situ parameters measured at each well were also measured at each pond sampling site. The three surface water sample locations were as follows:

- 1) Inlet pond to the Excess Service Water Ponds on the North Area of the North Platte River.
- 2) The pond formed at the base of the bluff near well M-12s on the North Area of the North Platte River.
- 3) The PCS coke setting pond on the South Area of the North Platte River.

Quality Assurance/Quality Control The sampling activities during these evaluations were supported by preparing and analyzing several sets of quality control (QC) samples. The QC samples fell into two major categories, including field blanks and field duplicates. Laboratory QC samples (performance evaluation sample) were not required by the laboratory.

Several types of QC blanks were employed during the evaluation. They included:

- o Trip blanks,
- o Field blanks,
- o Equipment blanks.

Trip blanks are used to determine if contamination is introduced from the sample containers. This includes the time during container transport to the facility and container storage at the facility. These blanks were prepared by the sampling team selected for the Texaco facility. They were prepared by using certified, organic free water of known high purity, and were sent with the other sample bottles to the field. For each analytical parameter group such as organic compounds, metals, and volatile compounds, one set of trip blanks was prepared and accompanied the monitoring personnel during the sampling activities.

Field blanks were used to determine if contamination was introduced by the sample collection activities or sampling environment. They were prepared by bringing a quantity of certified, organic free water to the field and using this water to prepare appropriate sample aliquots for each parameter.

Equipment blanks are used to determine if contamination is introduced by the sample collection equipment. Although the recommended procedure is to have dedicated equipment for each monitoring well to be sampled, there were occasions when some equipment, including bladder pumps and bailers, were reused. After the equipment was decontaminated, a quantity of certified, organic free water was passed through the instrument and aliquots collected for each analytical parameter. An equipment blank was collected by the sampling personnel each day that sampling equipment was reused during the evaluation. This was submitted for analysis in place of the field blank for that day of sampling.

Duplicate samples are a method of checking on the precision of analytical methods of the laboratory. The duplicate samples were submitted to the analytical laboratory along with all other samples. One duplicate sample was taken at well M-36.

Equipment All field equipment that was used for obtaining field measurements was calibrated prior to the investigation and at periodic intervals during use. Calibration records were maintained to demonstrate the precision and accuracy of field measurements made with a particular instrument.

Calibration records included:

- o A unique identification number assigned to the device.

- o The source and traceability of the standard(s) used for calibration.
- o The name of the person performing the calibration, the date and notation as to whether it was a routine check or one required by malfunction.

Equipment calibration was further supported by routine maintenance, as required by the individual types of equipment used. Routine maintenance included changing batteries in portable meters and lubricating moving parts of a sampling device with non-contaminating materials.

Maintenance records were kept similar to calibration records, and documented the type of work done (routine checks, emergency repairs), the person performing the work, and the identity of the equipment.

Decontamination Decontamination of all field equipment was performed prior to use. The decontamination was performed off-site whenever possible. The waste solvents were collected in a container for proper disposal. Decontamination procedures for smaller sampling equipment such as soil scoops and containers were not necessary, as the equipment was properly disposed of after use.

On-site decontamination was performed only when extenuating circumstances dictated. On-site decontamination was performed by the procedure as for off-site decontamination.

When bailers and bladder pumps were decontaminated on-site, an equipment blank was collected by rinsing the equipment with certified, organic free water and submittal of aliquots of the rinsate (equipment blank) to the laboratory for analysis.

Documentation Accountable field documents included items such as logbooks, field data records, correspondence, sample tags, graphs, chain-of-custody records, bench cards, analytical records and photographs.

All field logbooks, field data records, field laboratory logbooks, sample tags and chain-of-custody records were assigned to the inspection personnel for appropriate distribution and accountability. All pertinent factual information was recorded in these logbooks from the time each individual was assigned to the inspection team, until the inspection was completed. Logbook entries were dated, legible, and contained accurate and inclusive documentation of inspection activities.

Chain-of-Custody Each sample shipment was accompanied by a chain-of-custody record identifying its contents. The original record accompanied the shipment, and a copy was retained by the sampling team. When replicate samples were offered to the facility, it was noted in the remarks section of the custody form. The note indicated to whom the replicate samples were offered, and was signed by both the sampler and recipient.

Labeling and Packaging All samples collected were labeled in a clear and precise way for proper identification in the field and for tracking in the

laboratory. Sample labels had a pre-assigned, unique number that was indelible and waterproof. A two-part label was used so that the sample identification number was affixed to the sample bottle and also entered in the field logbook at the time of collection. The label attached to the bottle listed only the sample number; the label for the notebook included the sample number and the following information:

- o Project code number,
- o Station location and number,
- o Date and time,
- o Sample type (composite or grab),
- o Signature of sampler,
- o Preservative indication (yes and no; type),
- o Analyses required, and
- o Additional remarks.

Samples were properly packaged for shipment and dispatched to the CLP laboratory for analysis, with a separate custody record accompanying each shipment (e.g., one for each laboratory, one for samples driven to laboratory). Shipping containers were sealed for shipment to the laboratory. Only metal and plastic ice chests were utilized as the outside shipping container. The drainage hole at the bottom of each ice chest was permanently plugged to prevent any possibility of leakage through the hole. Each ice chest was clearly marked with arrows indicating the proper upright position of the container, a label indicating "THIS END UP" on the top, a label stating "ENVIRONMENTAL SAMPLES" on the lid, and a sticker containing the originator's name and address.

Each ice chest was securely taped shut. This was accomplished by wrapping reinforced tape around the ice chest near each end, where the hinges are located. Sample containers were packaged in the following manner:

Glass Containers

- o The containers were separated in the shipping container by cushioning to prevent breakage due to contact with other glass.
- o The small glass vials for volatile organic samples were placed inside a larger plastic container to minimize breakage and to contain any leakage.

Plastic Containers

- o The cap was tightened securely before it was placed in the shipping container.

- o The plastic containers were packaged so as to be protected from punctures from sharp objects.

All sample containers and wet ice were packed inside a sturdy plastic bag, placed inside the shipping container as an inner pack. The plastic bag was tightly closed after all of the sample containers and ice had been added to prevent any leakage of material from the bag.

Transportation Samples transported off-site to the CLP were packaged for shipment in compliance with current DOT and commercial carrier regulations. All required government and commercial carrier shipping papers were filled out and shipment classifications made according to current DOT regulations.

Sample traffic reports, chain-of-custody records, and any other shipping/sample documentation accompanying the shipment were enclosed in a waterproof plastic bag and taped to the underside of the cooler lid. All samples were shipped "Priority One/Overnight" to the CLP laboratory. If shipment requires more than a 24-hour period, sample holding times may compromise the integrity of the sample analyses. When holding times were exceeded, the analyses were not performed. The Sample Management Office (SMO) was notified immediately after sample shipment, and was provided with the following information:

- o Sampling contractor's name;
- o Project number;
- o Exact number(s) and type(s) of samples shipped;
- o The name of the facility and location from where the samples were being shipped;
- o The laboratory that the samples were shipped to;
- o Carrier, airbill number(s), method of shipment (e.g., priority, two-day);
- o Shipment date and time; and
- o Irregularities or anticipated problems, such as special handling needs, and hazardous samples.

b. Interpretation of Data

This subsection summarizes the usability of the Task Force results, the QA/QC results and provides a generalized interpretation of the Task Force data. Lockheed Engineering and Management Service Company, Inc. (Lockheed) provided the Task Force with the organic and inorganic usability audit reports. PRC Engineering provided the same with a QA/QC data evaluation report.

Two separate laboratories performed the actual analyses: Compu Chem Laboratories of Research Triangle Park, NC, for organic analyses and Centec Laboratories of Salem, VA, for the inorganic and indicator analyses. Both are utilized as CLP laboratories.

i) Organic/Inorganic Usability

The organic and inorganic usability audit report was prepared by Lockheed, and is presented in Appendix G. This report lists the sample number and the associated matrix for comparison. The following is a summary of their findings.

Organics - The organic analysis met the accuracy Data Quality Objectives (DQOs) established for the program, except eight of 22 average percent recoveries of matrix spike compounds. All the precision DQOs were met; the average RPDs for both matrix spike and surrogate compounds are within the DQOs for the program.

Volatiles by purge and trap data quality - The analysis of these compounds can be considered quantitative with a few exceptions. The detected compounds in samples Q0588 (M-36), Q0590 (M-36 Dup), Q0596 (SS-19), and Q0599 (SS-49) are judged semiquantitative. The high dilutions of the samples may have resulted in false negatives. The usability parameters are acceptable.

Semivolatile Data Quality - The semivolatile analysis is judged quantitative for 18 of 25 samples. However, all detected compounds in samples Q0586 (M-10D), Q0591 (M-51As), Q0596 (SS-19), Q0588 (M-36 Dup), Q0590 (M-36 Dup), Q0599 (SS-49), and Q0804 (SS-4) are considered semiquantitative with the possibility of false negatives. Samples Q0588 (M-36 Dup), Q0590 (M-36 Dup), Q0599 (SS-49), and Q0804 (SS-4) are considered suspect because of unusable QC surrogate data and matrix spike data.

Pesticide Data Quality - The pesticide analysis is judged suspect due to high dilutions, poor matrix spike and surrogate spike recoveries, problems with dibutylchloroendate shifts and unaddressed peaks in the chromatograms.

