

Appendix K - Stormwater Retention Pond Post-Closure Plan

**RCRA INTERIM STATUS POST-CLOSURE PLAN
STORM WATER RETENTION POND
KERR McGEE REFINING CORPORATION
WYNNEWOOD, OKLAHOMA**

VOLUME I

Prepared for:

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1.0 POST-CLOSURE PLAN

1.1 Introduction

The purpose of this document is to present an Interim Status Post-Closure Plan for a hazardous waste surface impoundment (the Storm Water Retention Pond) at the Kerr-McGee Refining Corporation (KMRC) Refinery in Wynnewood, Oklahoma. The surface impoundment will be closed in-place in accordance with the requirements of 40 CFR 265.228 and 265.310. This Plan describes the post-closure monitoring and maintenance activities to be followed for the closed surface impoundment, in accordance with the requirements of 40 CFR 265.118, 265.228, and 265.310.

1.2 Surface Impoundment Description

The interim status hazardous waste surface impoundment addressed by this Post-Closure Plan is a storm water retention pond (SWRP) located at the KMRC Wynnewood Refinery. The Wynnewood Refinery is engaged in petroleum refining and produces unleaded gasoline, diesel, propane, fuel oil, asphalts, distillates, and solvents. The SWRP is a 0.52 acre surface impoundment which receives storm water from the Refinery, as well as occasional dry weather flow. During heavy rain events which cause process water to commingle with storm

water, primary sludge from petroleum refining may be carried into the SWRP. The SWRP became newly regulated as a hazardous waste management unit on May 2, 1991, when primary sludge from petroleum refining became a newly listed hazardous waste (waste code F037).

1.3 Security

Security at the Refinery and SWRP area is maintained by a staff of trained security guards who monitor entry and exit from the Refinery and provide security measures within the Refinery. During off hours, regular patrols are conducted by Security Personnel to monitor activity.

The portion of the Refinery which contains the SWRP is entirely surrounded by a six foot chain link fence. The principal entrance to this area is through Guard Gate C-2. Several other gates are present, but access is controlled. Visitors and contractors entering the Refinery must sign a log sheet and obtain visitor passes. Visitors have authorization to go only to the area designated for their work or delivery.

The immediate perimeter of the closed surface impoundment will be marked with signs to prevent unauthorized activity which might damage the final cover.

In addition to the general security features of fencing, gates, guards, and signs, several other features contribute to the safety and security of the SWRP area. Ample lighting is provided throughout the Refinery site, and guards and operators are equipped with two-way radios to report upset conditions immediately. In addition to the two-way portable radios carried by guards and operators, an internal telephone system (with phones in most refinery areas) is also provided. The same telephone system is used for communication outside the Refinery.

1.4 Post-Closure Plan Administration

The contact person for information regarding the closed SWRP during the post-closure period will be the designated Facility Contact. The currently designated Facility Contact is:

Mr. Chris Hawley, Environmental Manager
Wynnewood Refining Company
906 South Powell
Wynnewood, Oklahoma 73098
(405) 665-6655 email: chawley @ gwec.com

1.5 Post-Closure Period

In accordance with 40 CFR 265.117 (a), the post-closure period initially established in this Plan is 30 years. The 30-year post-closure period may be shortened as set forth in 40 CFR 265.117 (a)(2)(i) if the Oklahoma Department

of Environmental Quality (ODEQ) finds that a reduced period is sufficient to protect human health and the environment.

Unless the post-closure care period is reduced, the post-closure care provided for in this Post-Closure Care Plan will continue for 30 years after the date of certification of closure of the surface impoundment.

1.6 Post-Closure Records

The Facility Contact listed in Section 1.4 will be responsible for maintaining the availability of the Post-Closure Care Plan during the post-closure care period. In addition, the Facility Contact will be responsible for maintaining all post-closure care records developed under the Post-Closure Care Plan. Such records will include all inspection and maintenance reports, in addition to information from the groundwater monitoring program.

1.7 Certification of Completion of Post-Closure Care

Within 60 days after final completion of the established post-closure care period for the surface impoundment, KMRC will submit a certification that the Post-Closure Care was performed in accordance with the Post-Closure Plan, as it may be approved and/or amended.

This certification will be:

1. submitted by registered mail to the ODEQ,
2. signed by an authorized representative of KMRC, and
3. signed by an independent registered professional engineer.

Documentation supporting the independent registered professional engineer's certification will be developed and maintained for submission to the ODEQ, upon request, until KMRC is released from the post-closure care financial requirements of 40 CFR 265.145.

1.8 Post-Closure Inspections and Maintenance

1.8.1 General

The KMRC Post-Closure Inspection Schedule is presented in Table 1. Post-closure inspections will be performed semiannually by an inspector who may be either the Facility Contact or another person designated by the Facility Contact, but who has been trained in the appropriate inspection procedures or is otherwise qualified. Post-closure inspections will also be performed following (within 24 hours) possible damage from storms, other natural events, or unforeseen circumstances.

A copy of the KMRC Post-Closure Inspection Form is presented in Table 2. During each semiannual inspection, the inspection form will be completed, with

specific notations of all problems identified. Upon completion of the semiannual inspection, the inspector (if different than the Facility Contact) will deliver the completed inspection form to the Facility Contact.

The Facility Contact will arrange for the appropriate maintenance or repair to be provided. The KMRC Post-Closure Inspection/ Maintenance Report shown in Table 3 will be used both to initiate and subsequently to document maintenance activities, repairs, or remedial actions determined to be necessary. Minor repairs which can be fully described and documented on the inspection form itself will not require use of an inspection/maintenance report.

Upon receiving an inspection form or inspection/maintenance report from an inspector which indicates that a problem requiring maintenance or repair has been identified, the Facility Contact will, within fifteen (15) working days, initiate actions to provide the required maintenance or repair.

Depending on the nature of action required and at the discretion of the Facility Contact, action may be taken to provide maintenance or repairs using Refinery personnel, to secure a contractor to perform maintenance or repairs, or to obtain the services of a professional consultant to provide advice and plans regarding remedial action.

The following typical time frames are established for completing maintenance and repair activities under normal conditions. Maintenance and repairs which can be performed by Refinery personnel will be completed within 30 days of completion of inspection. Maintenance and repairs which require an outside contractor's services will be completed within 45 days of completion of inspections. Maintenance and repairs requiring the services of a professional consultant preliminary to completion of repairs will be completed within 60 days of completion of inspections.

1.8.2 Recordkeeping

Records of all inspection and maintenance activities will be kept on file and maintained by the Facility Contact during the post-closure period. These will include all completed inspection forms, all completed inspection/maintenance reports, and other written documentation of repairs which may be developed.

1.8.3 Inspection/Maintenance Procedures

The post-closure components which will be routinely inspected on a semiannual basis during the post-closure period will include the following items:

1. Surface impoundment final cover,
2. Run-on and run-off control features,
3. Security structures,
4. Surveyed benchmarks, and

5. Surface components of groundwater monitoring wells.

Inspections will also be made following possible damage from storms, other natural events, or unforeseen circumstances.

1.8.3.1 Final Cover

During the post-closure period, the final cover of the surface impoundment will be inspected semiannually for the following items:

1. Indications of settling or subsidence of the underlying fill and clay cap.
2. Signs of erosion or other damage to the clay cap, as might be evidenced by the appearance or accumulation of clay cap material down slope in or on the final cover.
3. Damage to the final cover.
4. Signs of erosion or undercutting action at the perimeter of the surface impoundment where the cap and final cover join perimeter run-on/run-off control features.

Maintenance will be performed as needed during the post-closure period. Repairs to the cap or final cover may require the consultation of a Registered Professional Engineer to design repairs, or of a construction contractor to implement designed repairs.

1.8.3.2 Run-on and Run-off Control Features

The run-on and run-off control features will be inspected for the following items:

1. Presence of debris or sedimentation which restricts flow, particularly near drainage endpoints.
2. Erosion or undercutting against the cap, or final cover.

Semiannual monitoring inspections will determine whether repairs or maintenance activities are required. Inspections will also be made following storms, other natural events, or unforeseen circumstances.

1.8.3.3 Security Provisions

The security system, which includes (1) the fencing that surrounds the portion of the Refinery which contains the SWRP, and (2) signs posted around the SWRP, will be inspected during post-closure inspections for the following potential problems:

1. Damaged chain link mesh sections.
2. Damaged or improperly operating gates.
3. Inoperable gate locks.
4. Missing or illegible signs.

No regularly scheduled maintenance of security systems is necessary during the post-closure period. Fencing, gates, and signs will be maintained in good repair, but maintenance will be provided only on an as-needed basis to be determined during the semiannual post-closure inspections.

1.8.3.4 Surveyed Benchmarks

Those surveyed benchmarks which are used to document the closure and the monitoring well locations will be inspected on a semiannual basis, and maintained on an as-needed basis.

1.8.3.5 Groundwater Monitoring Well Surface Components

All components of the groundwater monitoring system will be inspected during each groundwater sampling event described in Section 2.1. If these inspections indicate siltation problems, monitoring well replacement or redevelopment may be required. In addition, the surface components of all groundwater monitoring wells will be inspected during each semiannual post-closure inspection. Any groundwater monitoring well which experiences damage or loss of integrity during the post-closure period will be repaired or redrilled and replaced.

The groundwater monitoring well surface components will be inspected for:

1. Missing, unlocked, or inoperable locks.
2. Damage to outer protective casing which could indicate potential damage to the monitoring well itself.
3. Lack of inner casing cap.
4. Ponded water at monitoring wells.
5. Erosion near monitoring well or under well pad.
6. Damage to the concrete well pad.
7. Proper identification noted on each monitor well.

Surface drainage will be controlled so that water does not normally pond around a monitoring well. Additionally, any erosion in the immediate vicinity of each monitoring well will be checked and repaired to prevent damage to groundwater monitoring well surface components or the monitoring wells themselves.

Maintenance of the surface components of groundwater monitoring wells will be on an as-needed basis determined by post-closure monitoring inspections.

2.0 POST-CLOSURE GROUNDWATER MONITORING PROGRAM

2.1 Introduction

The Storm Water Retention Pond (SWRP) is currently regulated under the RCRA interim status regulations described by 40 CFR Part 265. It is anticipated that a post-closure permit will be issued for the SWRP at some future date. At that time, the SWRP will become regulated under the permitting standards given in 40 CFR Part 264. However, until a permit is issued, the SWRP unit will remain subject to the interim status standards.

The applicable interim status groundwater monitoring regulations are described in 40 CFR 265 Subpart F. Kerr-McGee proposes to monitor the groundwater at the SWRP during the interim status period in accordance with the program described in Section 2.2. The proposed monitoring program constitutes an alternate groundwater monitoring program as allowed by 40 CFR 265.90 (d).

The propose alternate groundwater monitoring program will allow Kerr-McGee to establish a baseline of groundwater data. The proposed program also conforms to the 40 CFR 264 Subpart F groundwater monitoring regulations for a detection monitoring program (40 CFR 264.98). This will allow for smooth transition from monitoring under interim status regulations to monitoring in accordance with a RCRA post-closure permit. No changes to the groundwater monitoring program should be necessary at the time of permit issuance.

2.2 Groundwater Monitoring System Description

A discussion of key components of the post-closure care groundwater monitoring system is presented below.

2.2.1 Monitor Well Network

The proposed post-closure monitoring compliance well network is shown on Figure 1. This compliance well network will consist of at least four (4) shallow alluvial wells. Two (2) of the compliance monitor wells are presently constructed (SMW-5 and SMW-9), and two (2) compliance wells remain to be constructed and identified by number or other designation as shown on Figure 1. Monitor well SMW-5 is the upgradient monitoring well for the SWRP area. Monitor well SMW-9 is a downgradient well in the SWRP area. The two (2) additional downgradient monitor wells will be installed at the locations indicated on Figure 1.

Existing compliance wells SMW-5 and SMW-9 are screened in the upper ten (10) feet of the alluvial aquifer. The screen interval extends above the groundwater surface in these two (2) existing wells to allow for seasonal fluctuations in water levels. If the vertical dimensions of the uppermost aquifer exceeds 20 feet, then well nests will be installed at each compliance well location in order to screen all portions of the aquifer. The entire saturated thickness of the uppermost aquifer should be screened, but no well screen

will be more than 20 feet in length. At locations SMW-5 and SMW-9, additional compliance point wells will be installed to monitor the entire saturated thickness. As indicated, the upper ten (10) feet of saturated thickness is currently being monitored in wells SMW-5 and SMW-9. Additional wells will be added, as necessary, at these locations to monitor the entire saturated thickness of the aquifer, with the screen length being no more than 20-feet in length. At the two (2) other proposed (not yet installed) compliance monitoring well locations (west and southwest of SWRP), wells will be installed as necessary to monitor the entire saturated thickness of the aquifer, with the screen length being no more than 20-feet in any well. The monitor wells installed in the upper portion of the aquifer will be screened slightly above the water level to allow for seasonal fluctuation of the water table. A listing of the existing post-closure monitor wells is shown on Table 4. A summary of existing monitor well construction details, including well survey information, is included on Table 5.

An observation monitor well will be installed in the shallow alluvial zone. This well will be installed between the impoundment and stream as depicted on Figure 1. The observation well will primarily be utilized for additional piezometric information. However, for the first three (3) years of the monitoring program, a single annual sample from the observation monitor well will be obtained and analyzed for the same parameters as the other monitor

wells. After three (3) years of annual sampling and analysis of this observation well, annual sampling and analysis of this observation well will be discontinued if there are no significant levels of constituents detected.

2.2.2 Analytical Parameters

Groundwater quality data has been collected from numerous monitor wells installed at the Refinery since about 1980. Most of the groundwater sampling and analysis programs have been conducted under the supervision of the Oklahoma State Department of Health (ODEQ), which is now the Oklahoma Department of Environmental Quality (ODEQ). Based upon extensive analyses of groundwater, KMRC has identified certain principal hazardous waste constituents (PHCs) which have been detected in groundwater at the Refinery at levels of concern. These are:

Metal PHCs:	Vanadium, Barium, Chromium, Lead, and Selenium, as total
Volatile Organics:	Benzene, Toluene, Ethylbenzene, Total Xylenes, and Total Petroleum Hydrocarbons

Additionally, Kerr-McGee has agreed to an expanded list of PHCs at the request of the EPA. The expanded list of PHCs are:

Metals:	Antimony, Arsenic, Beryllium, Cobalt, Copper, Mercury, Nickel, and Zinc, as total.
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Acid/Base

/Neutral (ABN): 2-Methylnaphthalene, Acenaphthene, Anthracene, Benzo(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(ghi)perylene, Benzo(a)pyrene, Chrysene, Dibenzofuran, Fluoranthene, Fluorene, Phenanthrene, and Pyrene.

During the first three (3) years of post-closure groundwater monitoring, the expanded list of PHCs (ABN and metal parameters) will be analyzed annually in groundwater samples collected from each specified upgradient and downgradient well. Following the end of three (3) years of monitoring, analysis for the expanded list of PHCs will be dropped if these constituents are not detected at significant concentrations and upon approval from the EPA.

The volatile organics (BTEX and TPH) and metal PHCs (lead, vanadium, chromium, selenium, and barium) will be analyzed in groundwater samples quarterly during the first year, then semi-annually thereafter during the post-closure monitoring period.

A summary of the post-closure groundwater sampling parameters, analytical test methods, sample containers, sample preservatives, and holding times are presented on Table 6. A map showing the location of the monitoring well network is shown on Figure 1.

2.2.3 Sample Frequency, Target Detection Limits, & Compliance Standards

Representative groundwater samples will be obtained quarterly for one (1) year from each specified upgradient and downgradient shallow monitor well and nested wells (if installed). The samples will be analyzed for the metal and PHCs (BTEX, TPH, vanadium, chromium, lead, selenium, and barium). After the first year these parameters will be analyzed semiannually. The groundwater samples also will be analyzed annually for the expanded list of PHCs (ABN and metal parameters). Following the end of three (3) years of monitoring, analysis of the expanded list of metals and ABN will be dropped if these constituents are not detected at significant concentrations and upon approval from the EPA. The sampling frequency for all parameters is presented on Table 7. The data generated during the first year of sampling and analysis will establish a residual data set for statistical comparisons.

Target detection limits, termed practical quantitation limits (PQLs) in Appendix IX of 40 CFR 264, were determined for all groundwater monitoring parameters and are presented on Table 7. PQLs represent the lowest level that can be reliably determined within specified limits of precision and accuracy during routine laboratory operating conditions. However, most of the quality assurance data, presented in EPAs SW-846, was for water samples using an ultra-pure reagent grade water and controlled check samples spiked with known concentrations. Therefore, water samples consisting of water and chemical

compositions and mixtures other than the EPAs check samples may result in an increase in the PQLs. Factors that can cause the increase in PQLs include high oil content, high concentrations of one or two particular compounds, high concentrations of non-target compounds, and the composition of the groundwater matrix (i.e., high conductivity, high iron, etc.). To overcome the interfering factors described above, the laboratory must dilute the sample. The dilutions result in a PQL that has been adjusted relative to the final volume of the sample and the necessary dilution.

2.2.4 Groundwater Sampling Plan Description

A detailed post-closure Groundwater Sampling and Analysis Plan has been prepared by KMRC. This Plan has previously been submitted to the EPA, ODEQ, and Oklahoma Water Resources Board (OWRB) in the report titled: "A Comprehensive Plan for Groundwater Remediation, September 13, 1990". The Groundwater Sampling and Analysis Plan was included in Appendix D of this report. This Plan details sampling and analytical testing procedures which will be followed in the field during post-closure groundwater sampling activities. This plan was updated on August 15, 1993 and is included with this report as Attachment B.

2.2.5 Data Evaluation and Response Activities

The execution of the groundwater monitoring program will require the frequent review and assessment of monitoring results. Anomalous and unanticipated results may be obtained from the program. Review and assessment activities must, therefore, be able to identify these anomalous occurrences and initiate the proper response to the monitoring results.

2.2.6 Statistical Data Evaluation and Reporting Procedures

In accordance with 40 CFR 264.98 procedures, a determination as to whether there is statistically significant evidence of a release at each designated downgradient monitoring well will be performed after receiving all analytical results from the laboratory and submitted to the EPA within 30 days.

A statistical procedure initially selected by KMRC to determine whether differences in mean concentrations among background wells versus downgradient detection wells are statistically significant is a one-way parametric analysis of variance (ANOVA). The current regulations allow the owner or operator to change statistical methods as the monitoring data base is expanded. KMRC will evaluate the use of control charts as an alternate method after a more substantial data base has been generated. KMRC will begin using control charts at the end of the first three (3) years of post-closure monitoring, upon approval from the EPA. The use of control charts as a

comparison technique is allowed by the regulations. The control charts would provide a visual tool for detecting both trends and abrupt changes in concentration levels.

KMRC has reviewed the 40 CFR 264 regulations and the EPA guidance document entitled "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities", dated February 1989 and the draft addendum dated July 1992 and has selected a one-way analysis of variance (ANOVA) statistical method to evaluate the groundwater monitoring data.

ANOVA is a statistical procedure to determine whether differences in mean concentrations among wells or groups of wells are statistically significant. ANOVA models are used to analyze the effects of the independent variable or variables under study of the dependent variable. The concentration of monitoring constituents is the dependent variable. ANOVA is generally appropriate in situations where a background concentration for a particular parameter can be established and compared to downgradient sample data. Also, ANOVA calculations are amenable to personal computers and commercially available software. The one-way statistical ANOVA procedure presented in the EPA guidance document will be utilized by KMRC to perform the required statistical comparisons.

Listed below in outline form is the Guidance Manual ANOVA statistical procedure:

- Step 1. Tabulate sample data from background and detection wells.
- Step 2. Calculate total (sum) of all observations for each well, the mean (average) of all observations for each well, grand total, and grand mean of all observations.
- Step 3. Compute the sum of squares of differences between well means and the grand mean.
- Step 4. Compute the corrected total sum of squares.
- Step 5. Compute the sum of squares of differences of observations within wells from the well means.
- Step 6. Construct a one-way parametric ANOVA table to include the source of variation, sums of squares, degrees of freedom, mean squares, and calculated F statistic.
- Step 7. To test the hypothesis of equal means for all detection wells, compute the F statistic. Compare the computed F statistic from Table 2, Appendix B of the EPA Interim Final Guidance document. If the calculated F value exceeds the tabulated value at the 0.05 (5%) significance level, then reject the hypothesis of equal well means. Otherwise, conclude that there is no significant difference between the concentrations at wells and thus no evidence of a release.

- Step 8.** In the case of a significant F (calculated F greater than tabulated F in Step 7 above) the next procedure will determine which detection wells may show evidence of a release by comparing each detection well with the background well(s). First, obtain the total sample size of the background well(s) and compute the average parameter concentration for the background well(s). Then compute the differences between average parameter concentrations from each downgradient well and the average background well(s). Next, compute the standard error of each difference. Finally, obtain the t-statistic from Bonferroni's t-Table with a 0.05 (5%) error level and compute the M value (standard error x t) for each detection well.
- Step 9.** To interpret the results, if the differences between the average parameter concentrations from a detection well(s) and the average parameter concentration from the background well exceed the M value, conclude that the detection well has significantly higher parameter concentrations than the average background well. Otherwise, conclude that there is no evidence of a release.

The following procedures will be utilized to assess data below detection limits if this should occur:

- For a moderate to large percentage of nondetects (i.e., over 15%), then a nonparametric test will be selected for analysis of the data.
- If nondetects are present at less than 15% of the observations, then the nondetects will be assigned a concentration equal to the practical quantitation limit (PQL) divided by 2 and the one-way parametric ANOVA procedure presented previously will be followed for data analysis.

Kerr McGee will make a statistical determination of the groundwater data within 30 days of receiving all laboratory data. If it is determined that there is a statistically significant evidence of contamination for the chemical parameters monitored, the Facility will follow procedures outlined in 264.98(g). If a statistically significant release is indicated, the EPA will be notified of this finding within seven (7) days.

Following the establishment of a long-term data base at the end of the first three (3) years of monitoring, KMRC will discontinue the ANOVA statistical evaluation and begin using control charts. KMRC has selected the control chart methodology described in EPA's Interim Final Guidance and Addendum to Interim Final Guidance. A control chart for each monitoring well and each monitoring parameter will be constructed in the following manner.

First, initial sample data collected during the first three (3) years of monitoring, will be analyzed in order to establish baseline parameters for the chart, such as estimates of the well mean and well variance. Note that none of the sample results collected during the 3-year period are actually plotted on the chart before being used to construct the baseline mean standard deviation. As future samples are collected, the baseline parameters will be used to standardize the data. A standardized mean and cumulative sum (CUSUM) will be computed. Also, a decision interval value, a reference value, and a Shewhart control limit will be selected prior to plotting. Once the data have been standardized and plotted, a control chart is declared out-of-control if the sample concentrations become too large when compared to the baseline parameters. An out-of-control situation indicates statistically significant evidence of a release. In this situation, the ODEQ would be notified within seven (7) days. If the analytical result is nondetectable, then a value one half of the practical quantitation limit will be used to construct the control chart.

Groundwater level data will also be collected from each monitoring well in the post-closure monitoring well network. Groundwater potentiometric maps will be prepared for each sampling event to define the groundwater flow direction. The potentiometric surface map will be evaluated to insure that there has been no change in the groundwater flow direction which could affect the ability of a monitor well to properly monitor groundwater conditions beneath the SWRP.

Should a significant change in groundwater flow direction occur, KMRC will remeasure water levels in all wells and prepare a new potentiometric surface map to insure that no errors were made during the initial water level measurements.

If the groundwater still shows a significant difference from past flow maps, then KMRC will notify the ODEQ within seven (7) days of this finding. KMRC will then initiate appropriate measures to insure that a post-closure care monitoring network is properly in place to monitor groundwater quality in the SWRP area. These measures may include additional water level monitoring, installation of additional wells, or a re-evaluation of the existing well network as to well placement.

The depths of each well will also be measured to insure that no excessive silt buildup occurs. If the monitor wells experience siltation problems, then additional well development will be conducted.

2.2.7 Data Reporting

KMRC will prepare and submit to the ODEQ an annual report summarizing the past year's sampling activities, analytical results, and groundwater flow data. This report will be submitted no later than 30 days following receipt of the year's last quarterly or semi-annual sampling results. In addition to presenting

a summary of the sample analytical results, the annual report will include the laboratory analytical reports, and an assessment of the data relative to the objectives and approach of post-closure groundwater monitoring. The assessment section of the report will be organized in the following manner:

- Discussion of Site History
- Sampling and Analytical Procedures
- Variations in Groundwater Flow Pattern
 - Direction of Flow and Gradient
 - Velocity of Flow
- Statistical Evaluation of Data
 - Concentration of Constituents
 - Direction and Rate of Constituent Movement
 - Immiscible Phase Evaluation
- Comparison of Water Quality Data to Compliance Standards
- Recommendation for Continuation or Modification of Program
- Appendices
 - Water Quality Data
 - Water Level Data

2.3 Aquifer Characterization Data

A Hydrogeological Characterization of the uppermost groundwater system beneath the SWRP is provided in Attachment A. This Hydrogeological

Characterization Report provides a detailed summary of hydrogeological conditions in the SWRP area. All previous analytical data for monitor wells SMW-5 and SMW-9 have been summarized and are included in Attachment A (Appendix A-2). The information provided in this report provides technical information that is necessary to properly evaluate groundwater quality and flow data generated during the post-closure groundwater monitoring program.

ATTACHMENT A

**HYDROGEOLOGIC CHARACTERIZATION OF THE
KERR-McGEE REFINING CORPORATION
WYNNEWOOD, OKLAHOMA
STORM WATER RETENTION POND**

August 31, 1993

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**HYDROGEOLOGIC CHARACTERIZATION OF THE
KERR-McGEE REFINING CORPORATION
WYNNEWOOD, OKLAHOMA
STORM WATER RETENTION POND
August 31, 1993**

INTRODUCTION

The geology, topography, surface and subsurface hydrology, and climatic conditions are all factors which have been evaluated in the Storm Water Retention Pond (SWRP) area. These parameters are described in this report for the area of and adjacent to the Kerr-McGee Refining Corporation (KMRC) Storm Water Retention Pond at Wynnewood, Oklahoma.

LOCATION AND GENERAL FEATURES

The KMRC Wynnewood Storm Water Retention Pond (SWRP) is located in the southeastern part of Garvin County, Oklahoma (Figure 1). Garvin County is located in south central Oklahoma and is part of the Osage Plains Region which is a southwestern extension of the Central Lowlands Region. The Osage Plains Region is subdivided into several subregions in Oklahoma. The Wynnewood area lies within the Cross Timbers subregion. This region is characterized by nearly horizontal shale, sandstone and limestone units. Generally, the less resistant shales form the broad shallow valleys while the more resistant limestone and sandstone units form the small intervening ridges between the valleys.

The SWRP is approximately 3,700 feet south of the City of Wynnewood Corporate limits (Figure 2). The SWRP is located in the NW 1/4, SW 1/4, SE 1/4 of Section 23, Township 2 north, and Range 1 east on the Pauls Valley 7 1/2-minute U.S.G.S. quadrangle map. The nearest major highway is U.S. Route 77 located approximately 1,350 feet to the east. The nearest railroad is the Gulf, Colorado, and Santa Fe located about 150 feet to the west. The nearest major population center is Wynnewood, Oklahoma which had a 1980 census population of approximately 2615. Figure 3 shows the SWRP area and the location of nearby groundwater monitoring wells.

PHYSIOGRAPHY AND TOPOGRAPHY

The SWRP is located in the Central Lowlands section of the Great Plains Physiographic Province. Most of this area is a relatively flat, featureless plain developed upon sedimentary formations of Paleozoic and Mesozoic Age.

The portion of the Central Lowlands in the area including the Wynnewood Refinery is locally referred to as the Central Redbed Plains. The immediate area of the Wynnewood Refinery is a gently sloping surface developed within the Washita River flood plain and relic terrace deposits. Topographic relief increases near the edge of the Washita River flood plain to the east and in the Arbuckle Mountains to the south. The Washita River borders the western side of the area.

The topography in the general area surrounding the SWRP (Figure 2) ranges from approximately 820 feet above mean sea level (MSL) near the Washita River to the west to approximately 900 feet above MSL at the edge of the flood plain to the east. A topographic map for the SWRP area is shown in Drawing 1. This map shows that the topography at the SWRP ranges from approximately 839 to 850 feet above mean sea level.

SURFACE WATER AND DRAINAGE CHARACTERISTICS

The major stream system in this part of Oklahoma is the south-flowing Washita River and its tributaries. The SWRP lies within its drainage basin. At its closest approach, the Washita River is located approximately 7,400 feet (1.4 miles) northwest of the SWRP. The Washita River merges with the Red River at the Texas-Oklahoma border. In addition to the major drainage system of the Washita River, the area in the immediate vicinity of the SWRP is drained by three (3) tributaries of the Washita River. The largest of these tributaries is Turkey Sandy Creek, which at its closest approach is located approximately 3,000 feet (.57 mile) southeast of the SWRP. A second unnamed tributary is located at its closest approach approximately 20 feet from the southeast corner of the SWRP. A third tributary (Hogg Creek) is located 3,700 feet (0.70 mile) northwest of the SWRP. Figure 4 shows the location of the surface water streams, rivers, ponds, and lakes in the Refinery area.

CLIMATE

Introduction

The nearest source of climatic data to the SWRP is the community of Pauls Valley, located approximately 6.5 miles north of the Wynnewood Refinery. The climate of this area is described as being dry subhumid continental. The continental effect produces pronounced daily and seasonal temperature changes and considerable variations in seasonal and annual precipitation. The summer season is typically long and hot, with high temperatures ranging in the high nineties and, on occasion, the hundreds. The winter is relatively mild and short, with temperatures commonly dropping below freezing. January is generally the coldest month of the year.

Air Flow

The climate of the Pauls Valley-Wynnewood area is dominated by continental controls characteristic of the Great Plains region, punctuated by occasional warm, moist air from the Gulf of Mexico. Prevailing winds are out of the south (Figure 5). Wind velocities are relatively uniform, being greatest out of the south-southwest and north-northwest. The mean annual wind speed is approximately 9.6 knots (11.1 miles per hour) (Figure 6).

Precipitation

The mean annual calendar year precipitation for the Pauls Valley-Wynnewood area, based upon the 30-year period extending from 1958 through 1987, is 35.34 inches. Annual precipitation during this period ranged from a minimum of 19.02 inches (1963) to a maximum of 50.25 inches (1985). Snowfall averages less than 10 inches per year and seldom remains on the ground for any extended period. The 30 - year calendar precipitation data are presented in Table 1 and Figure 7. The maximum monthly precipitation recorded for this region during this period was 14.33 inches in May of 1982.

Spring and summer have historically been the wettest times of the year, with the winter months being the driest. Summer rainfall comes mainly from showers and thunderstorms. Winter precipitation is generally associated with large scale air mass movements.

Review of Figure 7 indicates that precipitation is not uniform, and suggests that annual precipitation is cyclic in nature, with relative wet and dry periods of several years duration alternative over the long term. Thus, those hydrologic factors dependent upon precipitation -infiltration, soil moisture storage, runoff, and percolation/groundwater recharge - will not be uniform.

It should be noted that years of unusually high precipitation can and do occur during "dry" periods, while years of unusually low precipitation can and do occur during otherwise "wet" periods. Precipitation data can also be significantly affected by intense, short-term thunderstorm events.

Temperature

The annual temperatures for the Pauls Valley-Wynnewood area are relatively uniform. The mean annual temperature, based upon the 30-year calendar year period 1958 through 1987, is 62.2°F. Annual mean temperatures for this period ranged from a minimum of 50.0°F to a maximum of 74.4°F. Table 2 lists mean temperatures for the 30-year period from 1958 to 1987.

Evaporation

The National Weather Service reports a mean annual "Class A" pan evaporation rate of 71 inches for this region; this value is approximately equivalent to 54 inches of evaporation annually from lakes and 64 inches annually from shallow ponds. These standing water evaporation rates are 161 and 191 percent of mean annual precipitation, respectively.

REGIONAL STRATIGRAPHY

This section is concerned primarily with the stratigraphic relationships and areal extent of the geological formations that underlie the SWRP and vicinity. Geological units ranging in age from Cambrian basement complex to recent alluvial deposits along the Washita River and its tributaries underlie the SWRP. This section considers the geological units of the upper-Pennsylvanian and Quaternary alluvial deposits. Deposits older in age than the upper-Pennsylvanian will not be considered since they occur at depths of several thousands of feet below ground level and have little hydrologic importance to the SWRP.

The Central Redbed Plains are underlain by sedimentary formations of Pennsylvanian and Permian age. Resistant dolomite, gypsum and sandstone ledges form sharp east-facing escarpments. Shale underlies the more gentle slopes. These rocks dip to the west-southwest at a gradient of approximately 20 to 90 feet per mile. The course of the Washita River is controlled by the underlying Pennsylvanian and Permian formation, generally following the strike of the rocks. Surficial sediments of Quaternary age alluvial, colluvial, and terrace deposits are found along the Washita River and its tributaries and adjacent slopes.

The stratigraphy of the Central Redbed Plains near the SWRP consists of Pennsylvanian dark shales, sandstones, marine limestones, and local conglomerates. In vertical section, geological formations consist of (in ascending order), the Vamoosa

Formation, the Ada Formation, the Vanoss Group, and the Oscar Group. These sediments were deposited in a marine environment. A generalized regional stratigraphic column for the Wynnewood area is shown in Figure 8. A generalized east-west regional geological cross-section of the Permian- Pennsylvanian bedrock in the Wynnewood area is shown in Figure 9.

The upper-Pennsylvanian Vamoosa formation consists mostly of shale sandstone, and chert conglomerate. This unit is subdivided into 12 members, each with coarse clastics at base overlain by shale. This unit is approximately 1000 feet thick in the Wynnewood area and occurs at a depth of approximately 2850 feet.

The upper-Pennsylvanian Ada Formation rests unconformably upon the Vanoss Formation. The Ada Formation consists mostly of shales, bituminous sandstones, and limestone conglomerates that are generally red-brown to gray. This formation is approximately 1400 feet thick in the Wynnewood area and occurs at a depth of approximately 1450 feet.