Metals - The average percent recoveries for total metals are within the program accuracy DQOs in 87% of the low concentration samples and 91% of the medium concentration samples. The average RPDs are within the program precision DQOs in 91% of the low concentration and 100% of the medium concentration samples for the total metals.

No laboratory blank contamination was reported. Al and Fe contamination was found in the sampling blanks. Analyses met the completeness goals.

All evaluation criteria used for the total metals are based on IFB WA 84-J092 (SOW 785).

Inorganic and Indicator Parameters - The average percent recoveries for the inorganic and indicator parameters are within the program accuracy DQOs in 92% of the low concentration and 100% of the medium concentration samples. All the inorganic and indicator parameters are within precision DQOs.

No laboratory blank contamination was reported. However, phenol and TOC contamination was found in the sampling blank. Analyses met the completeness goal.

All evaluation criteria used for CN are based on IFB WA 84-J092 (SOW 785).

ii) QA/QC Audit

The QA/QC audit was prepared by PRC Engineering and is presented in Appendix H. Summarized below are their findings.

Organics

Quantitative:	volatile and semivolatile results with exceptions.
Semi-quantitative:	volatile results for samples Q0588 (M-36 Dup), 590 (M-36 Dup), 596 (SS-19), 599 (SS-49), and 801 (SS-7); semivolatile results for samples Q0586 (M-10D), 591 (M-51As), and 596 (SS-19); and positive semivolatile results for samples Q0588, 590, 599, and 804 as previously mentioned.
Qualitative:	all pesticides results; all negative (non-detect) semivolatile results for samples Q0588 (M-36 Dup), 590 (M-36 Dup), 599 (SS-49), and 804 (SS-4) are qualified by a higher than usual probability of false negative results due to dilution.

Graphite Furnace Metals

Quantitative:	all arsenic, cadmium, thallium, and selenium results; antimony and lead results with exceptions.
Qualitative:	antimony results for sample MQ0586 (M-10D) and lead results for sample MQ0588 (M-36 Dup).
Unreliable:	antimony results for sample MQ0591 (M-51As) and lead results for sample MQ0596 (SS-19).

ICP Metals

- Quantitative:** all barium, beryllium, calcium, chromium, cobalt, copper, magnesium, manganese, nickel, potassium, silver, sodium, and vanadium results and medium concentration matrix results for aluminum with exceptions and iron and zinc.
- Semi-quantitative:** low concentration matrix iron results with exceptions listed below.
- Qualitative:** low concentration matrix positive aluminum results for samples MQ0588 (M-36 Dup), 589 (M-35), 590 (M-36 Dup), 591 (M-51As), 592 (M-33), 593 (SP-7), 598 (SS-34) and 806 (41A); medium concentration aluminum results for sample MQ0596 (SS-14); low concentration matrix zinc results; and low concentration matrix iron results for samples MQ0583 (M-1) and 586 (M-10D).
- Unusable:** low concentration matrix negative aluminum results; low concentration matrix positive aluminum results for samples MQ0583 (M-1), 584 (M-6), 585 (M-10s), 597 (M-12s), 599 (SS-49), and 801 (SS-7); iron results for sample MQ0803 (alluvial pond).

Mercury

- Quantitative:** all mercury results.

Inorganic and Indicator Analytes

- Quantitative:** all chloride, bromide, and sulfate results; nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, total phenols, TOC, and TOX results with exceptions; and cyanide results for samples MQ0596 (SS-19), 599 (SS-49), 802 (inlet pond), 803 (alluvial pond), 804 (SS-4), and 805 (PCS).
- Semi-quantitative:** all POX results; ammonia nitrogen results for samples MQ0582 (blank), 583 (M-1), 584 (M-6), 801 (SS-7), 802 (inlet pond), 803 (alluvial pond), 804 (SS-4), 805 (PCS) and 806 (M-41A); nitrate and nitrite nitrogen results for samples MQ0589 (M-35), 593 (SP-7), 597 (M-12S), 801 (SS-7), and 802 (inlet pond); TOC results for samples MQ0589 (M-35), 592 (M-33), 593 (SP-7), 596 (SP-19), 597 (M-12S), 801 (SS-7), 802 (inlet pond), and 803 (alluvial pond); and TOX results for samples MQ0584 (M-6), 585 (M-10S), 586 (M-10D), 587 (blank), 597 (M-12S), 599 (SS-49), and 600 (equipment blank).

Qualitative:	all POC results; and cyanide results for samples MQ0582 (blank), 585 (M-10S), 586 (M-10D), 592 (M-33), 593 (SP-7), and 597 (M-12S).
Unusable:	cyanide results with the above exceptions; total phenols results for samples MQ0592 (M-33), 593 (SP-7), 596 (SS-19), 597 (M-12S), 801 (SS-7), 802 (inlet pond), 803 (alluvial pond), 804 (SS-4), and 806 (M-41A); and TOC results for samples MQ0583 (M-1), 584 (M-6), 598 (SS-34), and 806 (M-41A).

iii) Analytical Results

Ground water and to a lesser degree surface water samples collected by the Task Force confirm that hazardous waste constituents or other indications of contamination exist beneath and around the Texaco facility. The Task Force sample results above detection limits are presented in Table 20. The raw data may be found in Appendix A. Figure 41 shows the 16 ground water and three surface water locations where the Task Force obtained samples.

Organic Analysis Analytical results confirm organic contamination on both the North and South Areas of the facility. In addition, several constituents were detected in the surface water of the PCS Pond. The results from the North Area are summarized below.

Wells M-1 and M-6b are located near the Excess Service Water Effluent Ponds (Figure 41), and show no evidence of organic contamination (the reader is continually reminded to refer to Table 20, as no quantitative results will be reiterated in this section). Well M-36 shows the highest overall organic concentrations of all wells sampled by the Task Force. Based on its location relative to the CEP and North Land Farm, and on past analytic data, this observation was expected. Furthermore, the relatively high level of contamination confirms that the source of ground-water contamination in the North Area is from the CEP and/or the North Land Farm. Downgradient wells M-10s, M-10d and M-51As (Figure 41) also indicate contamination, although in lower concentrations and numbers of organic species than in M-36. Wells M-33 and M-35 are located near the west and east property boundaries, respectfully. Neither wells indicate any organic contamination. These results, coupled with potentiometric surface maps, indicate that organic contaminants do not appear to be migrating off-site at those locations during the Task Force evaluation. It should be noted that a potential for off-site contamination still exists as the number of wells sampled by the Task Force totaled two wells.

Samples taken in the alluvial pond in the North Area clearly show that several organic species exist in this area. It seems likely that the source of these contaminants is from the CEP and North Land Farm, based on potentiometric surface maps. Well completion logs further

Table 20
Analytic Results (Task Force)
August 11-15, 1986

	M-1	M-6b	M-10a	M-10d	M-36	M-36	M-35	M-51Aa	M-33	INLET POND	SP-7	M-12s ALL. POND	SS-19	SS-4
						DUP								
Acetone			59		3806	3000		23				11		
Benzene			12	57	310	270		76					2000	600
2-Butanone					670	570								
Ethyl Benzene								15					170	30
Methylene Chloride														
Toluene			18	12	410	360		34				5.2	290	60
Total Xylenes			24		330	290		59					890	300
Anthracene														
Benzo (a) anthracene														
Benzo (b) fluoranthene														
Benzo (k) fluoranthene														
Benzo (a) pyrene														
Chrysene														
Fluorene														
Fluoranthene														
Naphthalene													770	280
2-Methyl-naphthalene													1800	320
Phenol					64000	62000								
2-Methylphenol					50000	40000		1600						
4-Methylphenol					93000	96000								20
2-4 Dimethylphenol				1100	14000	13000		2000						50
2-Nitrophenol			87											
4-Nitrophenol														
Pyrene														
Phenanthrene													340	20
Chlordane			48		480	300								
Heptachlor				0.26										

NOTE:

N - Spike recovery not within control limits.

- Blank indicates those concentrations below the lower limit of detection.

Table 20 (continued)

	SS-34	SS-7	SS-4	M-41A PCS POND	TRIP BLANK	FIELD M-36	BAILER BLANK	PUMP BLANK	BAILER BLANK
Acetone				12					
Benzene	38	1400	900						
2-Butanone						350	270	390	29
Ethyl Benzene		180	41						
Methylene Chloride				5.5				19	
Toluene			44						
Total Xylenes		460	140	27					
Anthracene			480						
Benzo (a) anthracene			860	33					
Benzo (b) fluoranthene				26					
Benzo (k) fluoranthene				26					
Benzo (a) pyrene				23					
Chrysene				68					
Fluorene			700						
Fluoranthene			560						
Naphthalene		230	610						
2-Methyl-naphthalene			960						
Phenol									
2-Methylphenol									
4-Methylphenol									
2-4 Dimethylphenol									
2-Nitrophenol									
4-Nitrophenol									
Pyrene			2100	120					
Phenanthrene			6000	59					
Chlordane									
Heptachlor									

Table 20 (continued)