The Vanoss Formation overlies the Ada Formation in the Wynnewood area. The Vanoss consists mostly of marine shales, arkosic sandstone, and limestone conglomerate. This formation is approximately 900 feet thick in the Wynnewood area and occurs at a depth of approximately 550 feet.

The Oscar Group overlies the Vanoss in the Wynnewood area. This Group consists mostly of shales with thin beds of arkosic sandstones and conglomerates near the Arbuckle Mountains. This unit is approximately 500 feet thick in the Wynnewood area. Here the top of this group occurs at a depth of 60 feet, in subcrop beneath the alluvial deposits. A map of the bedrock geology in the Wynnewood area is shown in Figure 10.

The youngest geological strata occurring in the Wynnewood area consist of alluvial and terrace deposits of Quaternary age. The alluvial deposits occur along the present day Washita River and its flood plain. The deposits consist mostly of gravels, sands, silts, and clays that were deposited by the present day Washita River. These deposits are approximately 60 feet thick in the Wynnewood area but increase in thickness to approximately 85 feet near the river. These deposits unconformably overlie the Oscar shales that underlie the SWRP. There are also small remnant terrace deposits that occur above the present day flood plain of the Washita River. These deposits also consist of gravel, sand, silt, and clay and may reach thicknesses of 30 feet in the Wynnewood area. A map showing the extent of the alluvial and terrace deposits in the Wynnewood area is shown in Figure 11.

Site Stratigraphy

The SWRP is underlain by Quaternary-age alluvial deposits that were deposited in the present-day flood plain of the Washita River. These alluvial sediments consist of

sand, silt, clay, and gravel that were deposited in the stream channel and flood plain of the present-day Washita River. The areal extent of these alluvial sediments are shown on the surficial geological map presented in Figure 11. This map also shows the extent of older alluvial deposits near to, but above, the present day flood plain of the Washita River.

The alluvial deposits beneath the SWRP are approximately 60 feet thick. However, these deposits increase in thickness to the west and south toward the Washita River where they reach reported thicknesses of 85 feet. The deposits thin eastward from the SWRP. The alluvial deposits rest unconformably upon the Pennsylvanian bedrock (Oscar Group) which is a gray shale. The detailed stratigraphy of the SWRP area is presented in Table 3.

The detailed geology beneath the SWRP is shown on the geologic cross-sections presented in Figures 12 and 13. Figure 3 shows the location of cross section lines A - A' and B - B'. As shown by the two (2) cross-sections, the upper 5 to 10 feet consists of silt and clayey silt that is laterally continuous in the SWRP area. Discontinuous units of sandy gravel, silty sand, and sand underlie this silt layer. This silty sand, sandy gravel, and sand is likely underlain by a gray plastic clay approximately 30 feet thick which rests unconformably upon the Oscar Group (shales) in the area. The basal clay unit typically slopes gently south and westward toward the Washita River.

STRUCTURAL GEOLOGY

Two major structural features occur in Garvin County, the Anadarko basin and the Arbuckle anticline. The short south limb of the former is also the north limb of the latter, whose extension in Garvin County is largely buried beneath red bed deposits. The Anadarko basin is a depositional feature, resulting largely from settlement into a pre-existing trough.

The Arbuckle anticline is clearly the result of horizontal movement. A number of small anticlines, synclines, and domes are present in various parts of the country. Evidence of subsurface faulting is rare in the Wynnewood area. No known active faults or surface lineations are recognized in the Wynnewood area. Figure 14 shows the major structural features nearest to Garvin County and the Wynnewood Refinery.

GEOLOGIC HISTORY

Precambrian granites were emplaced as magma beneath an ancient land surface, which was later stripped away. After extensive erosion, Middle Cambrian volcanic flows were deposited on the granite in the western part of the Arbuckle Mountains. A geosyncline, or large downwarped basin, began to develop in the Arbuckle Mountains and Criner Hills area, and many thousands of feet of Cambrian- Ordovician sediments were deposited in the sea that covered the area. The geosyncline extended westward into what is now termed the Anadarko basin. In the northern part of the Arbuckle area and on the north flank of the Anadarko basin, shallow-water conditions prevailed, and the sediments in these regions were much thinner than those in the geosyncline.

The younger Silurian, Devonian, and Lower Mississippian rocks do not seem to show subdivision into geosynclinal and shelf facies, and it is known that many unconformities (surfaces of erosion or non-deposition of sediments) were developed in this region during that period.

A geosyncline was established again during Late Mississippian and Pennsylvanian time. In Early Pennsylvanian time, the Criner Hills and northern Arbuckles began to rise, with most of the movement taking place in the Criner Hills. In Late Pennsylvanian time the Arbuckle anticline (an upfolded rock structure), Tishomingo

anticline, and associated structures were formed. Many faults (displacements of rocks) occurred, and many synclines (downwarped rock structures) were formed.

The Anadarko basin remained intact during Permian time, with the Arbuckle Mountains and Criner Hills slightly emergent above sea level. Throughout the Triassic, Jurassic, and Cretaceous periods, the entire area was probably close to or above sea level, undergoing erosion.

With inundation by an Early Cretaceous sea from the south, the rocks of the Dissected Coastal Plain were deposited. The entire area was gently uplifted after Cretaceous time, giving a regional, monoclinical, southward dip to the Cretaceous beds and imparting to them many local structures. Large rivers flowed over the region from the northwest, depositing gravel and sand during the Pleistocene ice ages. Although the continental glaciers of the ice ages did not advance as far south as Oklahoma, their repeated advances and retreats greatly influenced the flow in the rivers of southern Oklahoma. As the glaciers advanced, stream flow was reduced, and the rivers deposited sediments in their channels. The flow increased during glacial retreats because of the melt water made available, and the previously deposited sediments were eroded. Repetitions of this sequence resulted in the formation of many terrace levels along the present streams.

REGIONAL HYDROGEOLOGY

Most of the groundwater available in the Wynnewood area is from alluvial deposits along the Washita River. These deposits may reach thicknesses of up to 100 feet and may yield from 100 to 1200 gallons per minute (gpm). The quality of groundwater is of the calcium-magnesium bicarbonate type and contains dissolved solids of 500 to 1000 mg/L. The chemical quality of the water is generally fair to good. Several water wells are completed within these deposits in the Wynnewood area; however, use of this aquifer has dropped considerably due to the presence of readily available, better quality surface water. The unconsolidated deposits along the major tributaries of the Washita River are generally too thin or too fine grained for development.

The recharge to this unit occurs over the areas of outcrop along the Washita River, where the surficial clays are minimal or absent and where the permeable sands crop out at the surface. General groundwater movement in these alluvial deposits is toward the present day Washita River which is the regional discharge point for this aquifer. Local discharge from this aquifer may occur from pumpage of wells, evapotranspiration, leakage between stratigraphic horizons, and discharge to major tributaries of the Washita River. Groundwater in this aquifer is estimated to flow at rates from 10 feet/year to more than 100 feet/year in the thicker and more permeable deposits.

The underlying bedrock in the Wynnewood area consists of Pennsylvanian age shales, thin sandstone beds, and conglomerate limestone. These units typically yield only 1 to 2 gpm to drilled wells - enough water for minimum domestic needs only. The quality of the groundwater varies from good to saline. Typically the deeper the well, the poorer the quality of water. Groundwater typically moves down-dip in these formations at rates of 1 to 10 feet/year. These formations are recharged in the areas of outcrop, although recharge is small due to the low permeability of the shales. The depth to the base of the fresh groundwater (<10,000 mg/L dissolved solids) occurs between depths of 500 to 1000 feet in this area. This is within the Oscar Group or the Vanoss Group. The generalized water-bearing properties for the Pennsylvanian bedrock units is shown in Figure 8.

Site Hydrogeology

The SWRP area is underlain by alluvial sediments deposited in the present-day flood plain of the Washita River. These deposits comprise a major aquifer in this region of Oklahoma.

Detailed stratigraphic test borings indicate that the alluvial silt, sand and gravel deposits that underlie the SWRP are continuous over the site. This aquifer ranges in thickness from approximately 20 to 30 feet and is underlain by a low permeability clay.

The groundwater flow system of this stratigraphic unit has been investigated by installing several groundwater monitoring wells and piezometer wells completed to depths ranging from 15 to 20 feet below ground level. These wells are screened within the saturated interval of the alluvial deposits. The screened interval typically extends above the top of the saturated zone to allow for seasonal or climatic fluctuations. The locations of the wells were chosen based upon stratigraphy and local and regional flow conditions. Lithology logs and well construction diagrams for these wells are presented in Appendix A-1. Analytical data for monitor wells SMW-5 and SMW-9 are presented in Appendix A-2.

Figures 15 and 16 are potentiometric surface maps of the SWRP area on 1/29/92 and 4/23/92, respectively. The maps show that groundwater flow in the SWRP area is toward the south. Figures 17 and 18 are depth to groundwater maps for the SWRP area for 1/29/92 and 4/23/92, respectively. These maps show that the depth to groundwater varies from approximately 9 to 11 feet below natural ground surface in the SWRP area; and the depth to groundwater generally decreases toward the west and south. Groundwater hydrographs for SWRP wells SMW-4, SMW-5, and SMW-6 are shown on Figures 19, 20, and 21, respectively. The groundwater in the SWRP area shows a maximum fluctuation of approximately six (6) feet over the period of record (1989 to 1992).

Recharge to the alluvial aquifer in the area around the SWRP occurs mainly where the more permeable sands and gravel outcrop at the surface. The groundwater in this

aquifer is really recharged over its entire area with the outcropping sand and gravels accepting recharge and the surficial clays and silts inhibiting recharge. Groundwater is discharged from this aquifer through pumping from wells, evapotranspiration, and discharge to the Washita River and its larger tributaries.

The vertical movement of groundwater in the SWRP area is greatly restricted by the low-permeable clays which underlie this aquifer. This results in little vertical mixing of the water contained in the alluvial flood plain deposits and deeper bedrock strata. Because of this restricting thick clay layer, the hydraulic interconnection of the shallow alluvial deposits and the deeper bedrock strata is considered to be insignificant.

Aquifer tests were conducted on wells in the vicinity of the SWRP (wells LMW-2 through LMW-6), which penetrated the entire saturated thickness of the Alluvial Aquifer. The hydraulic coefficients determined from these aquifer tests are noted in Table 4. As noted, the transmissivities ranged from 760 to 23,300 gpd/ft with an average of 9440 gpd/ft. The horizontal hydraulic conductivities ranged from 38 to 1165 gpd/ft² or 1.79×10^{-3} cm/sec to 5.49×10^{-2} cm/sec. The storage coefficient was estimated at 0.1 for this strata.

Using these hydraulic conductivity values for the alluvial deposits, the hydraulic gradient (1/29/92) across the SWRP area as obtained from the potentiometric surface

map presented in Figure 15, and choosing conservative effective porosities of 0.20, the maximum groundwater flow velocity can be calculated through the use of the following equation based upon Darcy's law:

$$V = \frac{K_h I}{\Theta}$$

Where V = average groundwater velocity, feet/day

K_h = average horizontal hydraulic conductivity, feet/day

I = hydraulic gradient, dimensionless; and

Θ = effective porosity, dimensionless

Using the following conservative values for the alluvial flood plain deposits:

$$K_h = 472 \text{ gpd/ft}^2 \text{ or } 62.09 \text{ feet/day}$$

$$I = .00375$$

$$\Theta = 0.20$$

The maximum groundwater velocity would be 1.16 feet/day (425 feet/year). Laboratory vertical permeability tests were conducted on the surficial clays at the Land Treatment Facility, located immediately west of the SWRP. These permeability tests were conducted on clay samples using a filtered leachate from the sludges applied to the nearby Land Treatment Facility. The permeabilities of these surficial

clays ranged from 1.64×10^{-4} cm/sec to 4.46×10^{-7} cm/sec with an average permeability of 6.23×10^{-6} cm/sec. Using the method outlined in the RCRA Draft Permit Writer's Manual (Geotrans, 1983), the travel time for liquids migrating from a facility to the uppermost aquifer can be estimated using the same equation based upon Darcy's Law:

$$V = \frac{K_v I}{\Theta}$$

Where V = Interstitial velocity, feet/day

K_v = Vertical hydraulic conductivity (or permeability), ft/day

$I = h/l$: where h = difference in hydraulic head between facility and uppermost aquifer (feet),

and l = length of flow path (feet)

Θ = effective porosity

Using the following average values for the clays at the Land Treatment Facility:

$$K_v = 1.77 \times 10^{-2} \text{ feet/day}$$

$$\Theta = 0.05$$

$$l = 1.0, h = 1$$

Then the average vertical interstitial velocity is estimated at 0.354 feet/day. The vertical migration through the surficial clay layer is the most likely pathway for waste

migration into the uppermost water-bearing stratum in the Land Treatment Facility and SWRP area.

A well inventory was conducted in the area to identify water wells, oil and gas production wells and disposal wells within 1 mile of the SWRP. The principal source of data for this inventory was data on-file with the Oklahoma Water Resources Board (well records). This survey identified 26 water wells (most of which are abandoned), 2 disposal wells, 5 plugged and abandoned oil wells and 6 producing wells within a 1-mile radius of the SWRP. The location of these wells have been shown on Figure 22 and a tabulation of these wells presented in Table 5.

TABLES

TABLE 1

PAULS VALLEY PRECIPITATION
MONTHLY AND ANNUAL TOTALS AND LONG-TERM MEANS

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
58	2.28	1.47	2.71	2.56	4.08	3.59	3.31	1.44	0.86	0.20	2.17	0.99	25.68
59	0.39	1.30	1.14	2.62	4.53	1.72	2.77	2.73	6.72	5.30	1.84	2.96	34.03
60	2.11	2.10	1.35	2.61	8.99	1.15	4.60	3.43	3.71	7.36	0.17	4.73	42.33
61	0.13	1.60	4.68	0.60	4.25	4.19	3.46	0.99	6.57	2.83	3.17	1.21	33.70
62	0.38	1.16	1.48	2.86	2.92	6.88	1.38	0.17	3.42	5.44	2.40	3.12	31.63
63	0.14	0.00	4.33	2.58	1.11	0.75	2.01	2.19	1.28	0.36	2.77	1.47	19.02
64	0.86	1.73	2.89	2.55	6.74	1.74	0.37	6.68	4.01	0.83	6.61	0.86	35.90
65	2.35	1.05	1.25	1.90	4.27	2.78	0.80	3.48	3.65	2.02	0.53	0.54	24.64
66	0.96	1.51	0.74	4.12	0.86	1.36	3.73	4.23	2.50	0.98	1.17	0.94	23.12
67	0.08	0.10	1.22	6.35	6.70	3.24	3.37	0.58	4.18	3.22	0.57	1.47	31.09
68	3.88	1.87	2.59	2.18	7.90	6.22	2.54	3.48	6.38	2.46	5.25	1.56	46.34
69	1.84	3.33	2.83	4.10	3.13	2.81	2.31	3.37	2.59	3.91	0.44	2.86	33.54
70	0.18	1.23	2.01	5.02	2.12	3.78	1.83	1.47	5.99	11.00	1.10	0.45	36.20
71	2.47	1.48	0.45	2.80	3.37	3.14	2.65	1.66	1.94	5.41	0.35	5.20	30.94
72	0.37	1.19	0.48	3.37	4.51	1.43	1.02	2.44	4.30	7.88	3.80	0.72	31.54
73	3.41	1.38	3.98	6.50	4.00	7.11	2.09	0.19	7.24	5.33	5.49	0.56	47.30
74	0.25	1.77	1.61	4.33	3.75	4.66	1.23	7.11	6.74	6.95	1.33	1.23	40.98
75	2.42	3.11	5.45	3.54	9.19	4.93	6.98	1.40	3.75	0.66	2.03	1.59	45.06
76	0.01	0.48	3.23	5.32	3.56	1.21	1.86	2.22	2.28	3.33	0.45	1.73	25.70
77	1.45	1.61	2.95	2.89	13.35	1.91	1.35	4.20	2.14	2.32	1.10	0.19	35.48
78	1.00	2.74	1.99	2.94	8.14	3.96	0.78	0.54	1.37	0.99	3.28	0.74	28.50
79	1.72	0.59	3.10	5.08	3.64	9.20	2.63	2.34	1.10	3.45	4.26	1.75	38.88
80	1.28	1.36	1.27	1.74	9.61	2.10	0.00	0.29	3.68	1.80	1.73	2.30	27.16
81	0.07	2.51	2.85	1.52	6.04	5.51	3.48	2.59	2.36	9.58	2.06	0.55	39.13
82	1.70	1.74	1.85	1.80	14.33	5.09	3.50	0.84	1.19	1.95	4.22	2.78	40.99
83	3.45	0.78	3.15	3.33	7.78	3.14	0.09	3.14	2.71	9.15	1.41	0.61	38.74
84	0.36	1.22	3.00	1.90	1.92	6.35	0.32	1.28	1.60	4.89	2.43	5.78	31.06
85	2.36	4.43	5.34	4.74	2.64	8.19	0.93	2.23	7.77	8.53	2.34	0.73	50.25
86	0.00	1.87	1.83	3.74	10.08	2.43	0.72	2.12	9.32	3.15	4.80	1.59	41.65
87	2.72	4.91	2.83	0.94	12.56	4.06	4.09	1.22	4.74	2.50	3.14	5.81	49.53
MEAN:													
	1.35	1.72	2.49	3.22	5.87	3.82	2.21	2.33	3.87	4.13	2.41	1.90	35.34

TABLE 2

PAULS VALLEY MEAN TEMPERATURES (1958-1987)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
MEAN	38.5	42.5	52.8	63.2	70.7	78.5	83.4	82.5	74.8	64.0	51.8	42.0	62.2
MAX	50.4	54.7	65.5	75.8	82.4	89.9	95.6	95.2	86.7	77.1	63.8	53.5	74.4
MIN	26.5	30.3	40.0	50.6	58.9	67.1	71.2	69.8	62.9	50.9	39.7	30.6	50.0

**TABLE 3: SITE-SPECIFIC STRATIGRAPHIC COLUMN FOR
THE STORM WATER RETENTION POND AREA AND
THE LAND TREATMENT AREA,
WYNNEWOOD REFINERY**

GEOLOGIC AGE	GEOLOGIC FORMATION	APPROX. THICK- NESS	LITHOLOGIC DESCRIPTION
QUATERNARY	WASHITA RIVER ALLUVIAL DEPOSITS	0 - 2 FEET	BROWN TO BLACK CLAYEY AND SILTY LOAM TOPSOIL, SANDY, ORGANIC
		0 - 9 FEET	BROWN TO REDDISH-BROWN SILTY, SANDY CLAY
		6 - 14 FEET	REDDISH TO ORANGE-BROWN SILTY TO VERY SILTY FINE SAND. GRADES COARSER WITH DEPTH TO MEDIUM SAND
		10 - 18 FEET	REDDISH TO ORANGE-BROWN MEDIUM TO COARSE GRAINED SAND, SLIGHTLY SILTY. GRADES COARSER WITH DEPTH, BECOMING GRAVELLY WITH UP TO 30% FINE TO COARSE GRAVEL
		1 - 5 FEET	REDDISH-BROWN TO ORANGE BROWN PLASTIC CLAY, WITH GRAVEL AND COARSE SAND LENSES
PENNSYL- VANIAN	OSCAR GROUP	APPROX. 30 FEET	OSCAR GROUP: SILTY CLAY, GRAY & RED- BROWN MOTTLED, DENSE, HARD, STIFF (WEATHERED SHALE)
		APPROX. 500 FEET	OSCAR GROUP SHALE, RED- BROWN TO GRAY, WITH THIN BEDS OF ARKOSIC SANDSTONE AND LIMESTONE CONGLOMERATE

**TABLE 4: AQUIFER COEFFICIENTS FOR THE WYNNEWOOD STORM
WATER RETENTION POND AREA; ALLUVIAL AQUIFER;
DETERMINED BY "SLUG" METHOD**

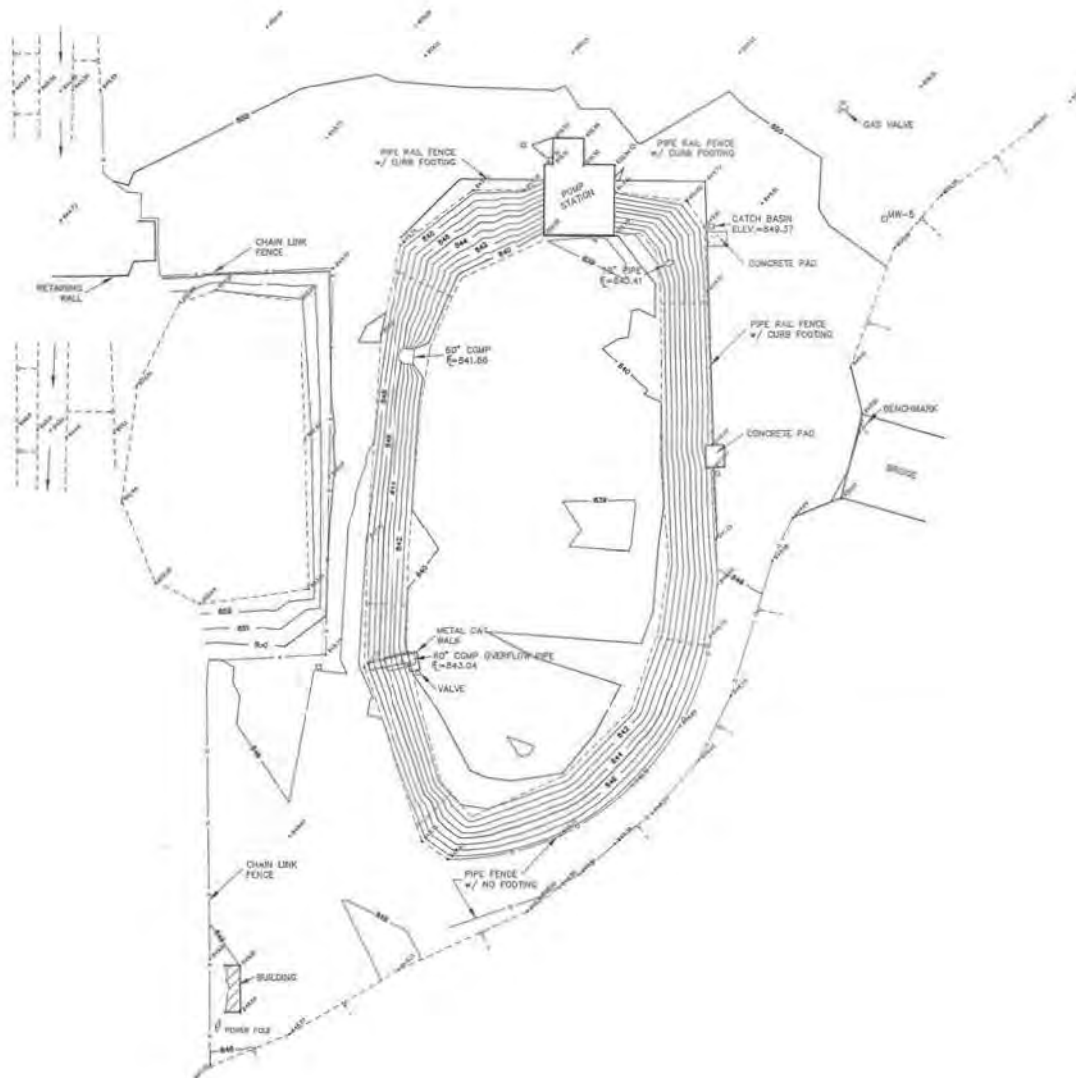
MONITOR WELL	HYDRAULIC CONDUCTIVITY	TRANSMISSIVITY
LMW-2	684 gpd/ft ²	13,680 gpd/ft
LMW-3	1165 gpd/ft ²	23,300 gpd/ft
LMW-4	85 gpd/ft ²	1,700 gpd/ft
LMW-5	38 gpd/ft ²	760 gpd/ft
LMW-6	388 gpd/ft ²	7,760 gpd/ft
AVERAGE	472 gpd/ft ²	9,440 gpd/ft

TABLE 5:

SUMMARY OF WATER, OIL AND GAS AND DISPOSAL WELLS WITHIN
ONE HALF-MILE OF THE KMRC WYNNEWOOD LAND TREATMENT FACILITY
AND STORM WATER RETENTION POND

WELL #	OWNER	WELL DEPTH	DATE DRILLED	WELL TYPE	PURPOSE OR USE
1	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
2	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
3	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
4	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
5	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
6	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
7	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
8	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
9	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
10	SMITH	UNKNOWN	UNKNOWN	WATER	UNKNOWN
11	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
12	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
13	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
14	TRIPP	UNKNOWN	UNKNOWN	WATER	UNKNOWN
15	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
16	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
17	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
18	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
19	UNKNOWN	UNKNOWN	UNKNOWN	WATER	UNKNOWN
20	DON SHARBER	UNKNOWN	-1955	WATER	IRRIGATION
21	KERR-McGEE	15	BEFORE 1922	WATER	NOT IN USE
22	KERR-McGEE	UNKNOWN	BEFORE 1922	WATER	NOT IN USE
23	KERR-McGEE	18	BEFORE 1922	WATER	NOT IN USE
24	KERR-McGEE	UNKNOWN	BEFORE 1922	WATER	NOT IN USE
25	KERR-McGEE	15	BEFORE 1922	WATER	NOT IN USE
26	KERR-McGEE	36	MAR 1950	WATER	NOT IN USE
1	KERR-McGEE	4400	1976	DISPOSAL	NEVER USED
2	B & A DISPOSAL	4232	UNKNOWN	DISPOSAL	UNKNOWN
1	DANIELSEL	UNKNOWN	UNKNOWN	OIL	PLUG & ABAND.
2	SHIRLEYON	UNKNOWN	UNKNOWN	OIL	PLUG & ABAND.
3	B. ANDERSON	UNKNOWN	UNKNOWN	OIL	PLUG & ABAND.
4	WITT	UNKNOWN	UNKNOWN	OIL	PLUG & ABAND.
5	UNKNOWN	UNKNOWN	UNKNOWN	OIL	PLUG & ABAND.
1	UNKNOWN		UNKNOWN	OIL	PRODUCING
2	UNKNOWN		UNKNOWN	OIL	PRODUCING
3	UNKNOWN		UNKNOWN	OIL	PRODUCING
4	UNKNOWN		UNKNOWN	OIL	PRODUCING
5	MURPHEY	UNKNOWN	UNKNOWN	OIL	PRODUCING
6	UNKNOWN		UNKNOWN	OIL	PRODUCING

DRAWINGS



- LEGEND**
- 848 — EXISTING DRAINING CONTOUR (1' INTERVAL)
 - - - - - EXISTING SPOT ELEVATION
 - - - - - TOP OF EXISTING SLOPE
 - - - - - TOE OF EXISTING SLOPE

BENCHMARK:
 "X" CUT IN CONCRETE AT NORTHWEST CORNER OF BRIDGE
 ASSUMED DATUM ELEVATION = 850.57

Sheet Title:	EXISTING TOPOGRAPHY	Client:	KERR-McGEE REFINING CORP.
Document Title:	SURFACE IMPOUNDMENT CLOSURE PLAN	Location:	WYNEWOOD, OKLAHOMA
ROBERTS/SCHORVICK & ASSOCIATES, INC. Environmental Consultants 808 East Avenue, Suite 100 Tulsa, Oklahoma 74101		PREPARED BY: WBS DATE: 1988 CHECKED BY: WBS DATE: 1988 DESIGNED BY: WBS PROJECT NO.: 00400-1 0312401 M13	

FIGURES

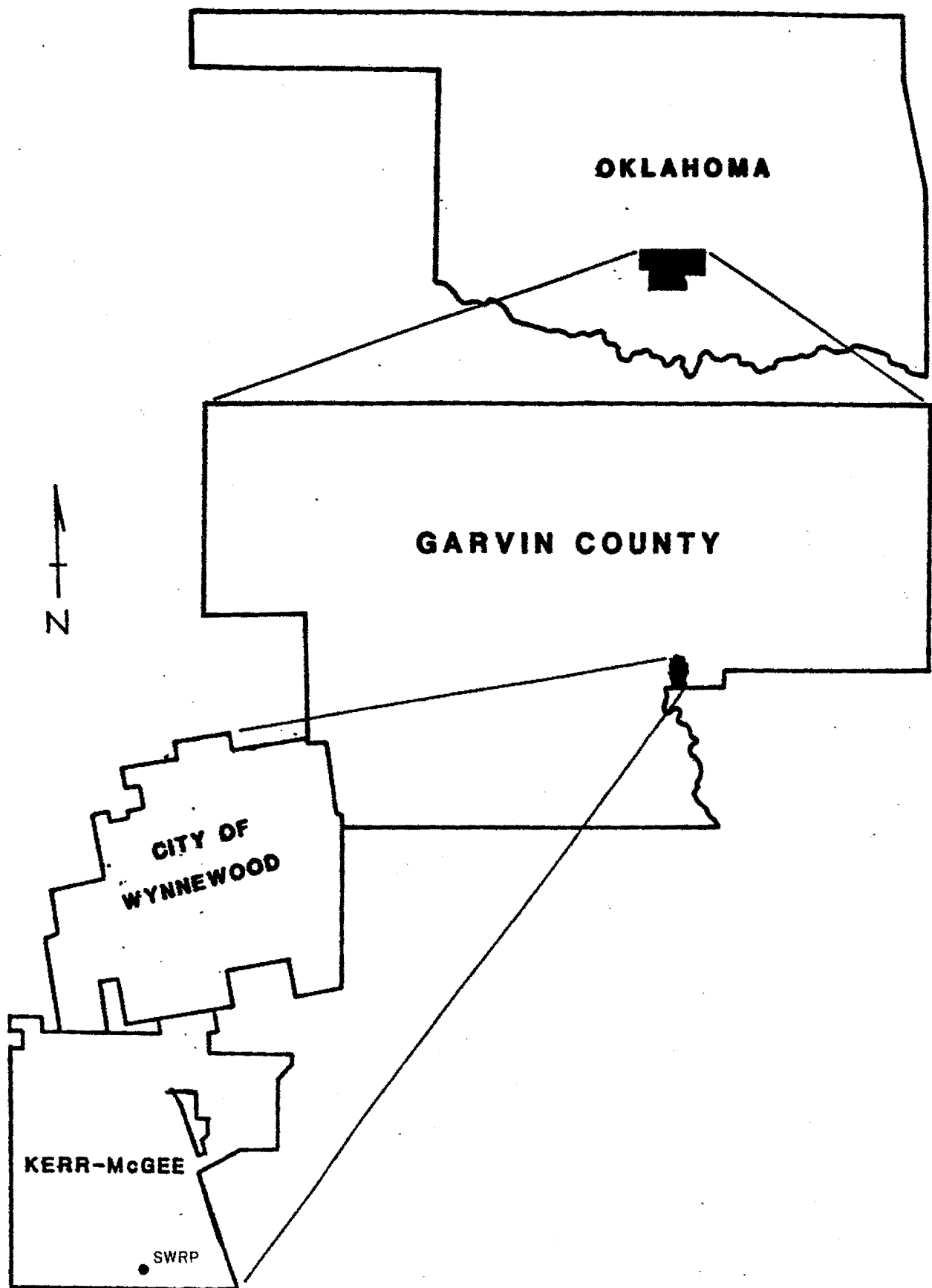
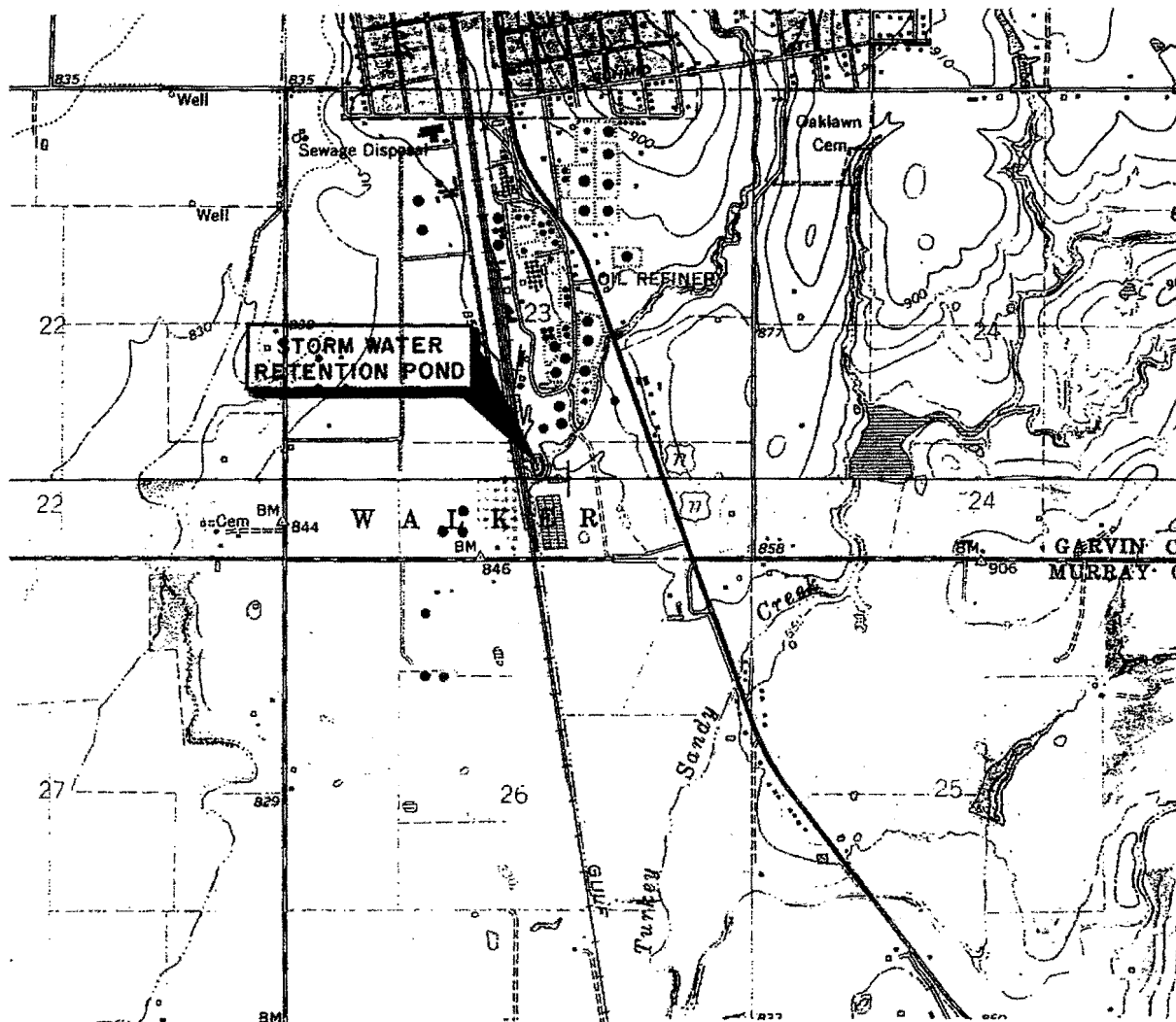