	M-1	M-6b	M-10a	M-10d	M-36	M-36	M-35	M-51Aa	M-33	INLET POND	SP-7	M-12a	ALL. POND	SS-19	SS-4
						DUP									
Aluminum	1180N	488	704N		3330N	2290N	5510N	20500N	3670N	154	5840N	1530N	131	2330N	206
Antimony			15.5		12.9	10.2							6.7		
Arsenic	12.3	13.7	53.6		196	229		79	3.2	7.1	10.9	31.5		14.4	10.
Barium	36	56	81	37	106	106	59	411	47	119	135	166	20	1160	250
Beryllium															
Cadmium							1.2	7.1						1.4	
Calcium	18300	259000	568000	193000	8510	8550	88100	268000	224000	250000	77100	92400	73900	130000	10800
Chromium					25	18									
Cobalt			16		25	31		44	8		12	8			
Copper								55							
Iron	914N	2270N	14800N	889N	2690N	2750	3460	224000	5360N	1110	17400N	12200	252	20300N	33700
Lead		6.7	10.2		8	8	5.2	31	13.5		14.4	36.1		11.1	
Magnesium	5920	87600	294000	121000	4220	4490	39600	176000	112000	278000N	72600	91700	58900N	80600	5920
Manganese	26	249	49800	483	112	119	279	2740	887	730N	2570	1760	357	1620	14
Mercury						0.2	0.4							0.2	
Nickle			29		257	266		38			44	32			
Potassium	3250	10600	5230	19300	8750	8800	11800	32000	18400	7960	15400	14800	12000	4900	671
Selenium			141		99.2	73.5	8.1	2.3		27.5		38.3			
Silver															
Sodium	206000	208000	196000	519000	939000	990000	107000	316000	420000	920000	456000	467000	432000	154000	11500
Thallium				2.0											
Vanadium			13		151	153		80			13		9		
Zinc	2630N	2950N	1090N	1660N	120N	34N	36N	15900N	42N		5200N	2320N		30N	
Total Phenols			6000	5500	394000	284000		4200	41	39	282	198	32	207	42
TOX		10	36	6.4				14	25	18	16		13	12	
POX														7	3
TOC	1200	7800	69000	69000	676000	726000	18000	125000	16000	16000	29000	36000	16000	33000	7900
POC					2600	2400		280		390		190		8100	920
NO3-N	270		1510			0.05	3000		470	20000	5000	6000			
NH3-N	300		19000	300	610000	580000		8000	1100		1800	4400		14000	1100
NO2-N															
Chloride	1400	280000	40000	87000	10000	80000	18000	50000	7000	190000	80000	70000	58000	43000	5000
Bromide				1900		1400		1600	550				250	600	55
SO4	120000	750000	2580000	370000	480000	540000	290000	150000	74000	11500000	590000	500000	970000	50000	
Cyanide			121N	414N				552	172N	36	145N	145N		20N	14

Table 20 (continued)

	SS-34	SS-7	SS-4	M-41A	PCS	POND	TRIP BLANK	FIELD M-36	BAILER BLANK	PUMP BLANK	BAILER BLANK
Aluminum	24900N	430N	347	113000N		311		136N			389
Antimony	6.9										
Arsenic	20.3		39.9	41		9.9					
Barium	564	928	1200	1640		376		4	4		5
Beryllium				5							
Cadmium				4.6							
Calcium	172000	43900	120000	398000	124000		296	532	277	533	394
Chromium	18			123							
Cobalt	23			58							
Copper	33			132							
Iron	56700N	4870N	52600	171000N		1580					107
Lead	140	6.9		138							
Magnesium	128000	79800	62900N	207000	16800N						137
Manganese	2370	874	797N	5100	625N						7
Mercury				0.7							
Nickle				89							
Potassium	10800	3360	4190	23500	8250						584
Selenium	2.8			6.2				2.4			
Silver											
Sodium	160000	112000	127000	154000	102000		759	511	431	394	574
Thallium											
Vanadium	72			309							
Zinc	220N	2120N	1870	881N							
Total Phenols		76	109	33	9754		86		43	16	41
TOX	11	20	17	9.9	12						
POX		7								5	
TOC	10000	25000	48000	5700	39000		2200			1300	3900
POC	650	4900	12000	620	420						
NO3-N		1000		910							
NH3-N	4200	130	400								
NO2-N											
Chloride	35000	31000	90000	26000	120000						
Bromide	400		550		250						
SO4	350000	480000	5700	1000000	1000000						
Cyanide			20								

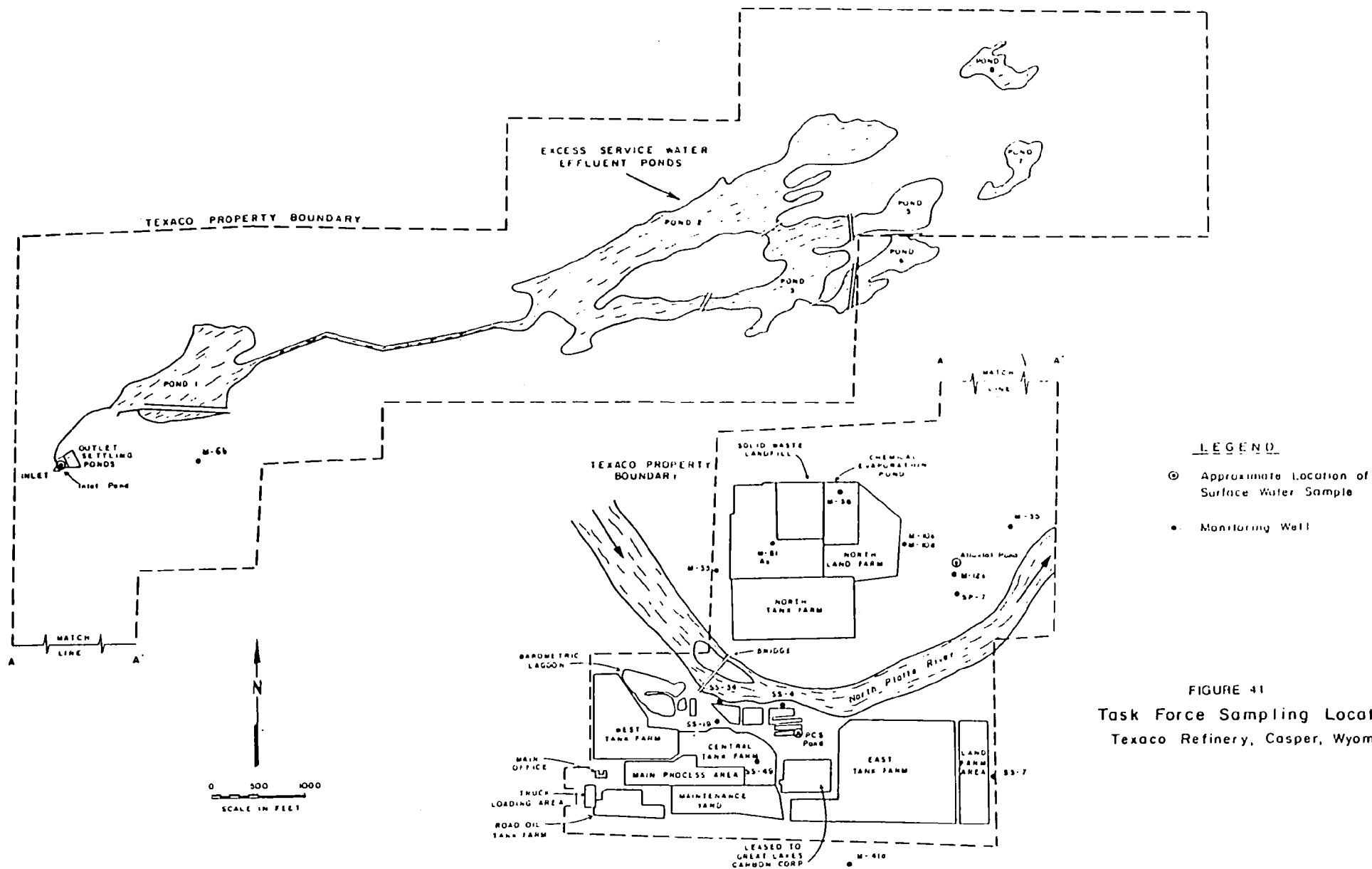


FIGURE 41
Task Force Sampling Locations
Texaco Refinery, Casper, Wyoming

support this notion as they reveal zones of higher conductivity within the confining unit. These zones most likely contribute to the discharge points, or seeps, located in the bluffs immediately above the alluvium.

Analytical results from the South Area further confirm organic contamination. Five of the six wells sampled by the Task Force indicate contamination above detection limits. Only well M-41A (Figure 41) did not indicate the presence of organics during the sampling event. This confirms this well as an upgradient background well. The PCS Pond was found to contain a wide variety of organic species, although in generally low concentrations.

The analytical results confirm that both light and dense phase immiscibles should be monitored for. This is due to the detection of constituents listed in Table 5 which are characteristic of light and dense phase refinery wastes. Of the organics detected at the Texaco facility, only two have established criteria for which comparisons can be made. These criteria include maximum concentration limits (MCLs) and recommended maximum concentration limits (RMCLs). Benzene was detected above the MCL of 5 micrograms per liter (mg/l) in ten of the 16 wells sampled by the Task Force. Xylenes do not have an MCL, although a Recommended Maximum Concentration Limit (RMCL) has been proposed. Four wells had concentrations of Xylenes above the RMCL of 440 ug/l. Three of these were located on the South Area and one in the alluvium on the North Area.

Inorganic Analysis Ground-water samples from the North Area indicate concentrations of metals and indicator parameters above MCL, RMCL, and Secondary Drinking Water Standards.

Arsenic and selenium have MCLs of 50 and 10 ug/l, respectively. Wells M-10s and both sets of samples from M-36 show concentrations which exceed these standards. A surface water sample from the inlet of the Excess Service Water Effluent Pond shows a value above the MCL for selenium. The RMCL of 10,000 ug/l nitrate was also exceeded at the inlet location.

Secondary Drinking Water Standards for iron, manganese and sulfate were exceeded at several wells and the inlet location.

Analytical results from the North Area alluvium indicate levels of iron, manganese, selenium and sulfate above the applicable standards. Most of these were from wells SP-7 and M-12s, although the alluvial pond displayed elevated concentrations of manganese and sulfate.

The South Area wells indicate the following parameters above the applicable standards: barium, iron, and sulfate. The PCS Pond also displays iron and sulfate above standards.

3. Data Comparison (Task Force and Texaco)

Ground-water and surface water samples were collected in the field for the Task Force by Versar, Inc. Sample splits were presented to Western Water Consultants on behalf of Texaco. The data comparison is presented in Table 21. Texaco's PARL laboratory analyzed samples from wells M-10s, M-10d, M-36, M-51As, SS-49, SS-34, SS-4, M-41A; from the Inlet Pond, Alluvial Pond, PCS Pond; two bailer blanks and one pump blank. Accu-Labs Research, Inc. analyzed Texaco's splits from wells M-1, M-6, M-35, M-33, SP-7, M-12s, SS-19, and SS-7. Accu-Labs ran the inorganic contaminants and indicator parameters but subcontracted the organic contaminants to Rocky Mountain Analytical Laboratory. The raw data are located in Appendix I for the Texaco samples. All analytes ran for organics, inorganics and indicators and detection limits are listed in Appendices I.

The Task Force data were analyzed by EPA contract labs under the CLP. The raw data, in addition to the detection limits reported by the lab(s), is included in Appendix A. It should be noted that three samples collected by the Task Force were medium concentration samples and, as such, the detection limit was elevated.

Often, the comparison of Task Force data was made on a limited list of constituents with Texaco's data from the two laboratories. For example, Texaco's PARL laboratory reported only a partial list of results for inorganics, organics and indicator parameters as shown on Table 22. For comparison, those analytes sampled by the Task Force are listed in Table 18.

Table 22

Analytes Reported by (Texaco) PARL Laboratory

<u>Inorganics</u>	<u>Indicator Parameters</u>	<u>Organics</u>
Arsenic	Cyanide	Benzene
Barium	Phenols	Toluene
Cadmium	Ammonia	Ethylbenzene
Chromium	Sulfate	Xylene
Copper	Chloride	
Lead	Conductivity	
Manganese		
Mercury		
Nickel		
Selenium		
Silver		
Vanadium		
Zinc		

Where blanks occur in Table 21, the analyte was either below the level of detectability, was not sampled for, or was not reported. These blanks can be investigated further by review of raw data from the Task Force and Texaco in Appendices A and I respectively. The capital letter "N" for the Task Force results denotes a spike recovery not within control limits.

Table 21
Analytical Comparison, Ground-Water Task Force vs Texaco

SAMPLE SOURCE PROPRIETOR LABORATORY	M-1		M-6b		M-10a		M-10d		M-36			M-35		M-51As	
	TF	TEX ACCU	TF	TEX ACCU	TF	TEX PARL	TF	TEX PARL	TF	TF DUP	TEX PARL	TF	TEX ACCU	TF	TEX PARL
Acetone					59				3806	3000				23	
Benzene					12		57		310	270	290			76	
2-Butanone									670	570					
Ethyl Benzene														15	
Methylene Chloride															
Toluene					18		12		410	360	420			34	
Xylene					24				330	290	140			59	220
Phenol	5		9		9260		3240		64000	62000	226000	6			9670

NOTE:

TF - Task Force (micrograms/liter)

TEX - Texaco (milligrams/liter converted to micrograms/liter)

N - Spike recovery not within control limits

- Blank indicates those concentrations below the lower limit of detection

Table 21 (continued)

SAMPLE SOURCE PROPRIETOR LABORATORY	M-33		INLET POND		SP-7		M-12s		ALLUVIAL POND		SS-19		SS-49	
	TP	TEX ACCU	TP	TEX PARL	TP	TEX ACCU	TP	TEX ACCU	TP	TEX PARL	TP	TEX ACCU	TP	TEX PARL
Acetone							11							
Benzene											2000		6000	6630
2-Butanone														
Ethyl Benzene			20								170		310	190
Methylene Chloride														
Toluene			20				5.2				290		620	550
Xylene											890		3000	4270
Phenol	11		90		44		56				290			640

Table 21 (continued)

SAMPLE SOURCE PROPRIETOR LABORATORY	SS-34		SS-7		SS-4		M-41A		PCS POND		BAILER BLANK	BAILER BLANK	PUMP BLANK	PUMP BLANK	BAILER BLANK	BAILER BLANK
	TP	TEX PARL	TP	TEX ACCU	TP	TEX PARL	TP	TEX PARL	TP	TEX PARL	TP	TEX PARL	TP	TEX PARL	TP	TEX PARL
Acetone									12							18
Benzene	38	30	1400		900	820					270		390		29	
2-Butanone			180		41	40										
Ethyl Benzene									5.5				19			
Methylene Chloride		40			44	50										
Toluene			460		140	240			27							
Xylene							30			920		20		90		
Phenol		230		33		4230										

Table 21 (continued)

SAMPLE SOURCE PROPRIETOR LABORATORY	M-1		M-6b		M-10a		M-10d		M-36			M-35		M-51As	
	TF	TEX ACCU	TF	TEX ACCU	TF	TEX PARL	TF	TEX PARL	TF	TF DUP	TEX PARL	TF	TEX ACCU	TF	TEX PARL
Aluminum	1180N	700	488		704N				3330N	2290N		5510N	4800	20500N	
Antimony					15.5				12.9	10.2				79	
Arsenic	12.3		13.7		53.6	30			196	229	30				
Barium	36		56		81	70	37		106	106	90	59		411	240
Beryllium															
Cadmium				18								1.2	10	7.1	
Calcium	18300	17000	259000	240000	568000		193000		8510	8550		88100	74000	268000	
Chromium				12		190		70	25	18					120
Cobalt				50	16				25	31			40	44	
Copper				6		60								55	
Iron	914N	780	2270N	2200	14800N		889N		2690N	2750		3460	3600	224000	
Lead		5	6.7	5	10.2	1420		670	8	8		5.2		31	1000
Magnesium	5920	5400	87600	75000	294000		121000		4220	4490		39600	34000	176000	
Manganese	26	36	249	210	49800	36710	483	400	112	119	100	279	320	2740	2540
Mercury				0.1						0.2		0.4	0.2		
Nickle		40		80	29	140		60	257	266	190		30	38	150
Potassium	3250	2800	10600	10000	5230		19300		8750	8800		11800	10000	32000	
Selenium					141	14			99.2	73.5		8.1		2.3	
Silver						120									60
Sodium	206000	190000	208000	190000	196000		519000		939000	990000		107000	94000	316000	
Thallium							2.0								
Vanadium					13	320		120	151	153	110		9	80	210
Zinc	2630N	3400	2950N	3300	1090N	1280	1660N	1660	120N	34N		36N	35	15900N	9800
INDICATOR PARAMETERS															
Total Phenols		5		9	6000	9260	5500	3240	394000	284000	226000		6	4200	9670
TOX			10		36		6.4							14	
POX															
TOC	1200	5000	7800	7000	69000		69000		676000	726000		18000	4000	125000	
POC		300		300					2600	2400				280	
NO3-N	270				1510							3000	3300		
NH3-N	300	400		400	19000	37400	300	1330	610000	580000	407000			8000	164000
NO2-N															
Chloride	1400		280000	270000	40000	52000	87000	98000	100000	80000	62000	18000	18000	50000	289000
Bromide							1900			1400				1600	
SO4	120000	130000	750000	740000	2580000	2766000	370000	581000	480000	540000	330000	290000	300000	150000	291000
Cyanide					121N	1700	414N	2040			1020			552	1550

Table 21 (continued)