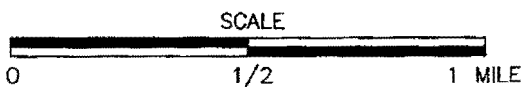
FIGURE 1: INDEX MAP OF WYNNEWOOD REFINERY,
WYNNEWOOD, OK

R 1 E



T
2
N

AFTER U.S.G.S. 7.5 MIN. TOPO. QUAD., PAULS VALLEY, OK, PHOTO REVISED 1980
AFTER U.S.G.S. 7.5 MIN. TOPO. QUAD., JOY, OK, PHOTO REVISED 1980



OKLAHOMA

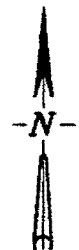
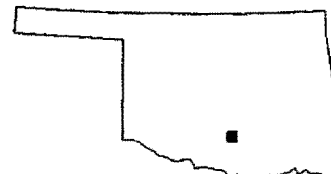
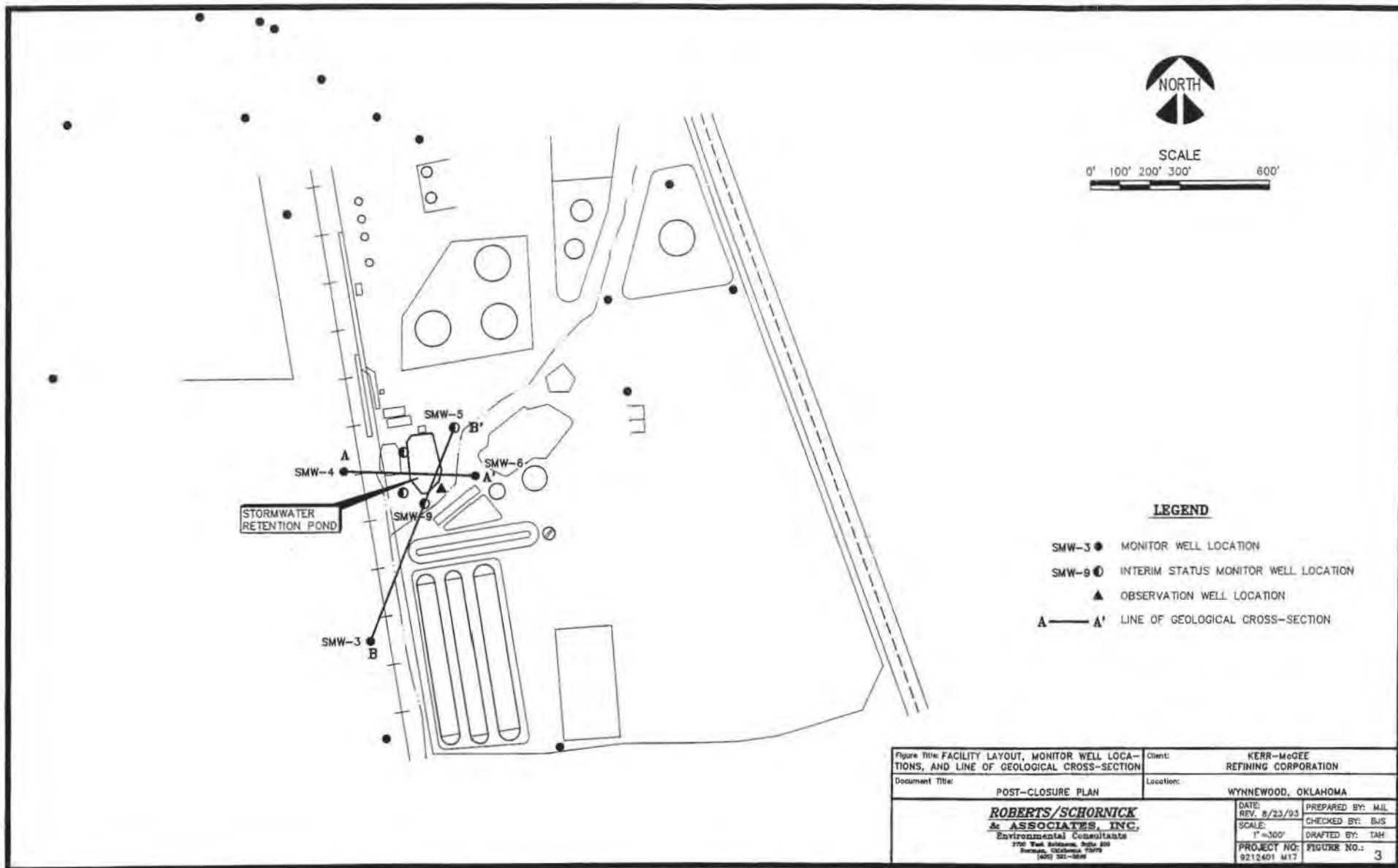


Figure Title: SITE LOCATION AND TOPOGRAPHIC MAP		Client: KERR-McGEE REFINING CORPORATION	
Document Title: POST-CLOSURE PLAN		Location: WYNNEWOOD, OKLAHOMA	
ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants 3700 West Robinson, Suite 200 Norman, Oklahoma 73072 (405) 321-3695		DATE: 11/17/92	PREPARED BY: MJL
		SCALE: AS SHOWN	CHECKED BY: BJS
		PROJECT NO: 92124 F01	DRAFTED BY: BDR
		FIGURE NO.:	2



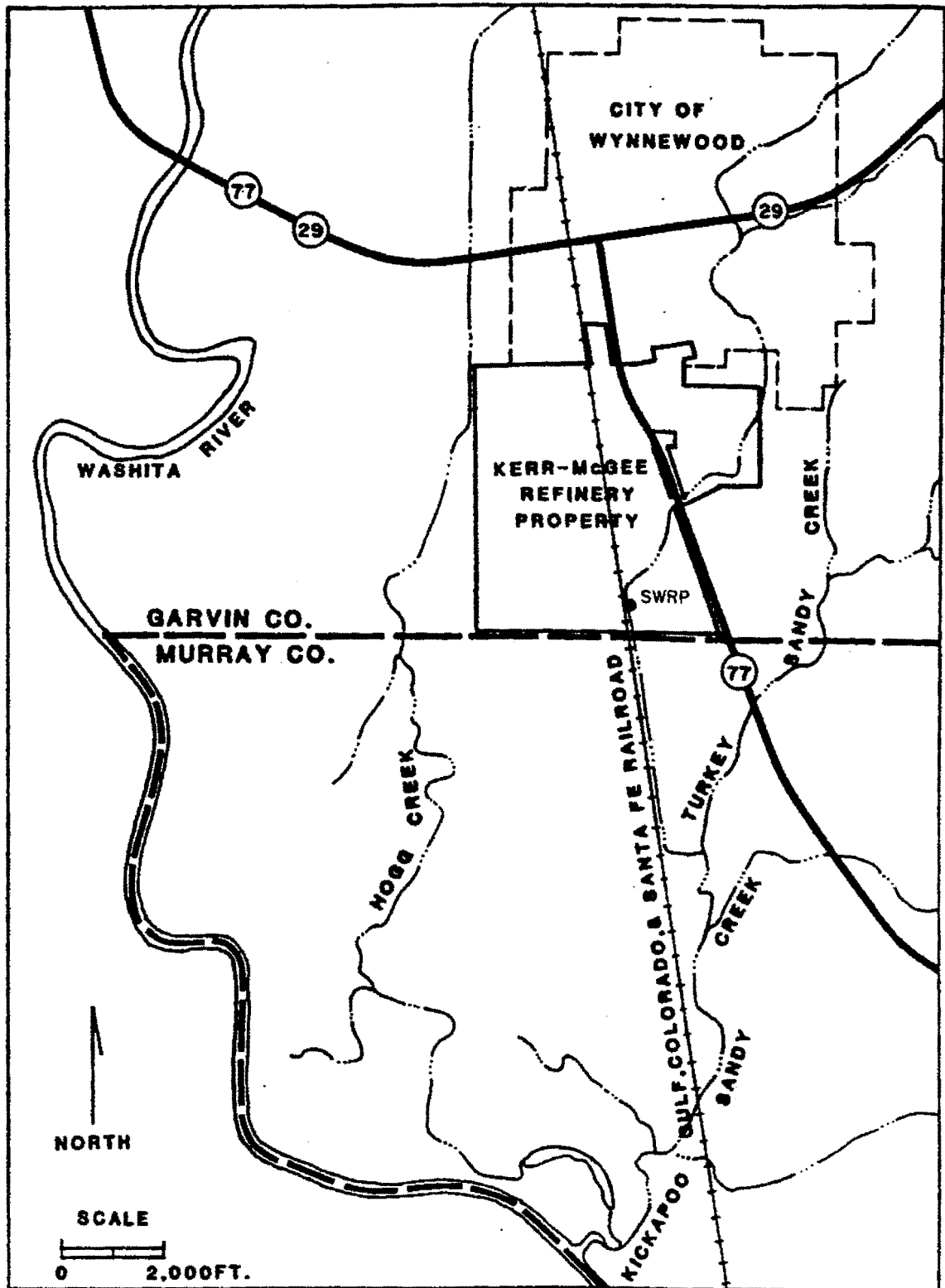
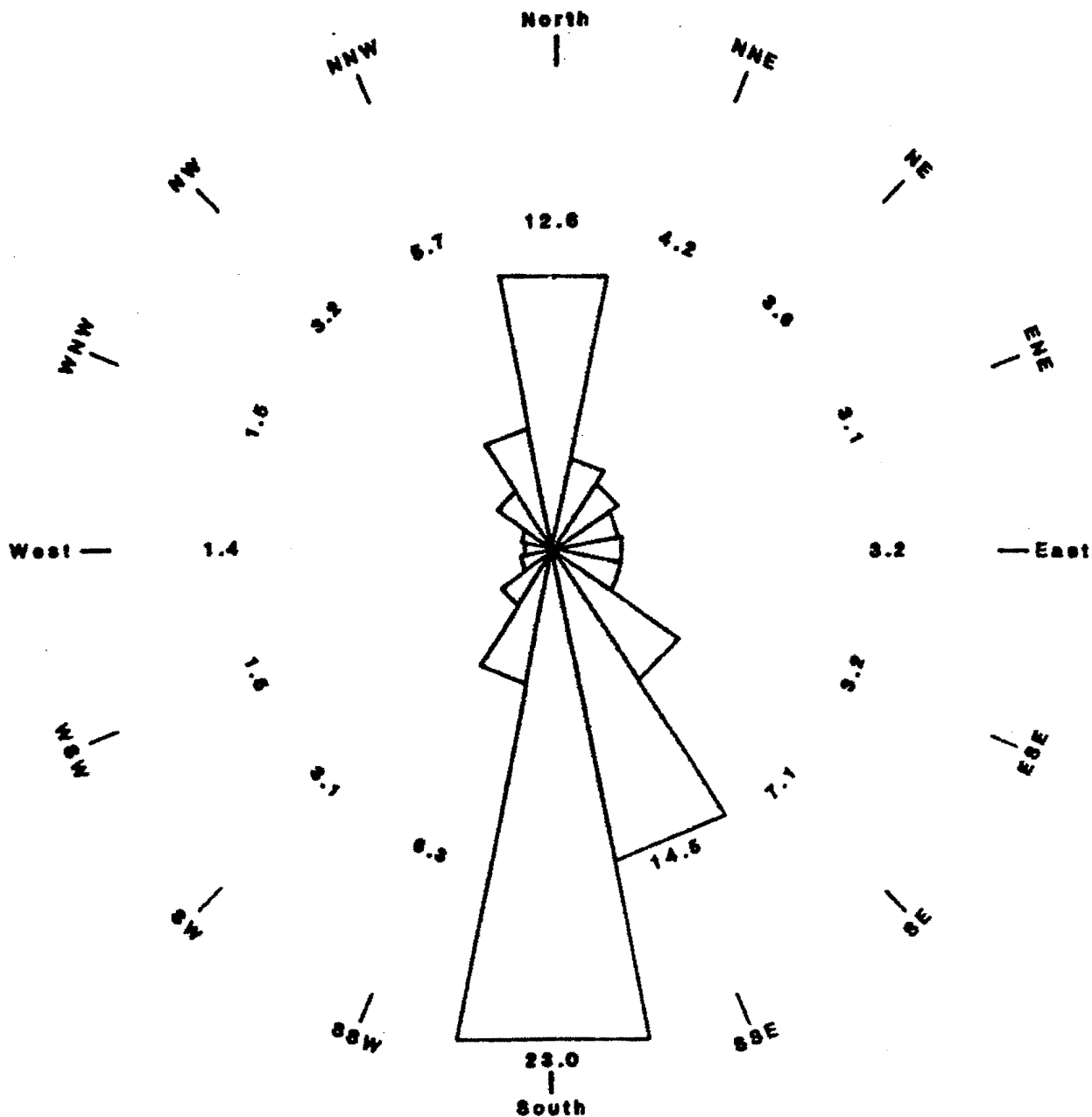


FIGURE 4:

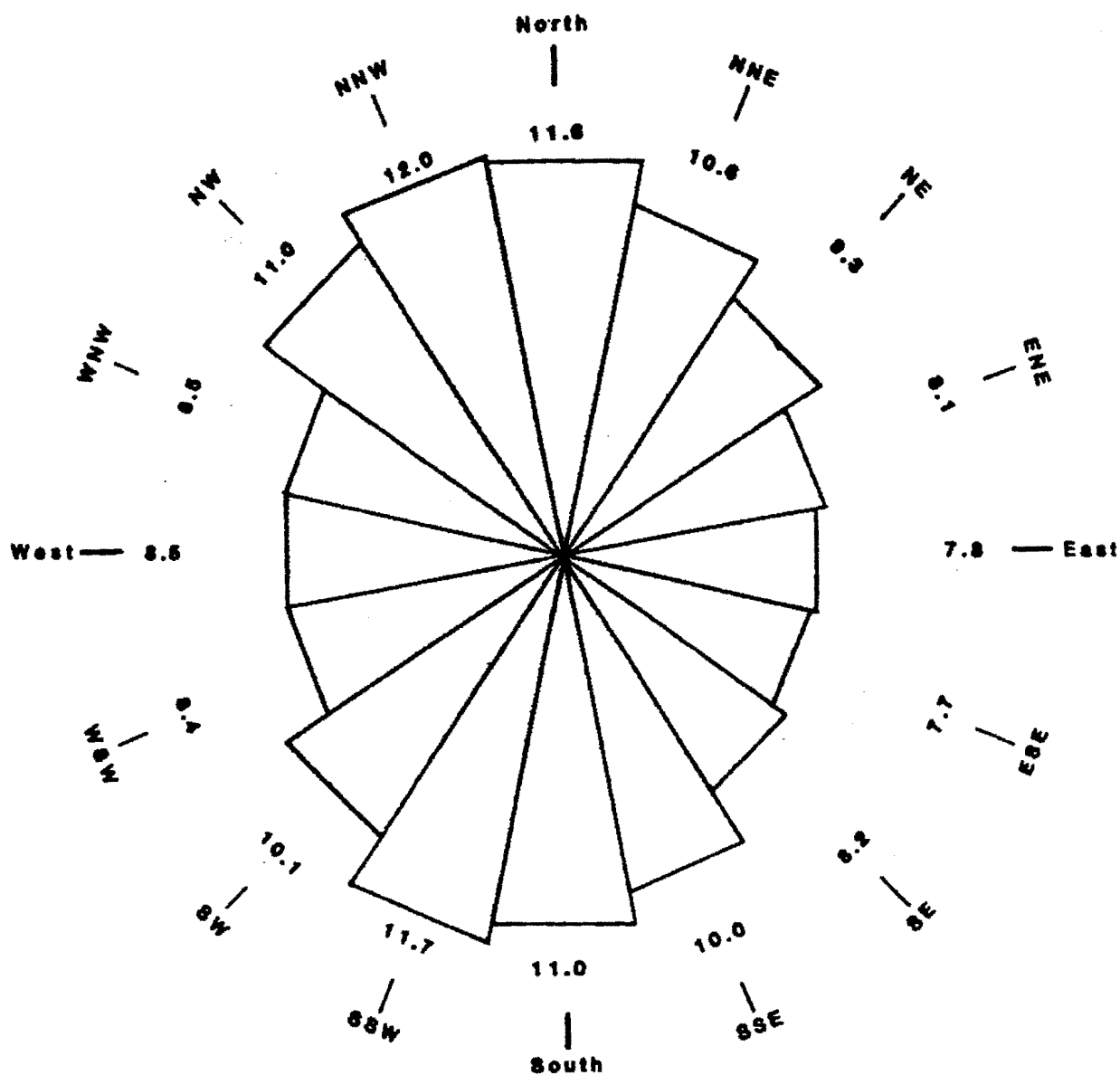
**LOCATION OF SURFACE WATER DRAINAGE IN
THE WYNNEWOOD AREA**



WIND ROSE SHOWING MEAN ANNUAL DIRECTION
(PERCENT OF TIME), OKLAHOMA CITY, OKLAHOMA.