SAMPLE SOURCE PROPRIETOR LABORATORY	M-33		INLET POND		SP-7		M-12s		ALLUVIAL POND		SS-19		SS-49	
	TF	TEX ACCU	TF	TEX PARL	TF	TEX ACCU	TF	TEX ACCU	TF	TEX PARL	TF	TEX ACCU	TF	TEX PARL
Aluminum	3670N	5200	154		5840N	4100	1530N		131		2330N	1200	206N	
Antimony									6.7					
Arsenic	3.2		7.1		10.9	11	31.5	32			14.4	12	10.1	
Barium	47		119	110	135		166		20		1160	1300	2500	2220
Beryllium														
Cadmium		18				13		11			1.4	9		
Calcium	224000	200000	250000		77100	70000	92400	86000	73900		130000	110000	108000	
Chromium		16		120		11				50				60
Cobalt	8	40			12		8	40						
Copper		20				15		13						
Iron	5360N	7700	1110		17400N	20000	12200	10000	252		20300N	20000	33700N	
Lead	13.5	12		1290	14.4	12	36.1	17		390	11.1			430
Magnesium	112000	98000	278000N		72600	64000	91700	81000	58900N		80600	72000	59200	
Manganese	887	830	730N	670	2570	2400	1760	1500	357	340	1620	1500	147	210
Mercury											0.2			
Nickle		100		90	44	100	32	110				50		
Potassium	18400	17000	7960		15400	13000	14800	13000	12000		4900	4000	6710	
Selenium			27.5				38.3							
Silver		6		50										
Sodium	420000	390000	920000		456000	420000	467000	430000	432000		154000	140000	115000	
Thallium														
Vanadium		12		220	13	11		6	9	50		8		70
Zinc	42N	60		320	5200N	4800	2320N	1500			30N	33		
INDICATOR PARAMETERS														
Total Phenols	41	11	39	90	282	44	198	56	32		207	190	425	640
TOX	25		18		16				13		12			
POX											7		31	
TOC	16000	24000	16000		29000	34000	36000	36000	16000		33000	41000	79000	
POC		100	390			200	190	200			8100	15000	9200	
NO3-N	470	360	20000		5000		6000							
NH3-N	1100	200		1210	1800	1200	4400	5400		230	14000	15000	11000	3110
NO2-N														
Chloride	7000	70000	190000	3408000	80000	72000	70000	76000	58000	1453000	43000	41000	50000	
Bromide	550								250		600		550	
SO4	74000	1100000	11500000	150000	590000	490000	500000	490000	970000	75000	50000	50000		36000
Cyanide	172N	150	36	250	145N	120	145N	130		450	20N	18	14N	120

Table 21 (continued)

SAMPLE SOURCE PROPRIETOR LABORATORY	SS-14		SS-7		SS-4		M-41A		PCS POND		BAILER BLANK	BAILER BLANK	PUMP BLANK	PUMP BLANK	BAILER BLANK	BAILER BLANK
	TF	TEX PARL	TF	TEX ACCU	TF	TEX PARL	TF	TEX PARL	TF	TEX PARL	TF	TEX PARL	TF	TEX PARL	TF	TEX PARL
Aluminum	24900N		430N		347		113000N		311						389	
Antimony	6.9															
Arsenic	20.3				39.9	20	41		9.9							
Barium	564	130	928	1100	1200	1060	1640	80	376	350	4				5	
Beryllium							5									
Cadmium							4.6									
Calcium	172000		43900	40000	120000		398000		124000		277		533		394	
Chromium	18	100				60	123	130		60						
Cobalt	23						58									
Copper	33						132	50								
Iron	56700N		4870N	4500	52600		171000N		1580						107	
Lead	140	770	6.9	7		460	138	960		460						
Magnesium	128000		79800	71000	62900N		207000		16800N						137	
Manganese	2370	2260	874	750	797N	860	5100	2170	625N	590					7	
Mercury							0.7									
Nickel		80		50			89	110								
Potassium	10800		3360	3000	4190		23500		8250						584	
Selenium	2.8						6.2									
Silver								50								
Sodium	160000		112000	110000	127000		154000		102000		431		394		574	
Thallium																
Vanadium	72	160				80	309	200		80						
Zinc	220N	360	2120N	2200	1870	1720	881N	560								
INDICATOR PARAMETERS																
Total Phenols		230	76	33	109	423	33	30	9754	920	43	20	16	90	41	
TOX	11		20		17		9.9		12							
POX			7													
TOC	10000		25000		48000		5700		39000				5		3900	
POC	650		4900	9600	12000		620		420				1300			
NO3-N			1000				910									
NH3-N	4200	4310	130	300	400	2930						1180		2260		18
NO2-N																
Chloride	35000	405000	31000	31000	90000		26000	752000	120000	122000						
Bromide	400				550				250							
SO4	350000	54000	480000		5700	75000	1000000	40000	1000000	55000						
Cyanide		1000			20	260		60		70		90		60		

Based on the QA/QC data validation reports discussed previously and presented in Appendices G and H, all analytical data reported for organics and inorganics are within the program accuracy Data Quality Objectives. Based on this conclusion the following discussion compares the Task Force data to Texaco's data. For ease, this is broken up into organics, metals and indicator parameters as they are presented in Table 21.

Organics

Table 21 shows the occurrence of acetone in five samples by the Task Force but not detected by Texaco. Concentrations appear to be low in all samples except at M-36 where 3000 to 3806 ug/l concentrations were detected. Lower concentrations may be attributed to sample handling contamination, although the concentrations in M-36 may be associated with degradation of petroleum waste constituents. At this time the relationship between acetone and petroleum waste degradation is not well understood. Samples analyzed by Texaco compare favorably with all other organic constituents except phenol with only slight discrepancies. Phenols are consistently detected by both of Texaco's laboratories, while the Task Force data reported concentrations above the detection limit only once. This was at well M-36, but even then the Task Force results did not compare favorably with Texaco's (see Table 21). Total phenol concentrations listed under Indicator Parameters in Table 21 for the Task Force appear to compare more favorably to Texaco's, although apparent discrepancies do exist. It is apparent that two different types of methods and possibly laboratories analyzed for phenols and/or total phenols, thus possibly explaining the variation between the Task Force and Texaco results. The Texaco data presented in both columns under phenols is the same concentration (i.e. repeated on the Table by the Task Force).

Metals

Metals analyzed by both Texaco and the Task Force show some discrepancies. In addition, some parameters at various wells exceed the primary drinking water standard (PDWS). A brief summary of notable discrepancies and exceedance to standards follows:

- o Values for arsenic appear to compare favorably between Texaco and the Task Force except at well M-36. Arsenic as reported by either Texaco and/or the Task Force exceeded the PDWS of 0.05 mg/l at wells M-10s, M-36 and M-51As.
- o Discrepancies were seen in barium concentrations at wells M-51As, SS-34 and M-41A. Wells where barium exceeded the PDWS of 1.0 mg/l as reported by the Task Force and/or Texaco include SS-19, SS-49, SS-7, SS-4 and M-41A.
- o Discrepancies in cadmium concentrations were seen at wells M-35 and SS-19, and then only slightly. Wells where the PDWS of 0.01 mg/l for cadmium was exceeded include M-6b, M-33, SP-7, M-12s, and M-35.
- o Numerous discrepancies in chromium concentrations were detected in most wells. It appears that chromium was consistently detected by Texaco's labs and not by the Task Force. No reason for this discrepancy could be given. The PDWS for chromium of 0.05 mg/l was exceeded in wells M -10s, M-10d, M-51As, SS-49, SS-34, SS-4, M-41A and the PCS, inlet and alluvial ponds.

- o Notable discrepancies in lead concentrations were also seen in numerous wells including M-10s, M-10d, M-51As, SS-49, SS-34, M-41A and the PCS, inlet and alluvial ponds. General trends indicate that Texaco's concentrations are usually higher and at several wells, Texaco detected high concentrations and the Task Force reported non-detectable. Those wells which exceed the PDWS for lead of 0.05 mg/l include M-10s, M-10d, M-51As, SS-49, SS-34, SS-4, M-41A and the PCS, inlet and alluvial ponds.
- o Discrepancies in nickel concentrations were seen at wells M-10s, M-51As, SP-7, and M-12s. Again, on several occasions the Task Force data was lower and even non detected in several wells while Texaco reported concentrations.
- o Results for selenium compared favorably except at well M-10s where Texaco's value was much less than the Task Force's. The PDWS for selenium of 0.01 mg/l was exceeded in wells M-10s, M-36, M-12s and the inlet pond.
- o Several discrepancies in silver concentrations were noted in that while Texaco reported values, the Task Force results were below the detection limit. Silver concentrations exceeded the PDWS of 0.05 mg/l at wells M-10s, M-51As, M-41A and the inlet pond.
- o Several discrepancies in vanadium concentrations were seen. For the most part, Texaco's values were consistently higher than the Task Force results and were also detected at times when the Task Force reported non-detectable.

Indicator Parameters

Only those indicator parameters for which discrepancies were noted are discussed below.

- o Several discrepancies were noted in the total organic carbon (TOC) concentrations, especially at wells M-1 and M-35. Other discrepancies, although slight, may be attributed to the detection of TOC in the pump and bailer blanks by the Task Force.
- o Other indicator parameters tend to compare favorably where reported by Texaco and the Task Force except as noted. Ammonia (N) was reported by Texaco in M-51As at 25 times the concentration reported by the Task Force. Bromide was detected in ten samples taken by the Task Force, but was not reported in any samples by Texaco. The cyanide results are interesting in that the concentrations detected by Texaco are consistently higher than those reported by the Task Force.

In summary, the analytical results reported show several discrepancies as noted above. General observations would be that for several inorganic parameters, it appears that Texaco is reporting consistently higher concentrations than the Task Force. In fact for several analytes, the Task Force often reported concentrations below the lower limit of detection while Texaco reported concentrations

significantly above the detection limit. For both parties, analytical results indicate that numerous analytes exceed the PDWS set forth in 40 CFR 265 Appendix III as discussed previously.

In the future, field blanks and/or reporting of internal QA/QC procedures utilized by Texaco's laboratories would assist in assessing the confidence of the reported analytical results. As previously mentioned, this field and laboratory QA/QC program should be discussed in detail in the sampling and analysis plan, and should be implemented in the field to assure that data quality objectives are met. This is especially important in reviewing data for an evaluation of the effectiveness of any type of remedial action program, especially when evaluating background ground-water quality.

4. Comparison to Past Texaco Data

Minimal data exist for comparison of past Texaco data with those of the Task Force. As previously mentioned, only three "comprehensive" sampling events in the North Area were performed by Texaco prior to the Task Force evaluation. Two sampling events in 1984 were analyzed for priority pollutants and one event in 1986 for the modified Skinner list (TriHydro, 1987a). A comprehensive sampling event has not been performed in the South Area.

The following constituents were chosen for comparison: benzene, toluene, phenol, 2,4-dimethylphenol and 2-butanone (methyl ethyl ketone). These were chosen because they occurred or were at least analyzed more often than other organic constituents. Furthermore, data comparisons could only be made in the following wells: M-10s, M-10d, M-33, M-35, M-36, M-51As and SP-7, as these were the only wells sampled by both the Task Force and Texaco in the past.

The above mentioned constituents were either not analyzed or not detected above the detection limit in both sampling events held by Texaco in 1984. Additionally, Texaco did not analyze or detect above the lower detection limit any constituents except in well M-36 in June, 1986. It should be noted that this is based on the previously mentioned wells only. Contamination was detected in other wells by Texaco, but for comparison purposes, will not be reviewed. Table 13 contains Texaco's summary table listing the constituents detected in the past and the associated wells.

In comparing Texaco's past organic data with the Task Force, no significant deviations or trends were observed. All the above mentioned constituents were detected in well M-36 by both parties in similar concentrations. Benzene was reported at 230 ug/l by Texaco and 310 ug/l by the Task Force. Toluene concentrations were 330 ug/l for Texaco and 410 ug/l from the Task Force. Both parties reported 64,000 ug/l of phenol. 2,4-dimethylphenol was reported at 25,000 ug/l by Texaco and 14,000 ug/l by the Task Force. Finally, 2-butanone (methyl ethyl ketone) concentrations were 520 ug/l as reported by Texaco and 670 ug/l by the Task Force.

To be consistent with the organic comparison, only June, 1986 inorganic data will be compared with the Task Force data. Only those wells which were sampled and analyzed by both parties are included. In addition, only those inorganic parameters which exceed drinking water standards during Texaco's June 1986 analysis were reviewed.

Nitrate was reported by Texaco in M-10s at 16,000 ug/l, while the Task Force reported 1,500 ug/l. Selenium exceeded the standard in two wells by both Texaco and the Task Force. Well M-12s showed concentrations of 100 and 38 ug/l for Texaco and the Task Force, respectively. Well M-36 concentrations were 30 and 90 ug/l, respectively. Cadmium was reported by Texaco in well M-33 at 20 ug/l, but not detected by the Task Force. Finally, arsenic concentrations from well M-36 were 200 ug/l from Texaco and 196 ug/l from the Task Force.

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Effects of Chemical Evaporation Pond Recharge

The Chemical Evaporation Pond (CEP) was operated at the North Area from 1955 to August 1982. The pond received wastewater from the process system, including the Hydro Treater Unit (HTU), Catalytic Polymerization Unit (Poly), Fluid Catalytic Cracking Unit (FCCU), Pressure Coke Stills (PCS), Vacuum Pipe Stills (VPS), Catalytic Reforming Unit (CRU), and Stabilizers. The process water system also received 138 tons of caustic soda per year from the merox system. Flow from the FCCU and PCS accounted for 50-60% of the waste stream to the pond; the Poly, HTU, CRU, and VPS contributed about 30-40% of the waste stream; and the stabilizers contributed about 10% (WWC, 1983a). An analysis of the quality of the waste waters is shown on Table 8.

In October of 1986, in an effort to augment contaminant degradation in the uppermost aquifer near the CEP, Texaco constructed a recharge pond from the southern third of the old CEP and began recharging the ground-water system with relatively clean water from the North Platte River.

The location of the CEP is shown on Figure 10. The pond had a surface area of 6.62 acres, and a maximum capacity of 16 million gallons. Seepage from the pond has been identified as the primary source of ground-water contamination in the North Area (WWC, 1983a). Contamination identified as originating from the pond includes TOC, pH, conductance, lead, chromium, selenium, phenols, ammonia, sulfide, and chloride, based on comparisons to National Interim Primary Drinking Water Standards, RCRA indicator parameters, and Wyoming Water Quality Criteria (WWC, 1983a). In addition, a number of hazardous organic constituents have been identified in wells near the CEP during sampling in 1984 and 1986.

In December 1982, Texaco ceased discharging process wastewaters to the CEP and implemented a program to abate ground-water pollution resulting from previous operation of the pond. Water remaining in the pond was treated by mechanical aeration from December 1982 until November 1983, and the treated water was then discharged to the Excess Service Water Effluent Ponds (WWC, 1984a). In October 1986, the sludge and some of the soil from the bottom of the CEP was removed to the North Land Farm as part of CEP closure (WWC, 1987a). Texaco was also relying on the natural processes of dilution, sorption, and biodegradation to attenuate ground-water contamination in the vicinity of the CEP (WWC, 1983a). Although Texaco investigated the viability of sorption and biodegradation to attenuate contaminant concentrations, they concluded that dilution would remain the principal means of attenuation (WWC, 1983a). Texaco monitored the progress of contamination abatement through a program of quarterly sampling of indicator parameters and water levels.

In October of 1986, in an effort to augment contaminant degradation in the uppermost aquifer near the CEP, Texaco constructed a recharge pond from the southern third of the old CEP and began recharging the ground-water system with relatively clean water from the North Platte River. About 8.8 million gallons of water were pumped into the pond between October and December 1986 (WWC, 1987a), and about an additional 35 million gallons were pumped into the pond in 1987 (WWC, 1988), or the relative losses from the pond due to evaporation and infiltration into the ground-water aquifer. However, no recharge occurred during the winter of 1986-87, when the pond was frozen (Hamilton, personal communication, 1988).

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Table 8 Quality of Waste Streams Feeding Chemical Evaporation Pond, Casper Texaco Refinery

Units Containing Flow	TDS (mg/l)	pH (mg/l)	Phenol (mg/l)	Iron (mg/l)	TOC (mg/l)	Ammonia (mg/l - N)	H ₂ S (mg/l)
FCCU & PCS	16	9.2	179	0.99	260	2022	--
Poly, HTU, CRU, and VPS	101	7.8	26	0.18	251	3250	7887
Stabilizers	2880	9.0	12.6	--	769	615	--

Note: Analyses are an average of three samples from the FCCU and PCS and are an average of two samples from the other two waste streams. All samples were taken between May 14 and June 1, 1981.

-- No Analyses

Hydraulic Effects of CEP

In addition to the degradation of ground-water quality noted above, the CEP also had a significant effect on local ground-water levels and ground-water flow directions. As a result of seepage from the pond, a distinct ground-water mound was established in the immediate vicinity of the pond. In the absence of the pond, the estimated potentiometric surface elevation beneath the pond would range from 5115 feet msl on the south, to 5118 feet msl on the north (WWC, 1983a). However, at the time the CEP was taken out of service in 1982, the potentiometric surface beneath the pond was in excess of 5124 feet msl (WWC, 1984a). The apparent mound in the potentiometric surface was approximately 1500 feet in diameter, and extended beneath essentially all of the CEP, the landfill to the west, and the land farm to the east. When recharge to the pond ceased in 1982, the mound began to decay, and potentiometric levels began to fall in the vicinity of the CEP. By the autumn of 1986, potentiometric levels beneath the pond had declined to approximately 5120 feet. An apparent mound still existed, but its diameter had been reduced to about 800 feet (WWC, 1987a). With the onset of river water recharge in late 1986, the mound was quickly reestablished. By June 1987, potentiometric levels beneath the recharge pond had risen to more than 5126 feet (and in excess of 5128 feet at well M-11s). The diameter of the apparent mound had increased to about 1200 feet. Furthermore, a review of the potentiometric level data for 1987 (WWC, 1988) indicates considerable variability in water levels during the year. At well M-11s (Figure 10), where maximum water levels were recorded, the water levels varied by more than four feet during the course of the year. Furthermore, a continual water level rise was not observed. The potentiometric level at well M-11s was about 5121 feet prior to recharge, rose to about 5127 feet by December 1986, fell to 5124 feet by March 1987, rose to in excess of 5128 feet by June 1986, and then fell to about 5126 feet by December 1986. These data suggest two things: first, potentiometric levels in the immediate vicinity of the recharge pond are very sensitive to the input of water at the pond; and second, it appears that the infiltration of water from the pond may be quite variable throughout the year, with a large proportion of recharge to the ground-water system occurring in late spring and early summer of 1987. No details on the operation of the system are available from which these conclusions could be confirmed, other than the cessation of recharge during the winter of 1986-87, when the pond was frozen. Reportedly, the recharge pond is operated so that a constant head is maintained in the pond (Hamilton, personal communication, 1988).

It should also be noted that water level fluctuations at well M-36 have been anomalous from the time the well was installed in 1984. Western Water Consultants (WWC, 1988), in their potentiometric level map for June 1987, indicate a localized depression in the potentiometric surface in the vicinity of well M-36. However, water levels at this well have continuously been depressed slightly with respect to water levels at other nearby wells since water levels were first reported for the well in April 1984. Furthermore, as water levels rose in response to recharge of river water at the CEP, the water levels at M-36 rose more slowly than the levels at nearby wells. Texaco reports that the elevation of this well is continually resurveyed (Hamilton, personal communication, 1988), so that it is unlikely that the reported water level in this well is in error. Texaco also reports that well M-36 does not recover abnormally slowly when the water level in the well is drawn down (Hamilton, personal communication, 1988). As will be noted below, water chemistry at M-36 has also not responded as directly as at other wells to the introduction of river water at the recharge pond. This evidence suggests that well M-36 may be hydraulically isolated in some manner from other nearby wells. A number of possible explanations for this phenomenon can be suggested, ranging from plugging of the well screen to installation of the well in a buried channel of high hydraulic conductivity. However, the

available information does not permit any definite conclusions to be drawn regarding the apparently depressed water levels at well M-36.