SOURCE: TABLE 11A (ANNUAL), AIRPORT CLIMATOLOGICAL
SUMMARY, WILL ROGERS WORLD AIRPORT, NATIONAL
OCEANIC & ATMOSPHERIC ADMINISTRATION.

FIGURE 5



WIND ROSE SHOWING MEAN ANNUAL WIND SPEED (KNOTS)
OKLAHOMA CITY, OKLAHOMA.

SOURCE: TABLE 11A (ANNUAL), AIRPORT CLIMATOLOGICAL
SUMMARY, WILL ROGERS WORLD AIRPORT, NATIONAL
OCEANIC & ATMOSPHERIC ADMINISTRATION.

FIGURE 6

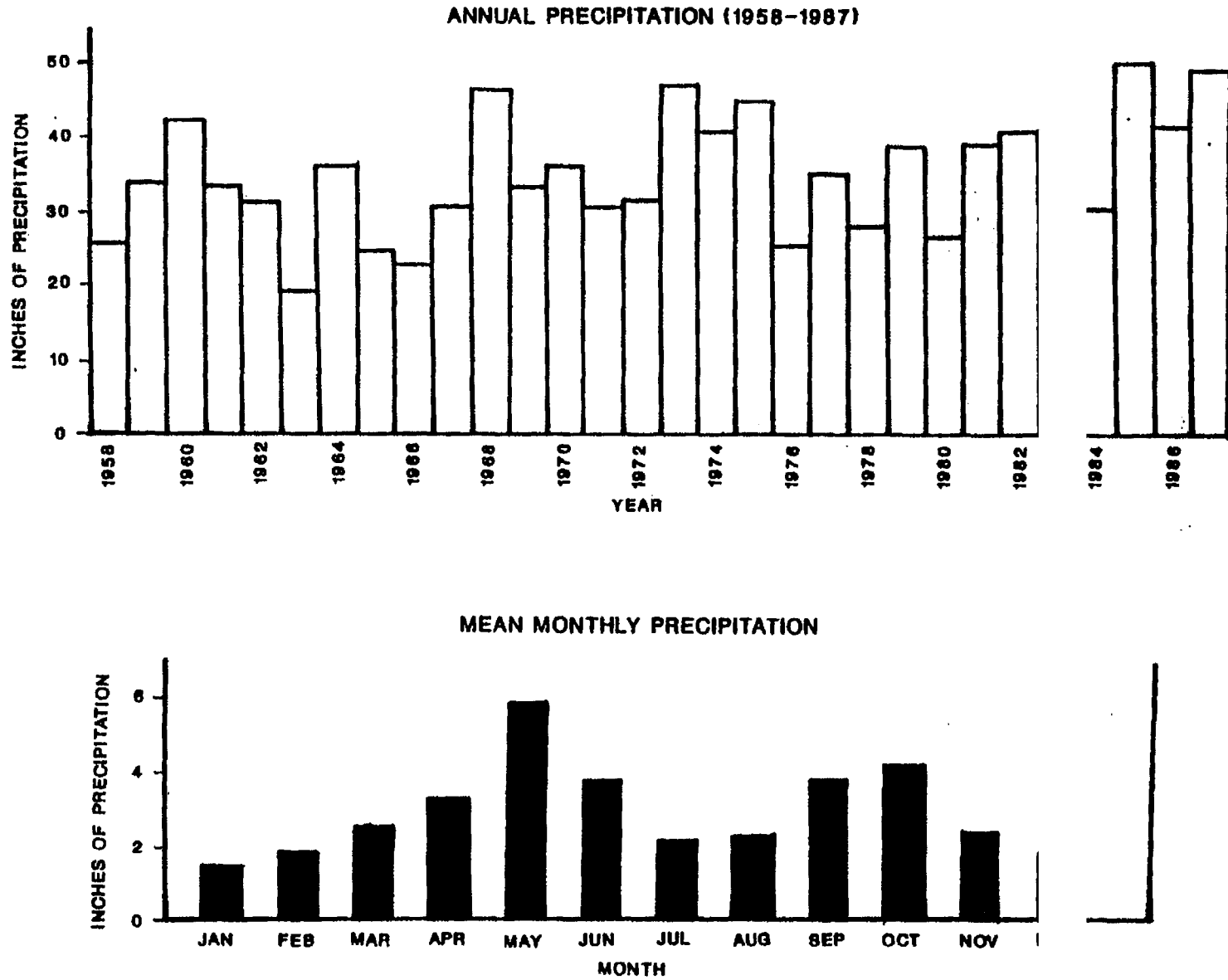


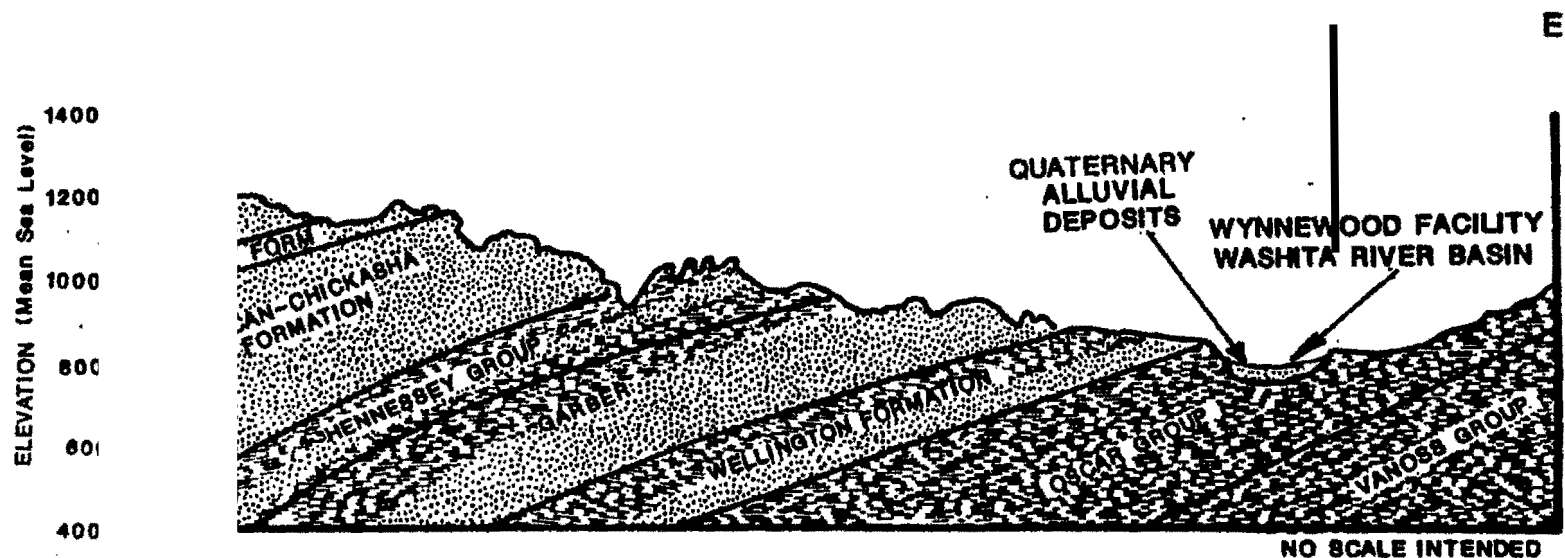
FIGURE 7: PAULS VALLEY PRECIPITATION DATA, RCRA FACILITY INVESTIGATION

/YNNEWOOD, OK

AGE	SYSTEM	STRATIGRAPHIC UNITS	ESTIMATED THICKNESS, feet	LITHOLOGY	WATER-BEARING PROPERTIES
RECENT	QUATERNARY	ALLUVIAL & TERRACE DEPOSITS	80±	Gravel, sand, silt, and clays in alluvial and terrace deposits adjacent to Washita River. Thickness ranges from 8 to 85 feet and averages 80 feet in the Wynnewood area.	alluvial and terrace deposits along Washita River may reach 100 feet thick. Wells generally yield 10 to 100 gpm. Water quality generally fair to good. Dissolved solids range from 10 to 1000 mg/L.
PALEOZOIC	UPPER PENNSYLVANIAN	OSCAR GROUP	500±	Predominantly shales, red-brown to gray with thin sandstone and limestone beds present.	Typically low permeability shales. Variable water quality, but typically fair to poor. Yield only small quantities of water to wells.
		VANOSS GROUP	900±	Predominantly shales, maroon, with thin beds of arkose sandstones and limestone conglomerate.	Probably will yield only small quantities of poor quality water to drilled wells.
		ADA FORMATION	1400±	Shales, red brown to gray with bituminous sandstones and limestone conglomerate.	Probably will yield only small quantities of poor quality water to drilled wells.
		YAMOOSA FORMATION	1000±	Shale, sandstone, and chert conglomerate, red-brown to buff fine- to coarse-grained sandstone.	Probably will yield only small quantities of poor quality water to drilled wells.

FIGURE 8: REGIONAL STRATIGRAPHIC COLUMN FOR OK AREA (Modified after Hart, 1974)

E WYNNEWOOD,



DSTONE

LE

FIGURE 9: GENERALIZED EAST-WEST REGIONAL GEOLOGICAL CROSS-SECTION OF PERMIAN-PENNSYLVANIA BEDROCK UNITS IN THE WYNNEWOOD AREA (Modified After Oklahoma Water Resources Board, 1968)

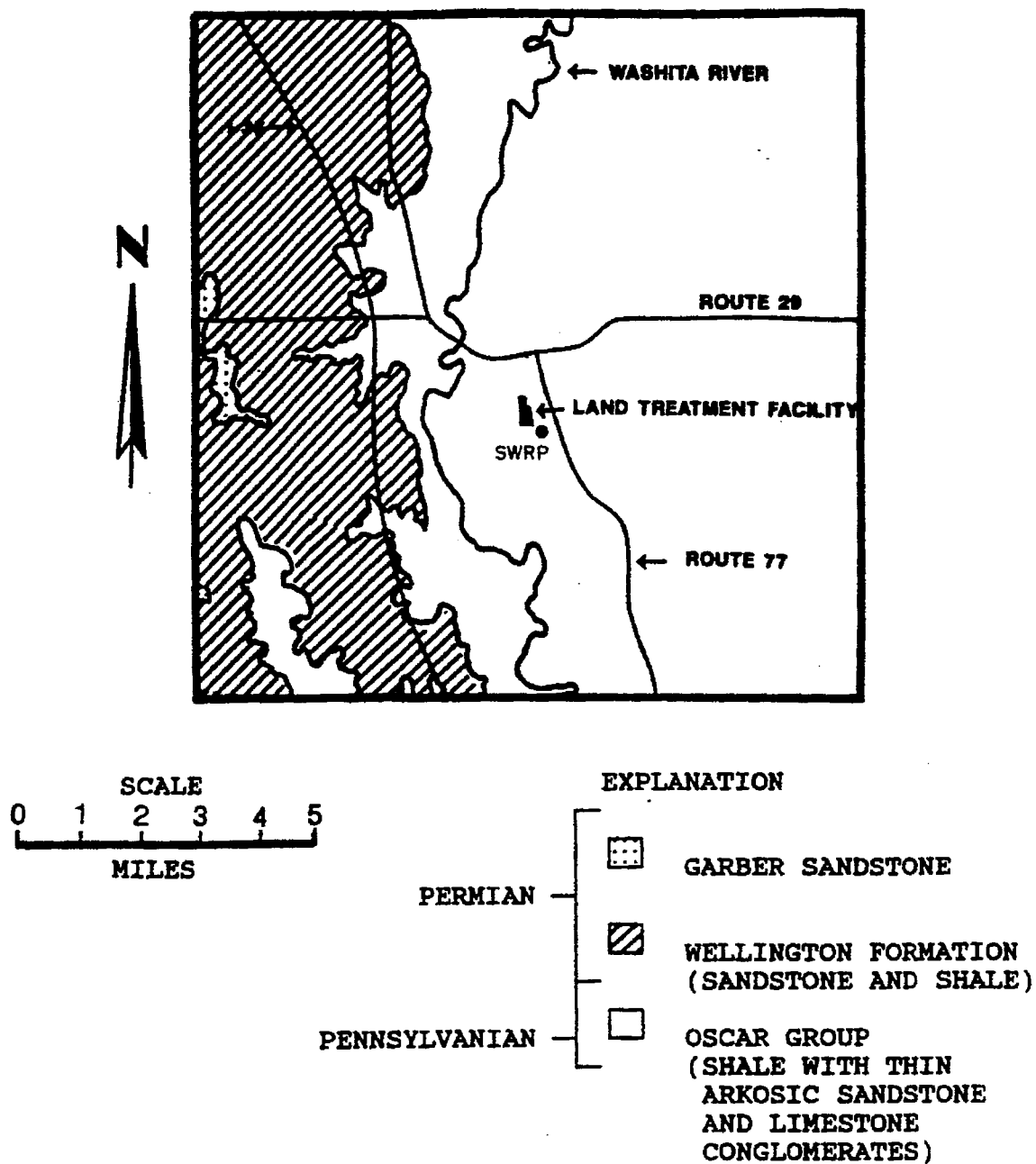


FIGURE 10

MAP OF THE BEDROCK GEOLOGY IN THE WYNNEWOOD AREA
(Modified after Hart, 1974)

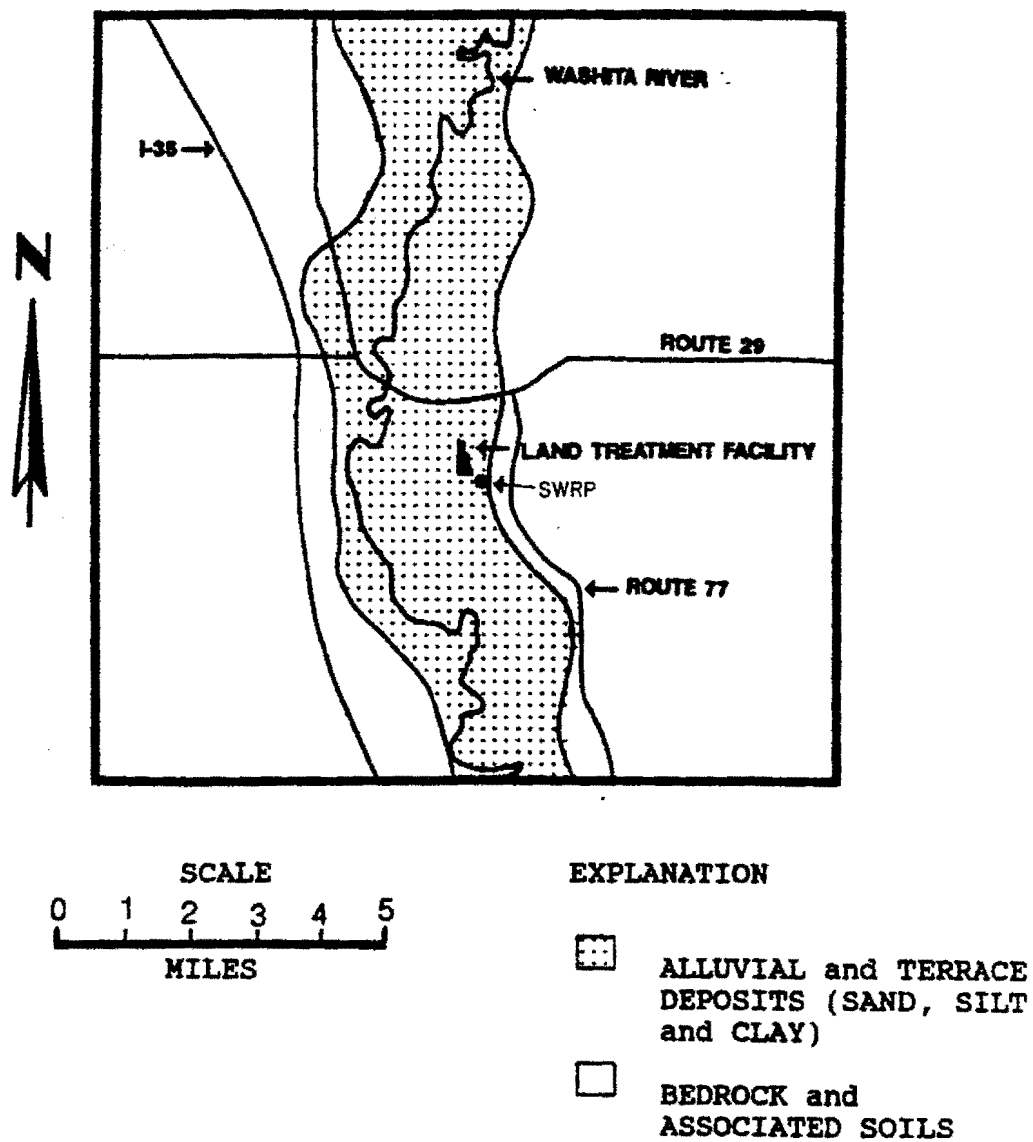
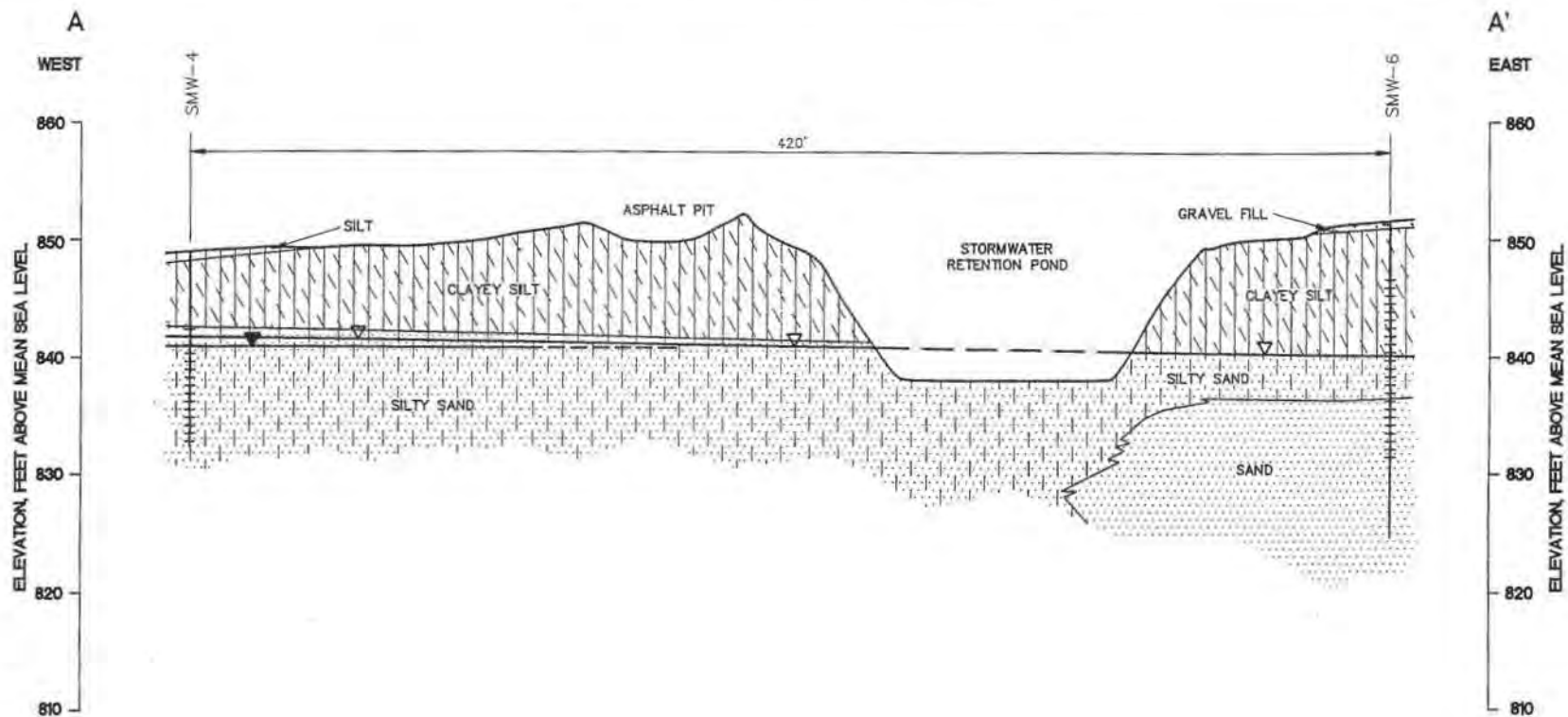


FIGURE 11

MAP SHOWING EXTENT OF ALLUVIAL AND TERRACE DEPOSITS
OF QUATERNARY AGE IN THE WYNNEWOOD AREA
(Modified after Hart, 1974)

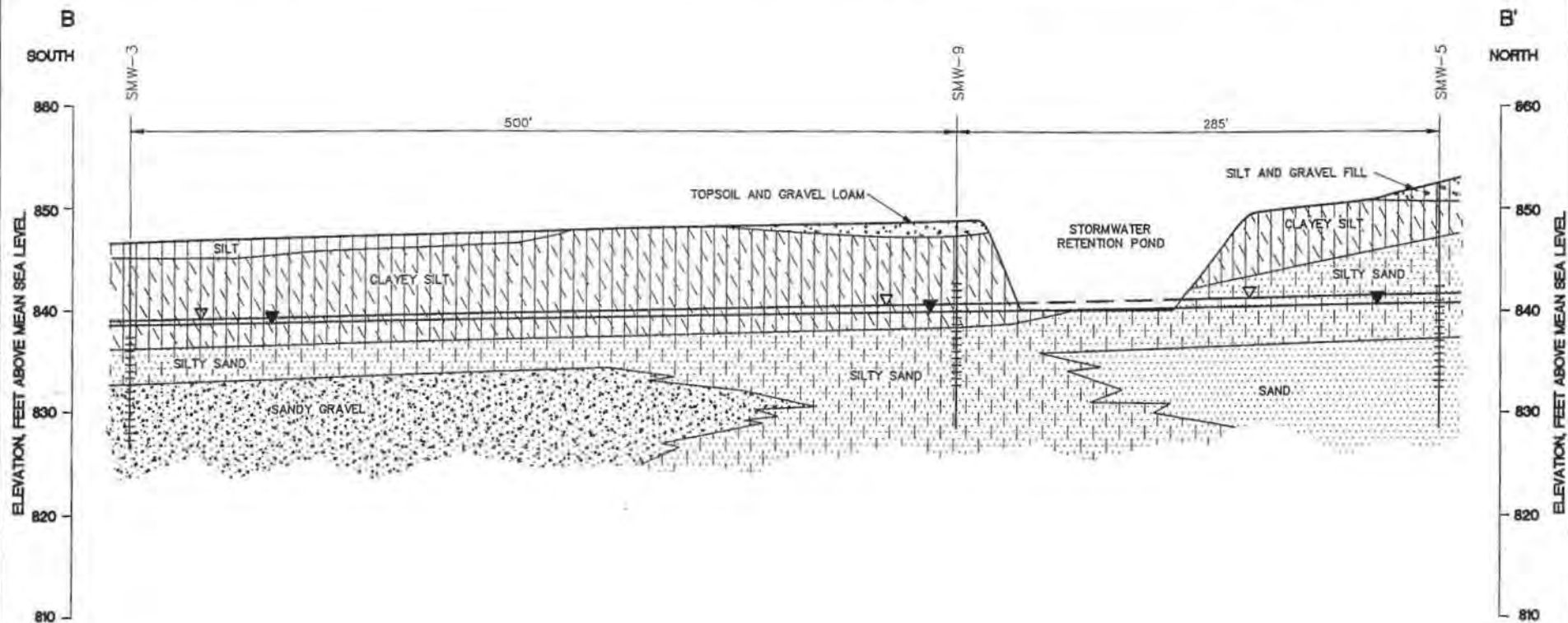


LEGEND

- MONITOR WELL SCREEN INTERVAL
- GROUNDWATER POTENTIOMETRIC SURFACE, 1/23/92
- GROUNDWATER POTENTIOMETRIC SURFACE, 4/23/92

SCALES: VERTICAL: 1"=10'
HORIZONTAL: 1"=40'
VERTICAL EXAGGERATION: x 4

Figure Title:	WEST TO EAST GEOLOGICAL CROSS-SECTION A-A'	Client:	KERR McGEE REFINING CORPORATION
Document Title:	POST-CLOSURE PLAN	Location:	WYNNEWOOD, OKLAHOMA
ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants 3700 East Oklahoma, Suite 200 Tulsa, Oklahoma 74119 (918) 521-3033		DATE:	11/16/92
		SCALE:	AS SHOWN
		PROJECT NO:	9212401 M10
		FIGURE NO:	12
		PREPARED BY:	MJL
		CHECKED BY:	BJS
		DRAFTED BY:	TAH



LEGEND

- MONITOR WELL SCREEN INTERVAL
- GROUNDWATER POTENTIOMETRIC SURFACE, 1/29/92
- GROUNDWATER POTENTIOMETRIC SURFACE, 4/23/92

SCALES: VERTICAL: 1"=10'
HORIZONTAL: 1"=50'
VERTICAL EXAGGERATION: x 6

Figure Title:	SOUTH TO NORTH GEOLOGICAL CROSS-SECTION B-B'	Client:	KERR-McGEE REFINING CORPORATION
Document Title:	POST-CLOSURE PLAN	Location:	WYNNEWOOD, OKLAHOMA
ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants 2700 East Oklahoma, Suite 900 Tulsa, Oklahoma 74102 (405) 421-0264		DATE:	11/16/92
		SCALE:	AS SHOWN
		PROJECT NO.:	8212401 M111
		FIGURE NO.:	13
		PREPARED BY:	MJL
		CHECKED BY:	BJJ
		DRAFTED BY:	TAM

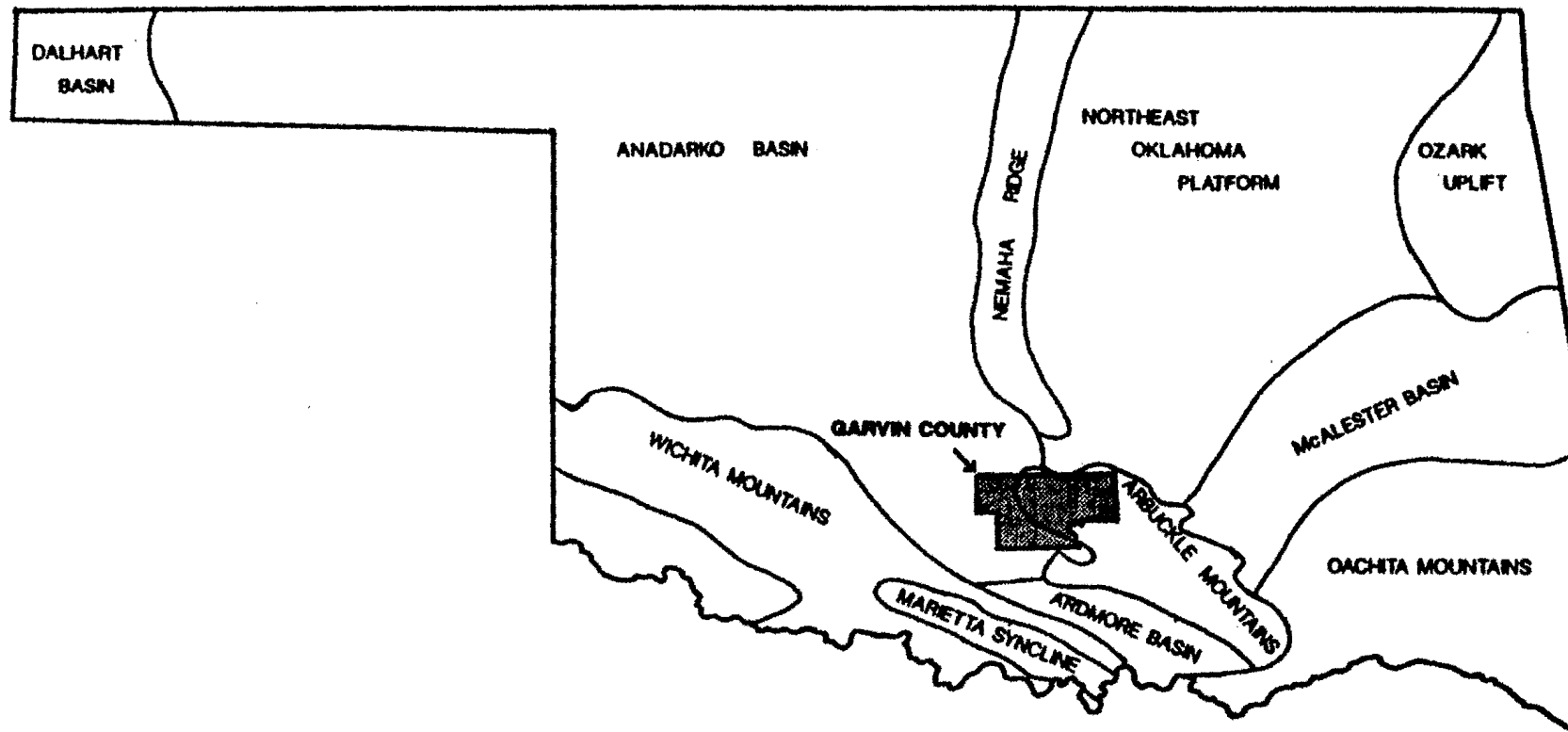
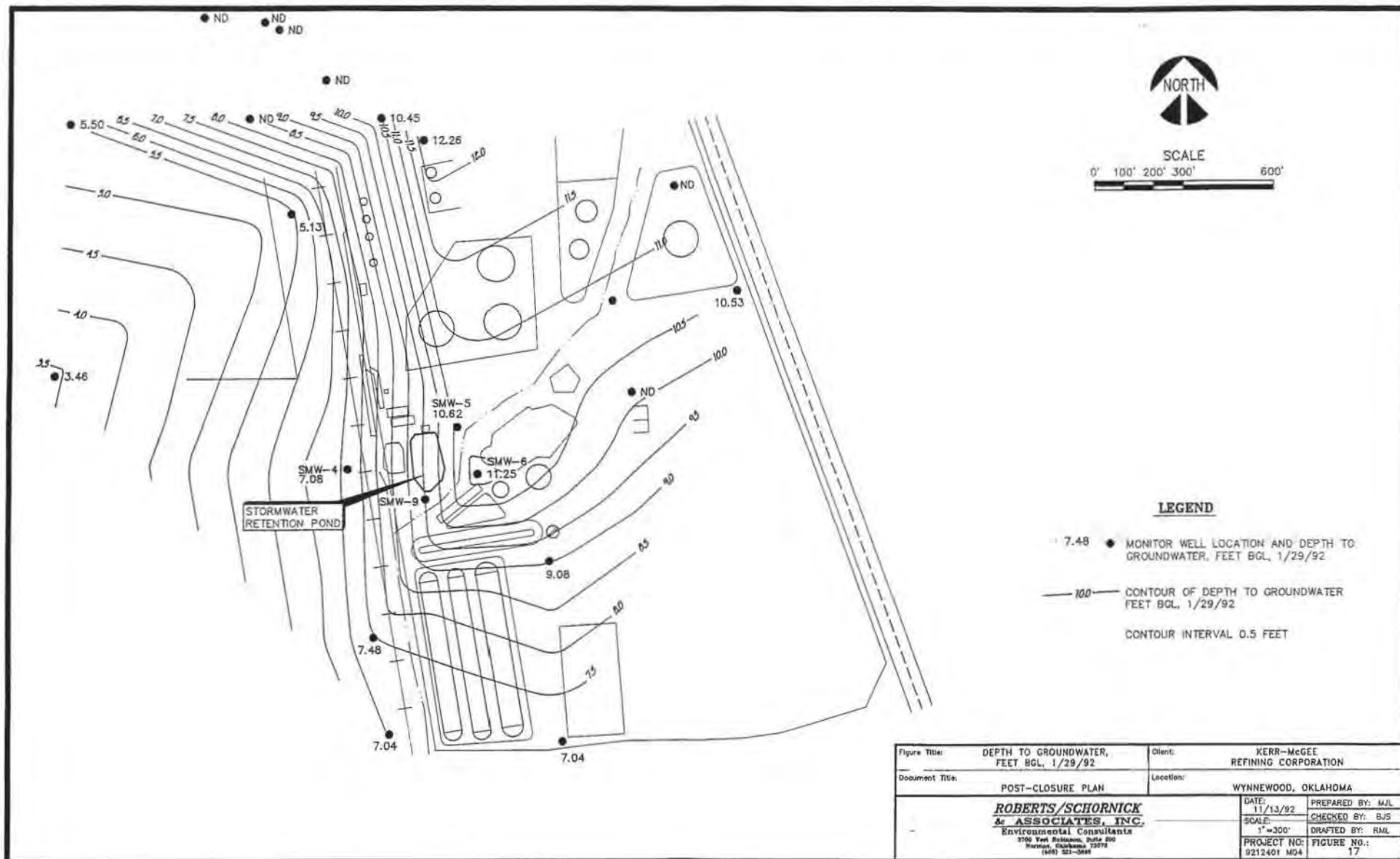


FIGURE 14:

INDEX MAP SHOWING LOCATION OF GARVIN COUNTY IN RELATION TO GEOLOGIC PROVINCES OF OKLAHOMA

(Modified after AAPG, 1959)