Chemical Effects of the CEP

As noted previously, the use of the CEP prior to 1982 has been identified by Texaco as the primary cause of ground-water contamination in the North Area. The pond has apparently allowed the introduction of a wide range of contaminants, including several hazardous constituents, into the uppermost aquifer. The mounding of the potentiometric surface beneath the CEP also induced flow radially outward away from the CEP, with some contaminated ground water apparently discharging from the uppermost aquifer at the seeps along the bluff southeast of the CEP and subsequently entering the alluvial aquifer downslope from the seeps.

Following cessation of discharge to the CEP in 1982, Texaco has documented general declines in contaminant concentrations in the vicinity of the CEP. Texaco attributes these declines to a combination of dilution of contaminated water with uncontaminated water from upgradient; sorption of contaminants onto soil particles; biodegradation; and other chemical degradation phenomena (WWC, 1984a, 1985, 1987a, 1988). However, Texaco has provided few details as to the nature or relative magnitudes of these various possible mechanisms for attenuation of contaminant concentrations. Early in the program, Texaco did investigate the availability of microorganisms in ground water in the CEP area, and did investigate the relative efficiencies of dilution and other degradation mechanisms. They concluded that the ground water did contain microorganisms capable of degrading some organic contaminants, although perhaps not within the ground water immediately adjacent to the CEP where contaminant concentrations were very high. They also concluded that whereas phenomena other than dilution were apparently effective in attenuating concentrations, dilution was probably the principal mechanism (WWC, 1983a, 1984a).

The recharge of relatively uncontaminated river water at the CEP beginning in late 1986 was expected to augment the rates of contaminant attenuation within the uppermost aquifer. In addition to the obvious potential for concentration reduction due to increased dilution, it was expected that the relatively oxygen-rich river water would enhance the rates of aerobic microbial degradation of contaminants. One of the major objectives of the Ground Water Task Force has been to assess whether the recharge of river water has in fact enhanced the degradation of organic contaminants in the aquifer, or whether the effects of such recharge have been largely the hydraulic ones of dilution and lateral transport away from the recharge basin.

In an effort to assess the effectiveness of river water recharge in augmenting rates of natural attenuation of contaminant concentrations, the Task Force has conducted a variety of preliminary investigations, utilizing primarily data reported by Texaco, supplemented where possible with data collected by the Task Force. These preliminary investigations have included the following:

- o Estimating the changes in total mass of various indicator chemicals in the system as a function of time.
- o Estimating the changes in total mass of individual organic contaminants in the system as a function of time.
- o Reviewing changes in contaminant concentrations as a function of time at individual wells.

- o Reviewing the reported rates of decline of maximum quarterly concentrations of various indicator chemicals.
- o Assessing the rates of ground-water underflow beneath the CEP relative to the rate of river water recharge.
- o Reviewing the response of the ground-water mound to the recharge of river water.

The first assessment attempted by the Task Force was the consideration of variations in the estimated total mass of contaminants in the system. For each of three indicator species (chloride, TOC, and total phenols), the total mass in the system at any given time was estimated from the isopleths reported by Texaco (WWC, 1984a, 1987a, 1988). For each map of contaminant distribution, the area encompassed by different isopleths was estimated, and the area enclosed by two successive isopleths was calculated. The area enclosed by two successive isopleths was then multiplied by an estimate of the average concentration within the isopleths, and then multiplied by an assumed average thickness of the uppermost aquifer (25 feet) and an assumed effective porosity (25%), to yield an estimate of total mass of that contaminant enclosed by the isopleths. The mass enclosed by all of the successive pairs of isopleth lines was then summed to get an estimate of total mass of that constituent in the uppermost aquifer. This process was complicated in some cases by the fact that isopleths, as displayed by Texaco, often extended beyond the boundary of Texaco property, although the isopleths were terminated at the property line. In these cases, it was necessary to estimate the extent of the isopleths beyond the property line (and in fact beyond the extent of available data). Any errors made in such extrapolation of the available data would be expressed in the consequent estimates of total mass in the system. In order to reduce the effects of this class of error, it was necessary in some cases to limit the estimate of total mass to the mass contained within a particular isopleth (e.g., the 50 mg/l isopleth for chloride, TOC, and phenol). Consequently, any mass occurring outside of this isopleth, or transported outside of the previous location of this isopleth, will not be accounted for in the analysis.

This approach was also attempted for specific individual constituents for which sufficient data existed to permit contouring of isopleths (benzene, toluene, and total cresols). However, since these constituents were observed in only three or four wells, accurate contouring of the data was extremely difficult, and the resulting estimates of total mass are not considered reliable. They will, however, be discussed here for the sake of completeness.

Table 9 summarizes the resulting estimates of total mass of various constituents as a function of time. For each constituent, the mass relative to that estimated for the system in June 1984 is also given. In general, the chloride mass in the system remains somewhat constant, in relative terms, from 1982 to 1986, and then declines somewhat in 1987. TOC concentrations decline rather steadily from 1982 to 1986, and then seem to stabilize. Phenol concentrations vary considerably, sometimes declining considerably in a year, sometimes rising dramatically. Benzene mass declines from 1984 to 1986 at a rate comparable to that for chloride. Toluene increases substantially from 1984 to 1986, and total cresols decline by more than 50% from 1984 to 1986. In terms of absolute rates of mass decline, chloride mass declined at an average rate of about 12 million grams per year, TOC at a rate of about 17 million grams per year, phenols at a rate of about 13 million grams per year, and total cresols at a rate of about 28 million grams per year.

Table 9
Estimates of Total Contaminant Mass in
Uppermost Aquifer, North Area
 (10⁶ grams)

<u>Parameter</u>	<u>6/82</u>	<u>6/83</u>	<u>6/84</u>	<u>6/85</u>	<u>6/86</u>	<u>6/87</u>
Chloride	232 (.943) *	252 (1.024)	246 (1.000)	--	215 (.874)	192 (.780)
TOC	199 (1.276)	184 (1.179)	156 (1.000)	162 (1.038)	126 (.808)	126 (.808)
Phenols	79.2 (1.520)	78.7 (1.511)	52.1 (1.000)	40.5 (.777)	55.8 (1.071)	27.1 (.520)
Benzene	--	--	.0885 (1.000)	--	.0774 (.875)	
Toluene	--	--	.124 (1.000)	--	.166 (1.339)	
Cresols	--	--	80.2 (1.000)	--	35.9 (.448)	

* Mass relative to that in the system in June 1984

The results of these analyses are somewhat inconclusive. In terms of relative annual changes in concentrations, chloride remains relatively constant from 1982 until 1986, and then declines somewhat with the onset of river recharge. Since chloride is a conservative and relatively non-reactive species, this is as would be expected. The decline in total concentration between 1986 and 1987 can be attributed to the lateral transport of chlorides beyond the 50 mg/l isopleth, and thus not considered in the analysis. The gradual decline in TOC mass from 1982 to 1986, and the average rate of mass decline which is about 40% higher than that for chloride, may be attributed to degradation phenomena other than dilution. However, the apparent stabilization of mass from 1986 to 1987 is anomalous, and suggests at the least that the recharge of river water did not accelerate the degradation of TOC. The variation in phenols was not very consistent, although there is an overall trend of declining mass at a rate comparable to that for chloride. The approximately 50% decline in total mass of phenols from 1986 to 1987 may be attributed to the operation of the recharge pond, and is greater than the mass decline in chlorides or other species, and thus might indicate enhanced degradation of phenols. However, a comparable relative decline in total cresols was observed from 1984 to 1986, prior to the onset of river water recharge. In terms of absolute rates of annual decline in mass, chloride, TOC, and phenols all declined at approximately equal rates, while total cresols declined at a rate approximately twice that of the other parameters. With the possible exception of phenols, no acceleration in the rate of mass decline was observed with the onset of river water recharge.

In general, the results of this analysis suggest the possibility that degradation phenomena beyond mere dilution may be acting to reduce the concentrations of some contaminants, but the evidence is not very clear, and on the basis of the absolute rates of estimated mass decline, it appears that TOC and phenols decline at approximately the same rates as chloride, and thus probably subject to much the same phenomena.

A second line of analysis attempted by the Task Force involved reviewing changes in contaminant concentrations as a function of time at individual wells. With the onset of river water recharge, a few wells experienced declines in contaminant concentrations, many wells exhibited no immediate response, and some wells exhibited increases in some indicator parameters. Significant declines in TOC and phenols concentrations with the onset of recharge were observed at wells M-49A and M-9s; declines in TOC and phenols concentrations at well M-11s were observed, although they did not begin until June 1987. Chloride concentrations also declined significantly at well M-49A, but not nearly so significantly at wells M-9s or M-11s. At wells M-36, M-51As, and SP-1, none of the indicator parameters considered (TOC, phenols, and chlorides) appeared to respond to the river water recharge, remaining at approximately the same levels as they had been during 1986. At two of the wells considered, M-13 and M-8sa, the river water recharge seems to have induced a temporary increase in the levels of indicator parameters. At both of these wells, TOC, phenols, and chloride concentrations generally rose from September 1986 until June 1987, and then began to decline.

The results of this phase of the Task Force assessment indicate that with the onset of river water recharge, concentrations of indicator parameters generally declined at wells closest to the recharge pond, temporarily rose at wells a little further away, and were essentially unchanged at wells beyond about 750 feet from the recharge pond. This evidence suggests that the principal effect of the river water recharge was a dilution of contaminated water immediately beneath the pond, accompanied by a lateral "flushing" of contaminated water away from the recharge pond as the ground-water mound beneath the pond was reestablished. Although the recharge of oxygenated river water may have enhanced aerobic biodegradation, the effects of any such activity would appear to be largely outweighed by the effects of dilution and lateral transport, to the extent that the

possible effects of other degradation phenomena can not be clearly seen in the data considered.

Texaco (Hamilton, personal communication, 1988) has also considered variations in sulfate concentrations as a possible indicator of biodegradation activity, with a rise in sulfate concentrations possibly indicating aerobic biodegradation of sulfides, and a decrease in sulfates suggesting anaerobic biodegradation. In general, however, it is difficult to observe any distinct changes in sulfate concentrations corresponding to the onset of river water recharge at the CEP, except for decreases in sulfate concentrations at wells M-10s and M-10m, and increases in sulfates at wells M-17 and M-19. All four of these wells are downgradient of the CEP and to its east, with wells M-17 and M-19 located further downgradient than wells M-10s and M-10m (Figure 10). Since the trends in these changes in sulfate concentrations are contrary to what would be expected with increased aerobic biodegradation near the pond, and since even wells closer to the pond showed no definite correlations of sulfate with river water recharge, it is not possible to assert that recharge of aerated river water enhanced biodegradation based on this evidence.

The Task Force also reviewed the reported rates of decline of maximum quarterly concentrations of various indicator chemicals (WWC, 1985, 1987a, 1988). According to Texaco, these maximum quarterly concentrations continued to decline, even through 1987, although the rates of decline as calculated by Western Water Resources (1985, 1987a, 1988) were decreasing in some cases. Upon closer inspection of the reported data, it appears that the quarterly maxima for several parameters (TOC, phenols, sulfide, and chloride) have actually stabilized since about 1985, with no apparent effect of river water recharge. Ammonia and conductance maxima appear to have remained fairly steady since 1982, although the maxima for both of these parameters declined late in 1987. Again, these trends would be consistent with dilution and lateral transport as the primary mechanisms of contaminant attenuation, with no apparent enhancement of contaminant degradation as a result of river water recharge. The apparent stabilization of quarterly maxima might reflect a gradual outward transport of contaminants, with no continuing attenuation of concentrations by means of any phenomena.

Finally, as noted previously, the ground-water mound beneath the CEP has responded immediately and directly to the recharge of river water. This is not surprising, since it appears that the rate of recharge of river water far exceeds the rate of natural ground-water underflow beneath the area of the CEP. Average recharge of river water during 1987 was 35 million gallons over the course of the year, or about 100,000 gallons per day. Natural underflow is difficult to estimate because of the absence of ground-water level data unaffected by the CEP, and because of the wide variation in estimated hydraulic conductivity of the "colian" sands (ranging from 1.5 to 1067 gpd/ft² (WWC, 1983a). Based on the potentiometric contours for June 1987 (WWC, 1988), the water-level gradients to the southeast and southwest, relatively unaffected by the CEP, are about 0.02 (the estimated gradient beneath the CEP following total decay of the ground-water mound was about 0.006 (WWC, 1983a). It should be noted that the maximum estimated values of hydraulic conductivity are for well M-49a, the tested well nearest the CEP (Figure 10). Excluding data for this well, the mean hydraulic conductivity measured for the "colian" sands in the area unaffected by the CEP (the area where the gradient was estimated) would be 14 gpd/ft². For an assumed gradient of 0.02, hydraulic conductivity of 15 gpd/ft², and aquifer thickness of 25 feet, the underflow through a cross section 2400 feet wide (the approximate width of the estimated phenol plume in 1986) would be about 18,000 gpd. Thus, it appears that natural underflow beneath the CEP may be as low as 20% of the annual average recharge of river water. Even if the estimated rate of ground-water underflow were increased by an order of magnitude, the rate of river water recharge would remain more than 55% of the underflow. This again suggests that dilution and

lateral transport of contaminants away from the reestablished water-level mound may be the major phenomena affecting contaminant attenuation in the vicinity of the CEP.

Recommendations

These preliminary Task Force calculations suggest the variety of analyses that could be brought to bear on the question of attenuation of ground-water contamination in the North Area. Although Texaco maintains that several mechanisms for attenuation of contaminants may be at work in the North Area ground-water system (WWC, 1983a, 1984a, 1985, 1987a, 1988; Hamilton, personal communication, 1988), analyses of the data to support this contention has largely been limited to documenting long-term trends in declining constituent concentrations. Attempts at quantification of the relative effects of dilution, hydrogeochemical, and hydrobiological phenomena have apparently not been consistently applied. In order to permit a rational assessment of the potential for river water recharge to enhance natural attenuation mechanisms, it is recommended that Texaco provide quantification and discussion of the relative effects of all possible attenuation mechanisms.

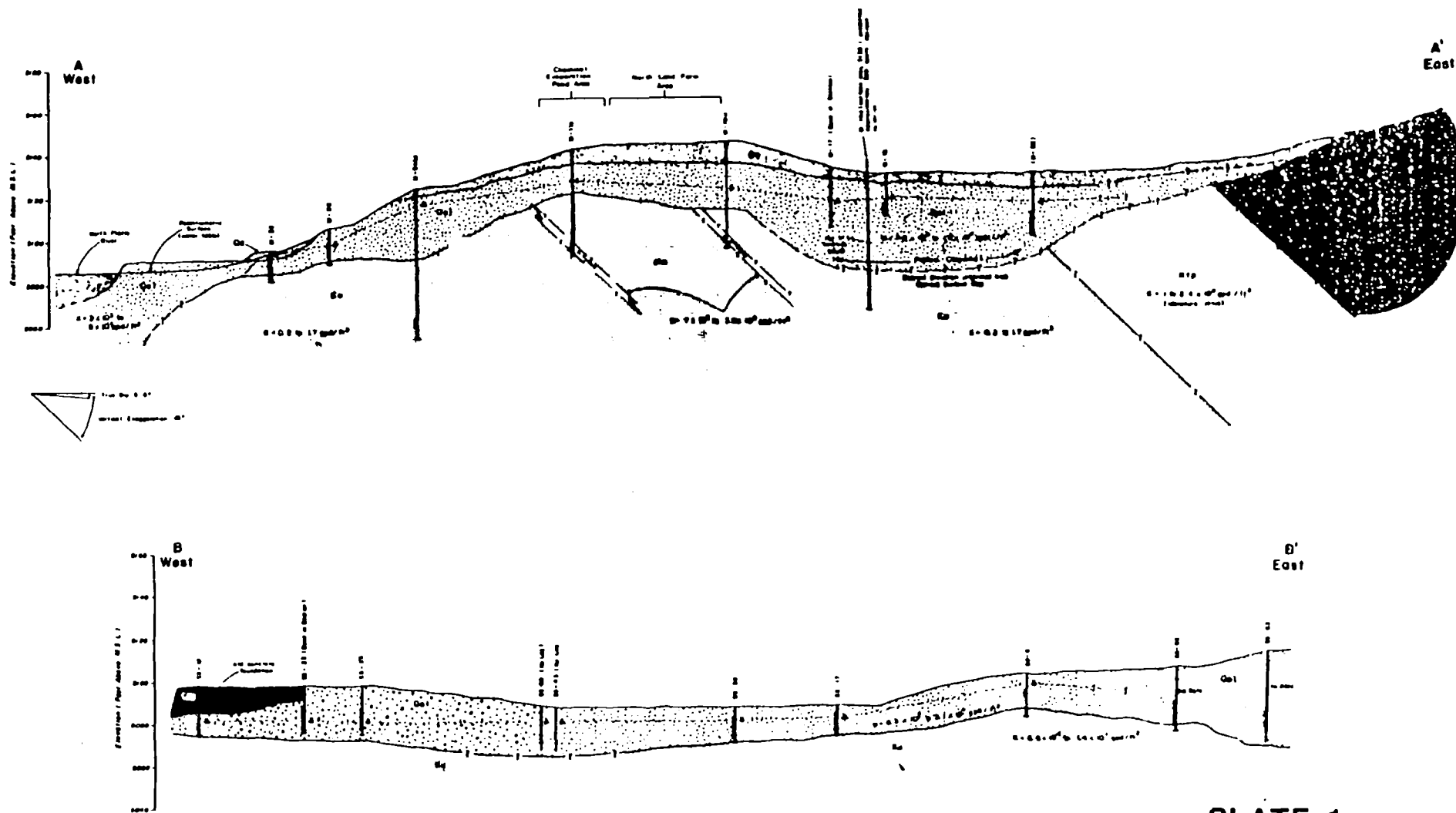


PLATE 1

Generalized Hydrogeologic Cross Sections

Casper Texaco Refinery