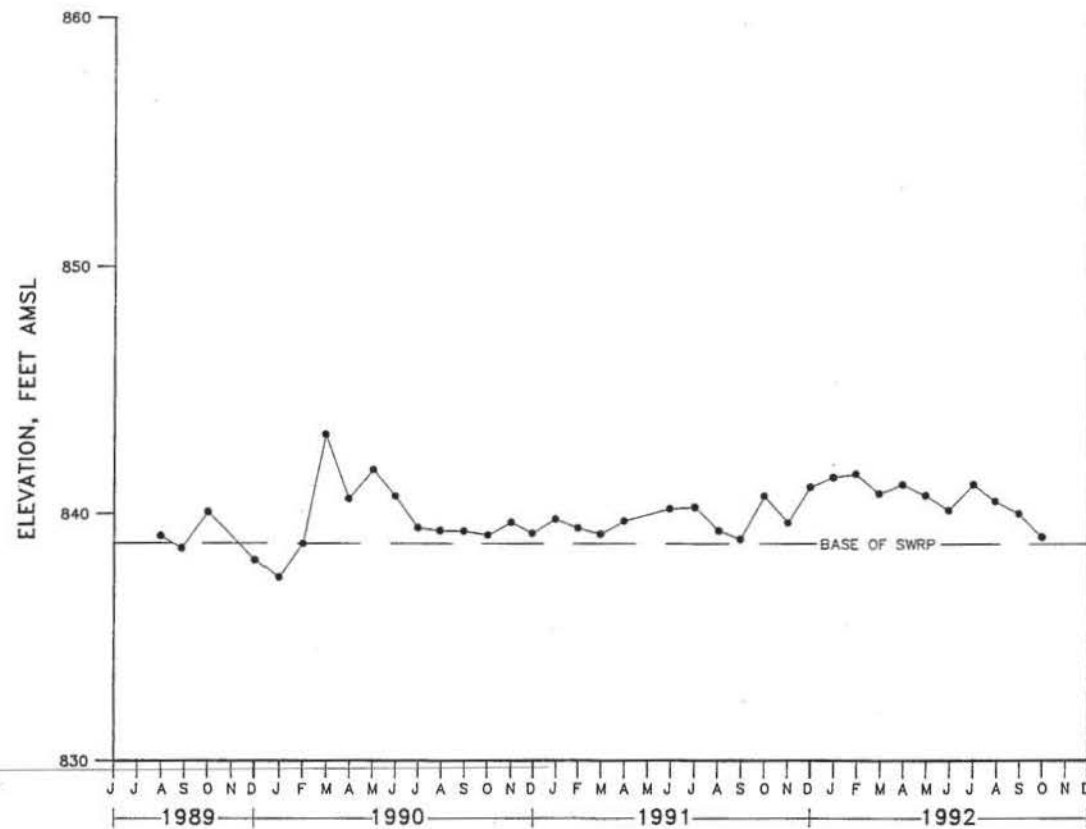


Figure Title:	HYDROGRAPH OF GROUNDWATER ELEVATION, FEET AMSL, SMW-4	Client:	KERR-McGEE REFINING CORPORATION		
Document Title:	POST-CLOSURE PLAN	Location:	WYNNWOOD, OKLAHOMA		
<i>ROBERTS/SCHORNICK & ASSOCIATES, INC.</i> Environmental Consultants 3700 West Eastman, Suite 200 Tulsa, Oklahoma 74107 (405) 521-5555		DATE:	11/13/92	PREPARED BY:	MJL
		SCALE:	AS SHOWN	CHECKED BY:	BJ/S
		PROJECT NO:	9212401 M07	DRAFTED BY:	BDP
		FIGURE NO.:	19		

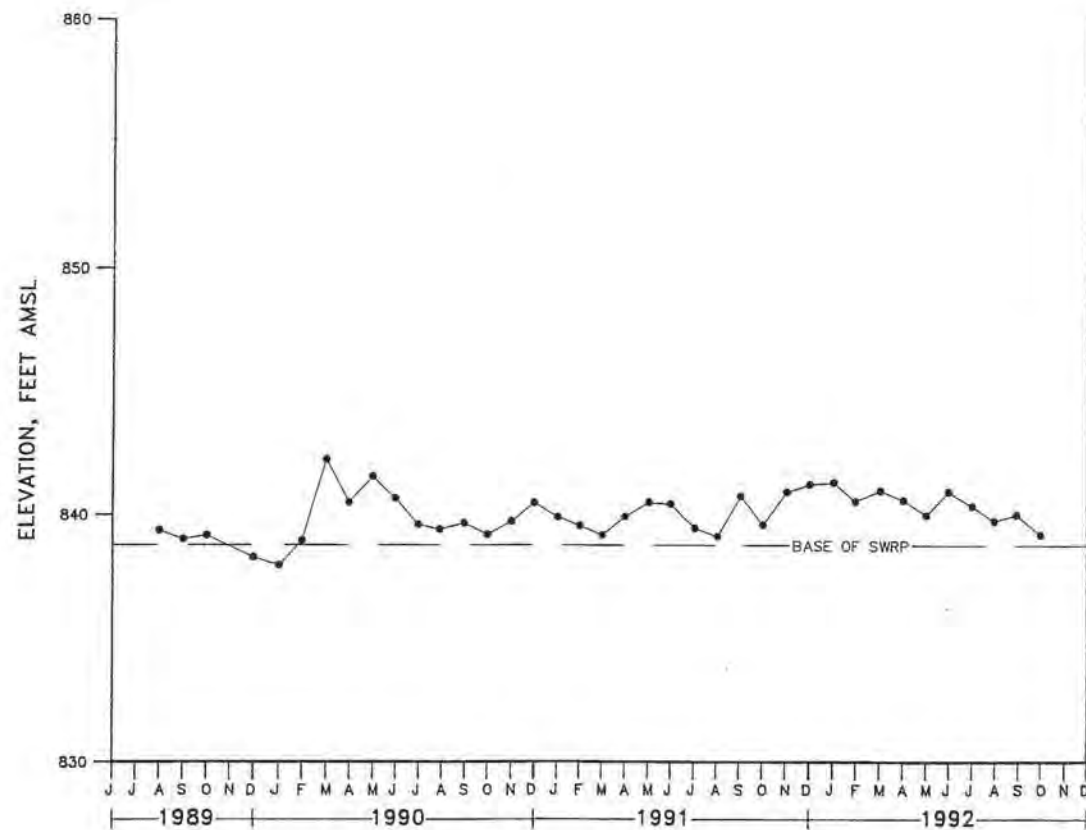


Figure Title:	HYDROGRAPH OF GROUNDWATER ELEVATION, FEET AMSL, SMW-5	Client:	KERR-McGEE REFINING CORPORATION
Document Title:	POST-CLOSURE PLAN	Location:	WYNNEWOOD, OKLAHOMA
<u>ROBERTS/SCHORNICK</u> <u>& ASSOCIATES, INC.</u> Environmental Consultants 2700 West Oklahoma, Suite 200 Norman, Oklahoma 73071 (405) 321-0444		DATE:	11/13/92
		SCALE:	AS SHOWN
		PROJECT NO:	9212401 M08
		FIGURE NO.:	20
		PREPARED BY:	MJL
		CHECKED BY:	BJS
		DRAFTED BY:	BDR

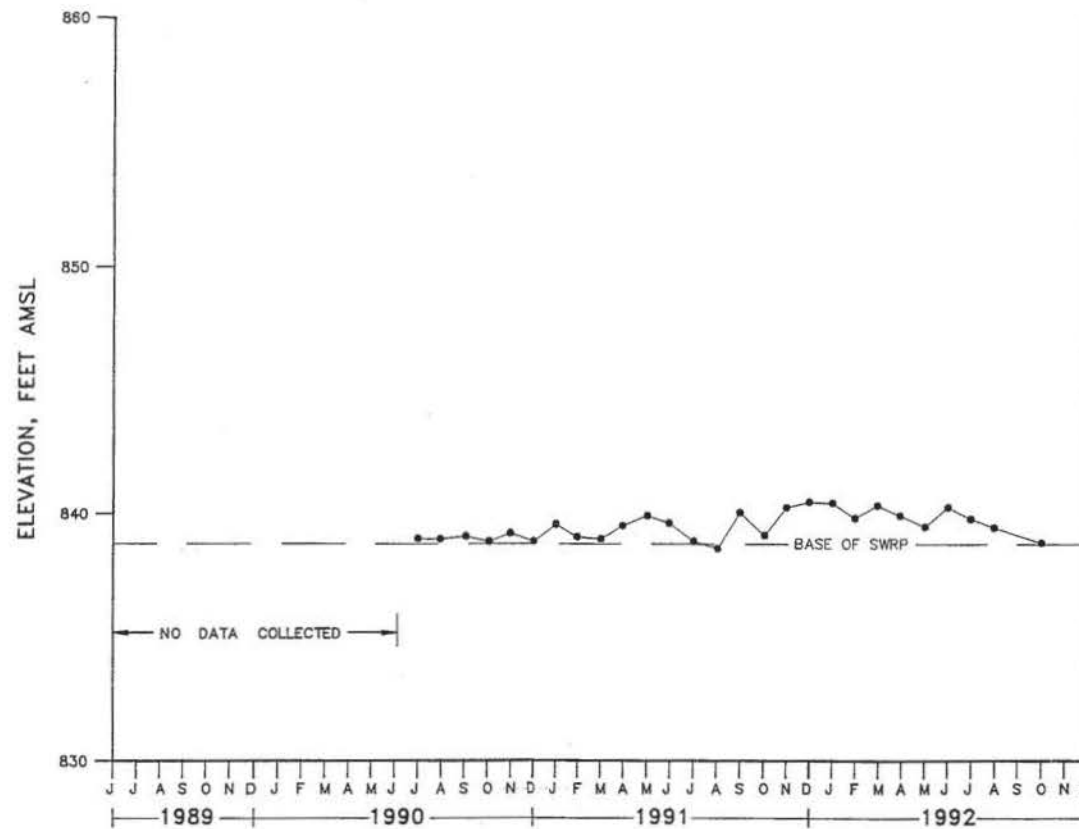


Figure Title:	HYDROGRAPH OF GROUNDWATER ELEVATION, FEET AMSL, SMW-6	Client:	KERR-McGEE REFINING CORPORATION
Document Title:	POST-CLOSURE PLAN	Location:	WYNNWOOD, OKLAHOMA
<u>ROBERTS/SCHORNICK & ASSOCIATES, INC.</u> Environmental Consultants 2700 West Robinson, Suite 200 Norman, Oklahoma 73076 (405) 321-3555		DATE:	11/13/92
		SCALE:	AS SHOWN
		PROJECT NO:	9212401 M09
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		PREPARED BY:	M.J.L.
		CHECKED BY:	B.J.S.
		DRAFTED BY:	B.C.R.

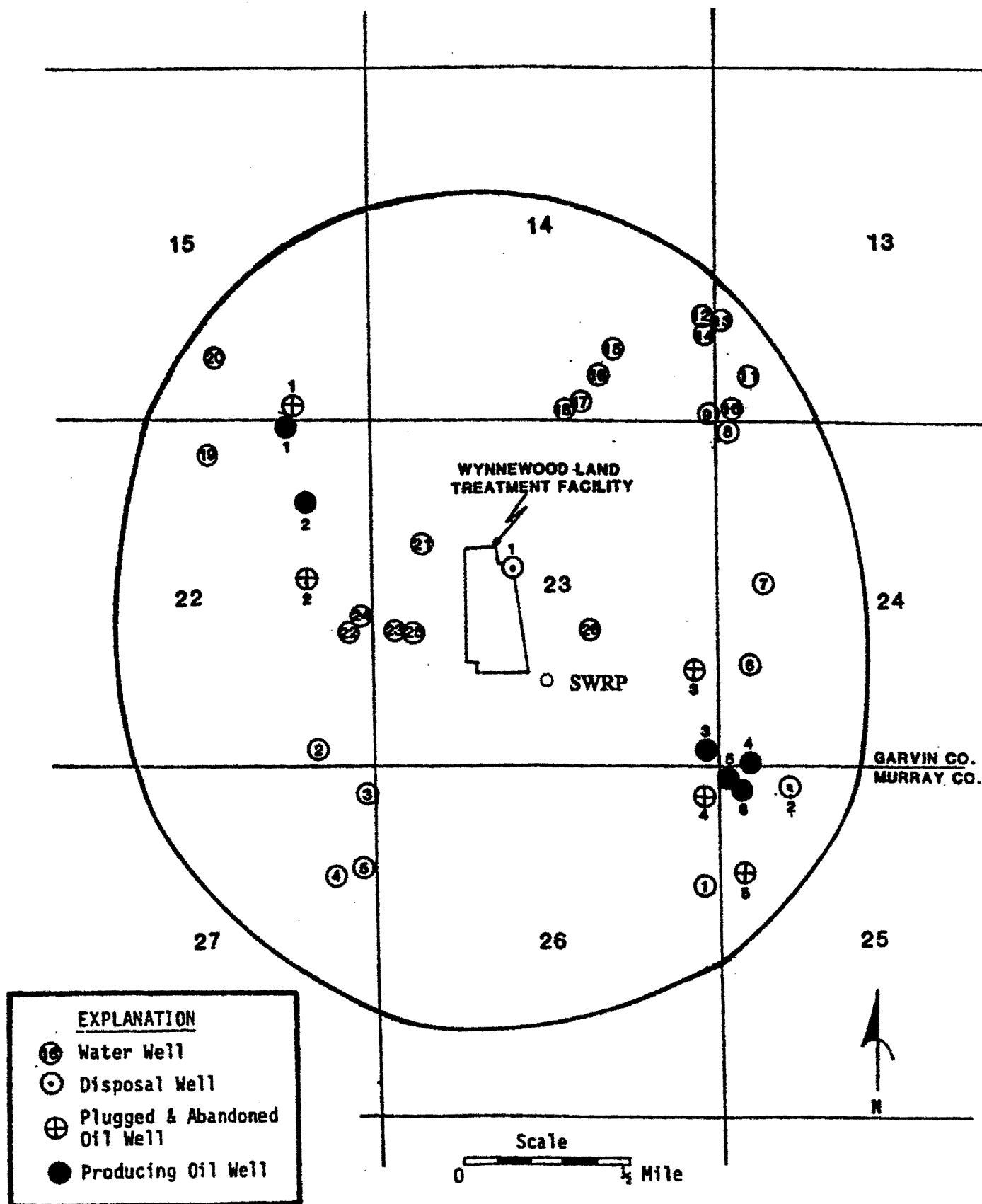


FIGURE 22; MAP SHOWING LOCATIONS OF WATER, OIL, AND DISPOSAL WELLS WITH-
IN ONE MILE OF THE WYNNEWOOD LAND TREATMENT FACILITY AND SWRP.

APPENDIX A-1

LITHOLOGICAL LOGS AND WELL COMPLETION DIAGRAMS

WELLS SMW-4, SMW-5, SMW-6, AND SMW-9

SOIL BORING LOG KM-3655-A

KERR-McGEE CORPORATION Hydrology Dept. Engineering Services			KIM SUBSIDIARY REFINING		LOCATION WYNNWOOD, OK		BORING NUMBER 34W-7			
DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNITED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE				REMARKS OR FIELD OBSERVATIONS
						NO.	TYPE	DEPTH	REC.	
0	BROWN SILTY CLAY LOOSE		ML	0						
5	DARK BROWN CLAYEY SILT FINE SAND - 10% - 20% LOW PLASTICITY, MOISTURE 250 AND WATER 14 DEPTH		ML-CL	0		1		3.7		SAMPLE 34W-4A FROM 1.5-2.5'
6.5	BROWN SILTY FINE SAND, WELL-GRADED, ALTERNATING INT. SANDY CLAYSTREETS			0		2		4.4		SAMPLE 34W-4B FROM 7.5-8.5'
10	LIGHT BROWN AND SOFT AT BOTTOM			0		3		3.2		SAMPLE 34W-4C FROM 10-11' $\frac{D}{2}$
15	DARK BROWN SILTY FINE SAND, SATURATED, WELL-GRADED			113 4/7		4	X	2.0		SAMPLE 34W-4D FROM 14-16'
20										

EXPLANATION		Water Table (24 Hour)	GRAPHIC LOG LEGEND		CLAY		DEBRIS FILL
		Water Table (Time of Boring)			SILT		HIGH ORGANIC (PEAT)
		PID NO. TYPE Photoionization Detection (ppm) Identifies Sample by Number Sample Collection Method			SAND		SANDY CLAY
		SPLIT-BARREL			GRAVEL		CLAYEY SAND
		THIN-WALLED TUBE			SILTY CLAY		CLAYEY SILT
		AUGER		ROCK CORE		NO RECOVERY	
		CONTINUOUS SAMPLER					

DATE DRILLED 6-29-89	PAGE 1 of 1
DRILLING METHOD HELIX SIGN AUGER	
DRILLED BY JIM WANNOK DRILLING	
LOGGED BY J. L. L.	
EXISTING GRADE ELEVATION (FT AMSL) 	
LOCATION OR GRID COORDINATES 	

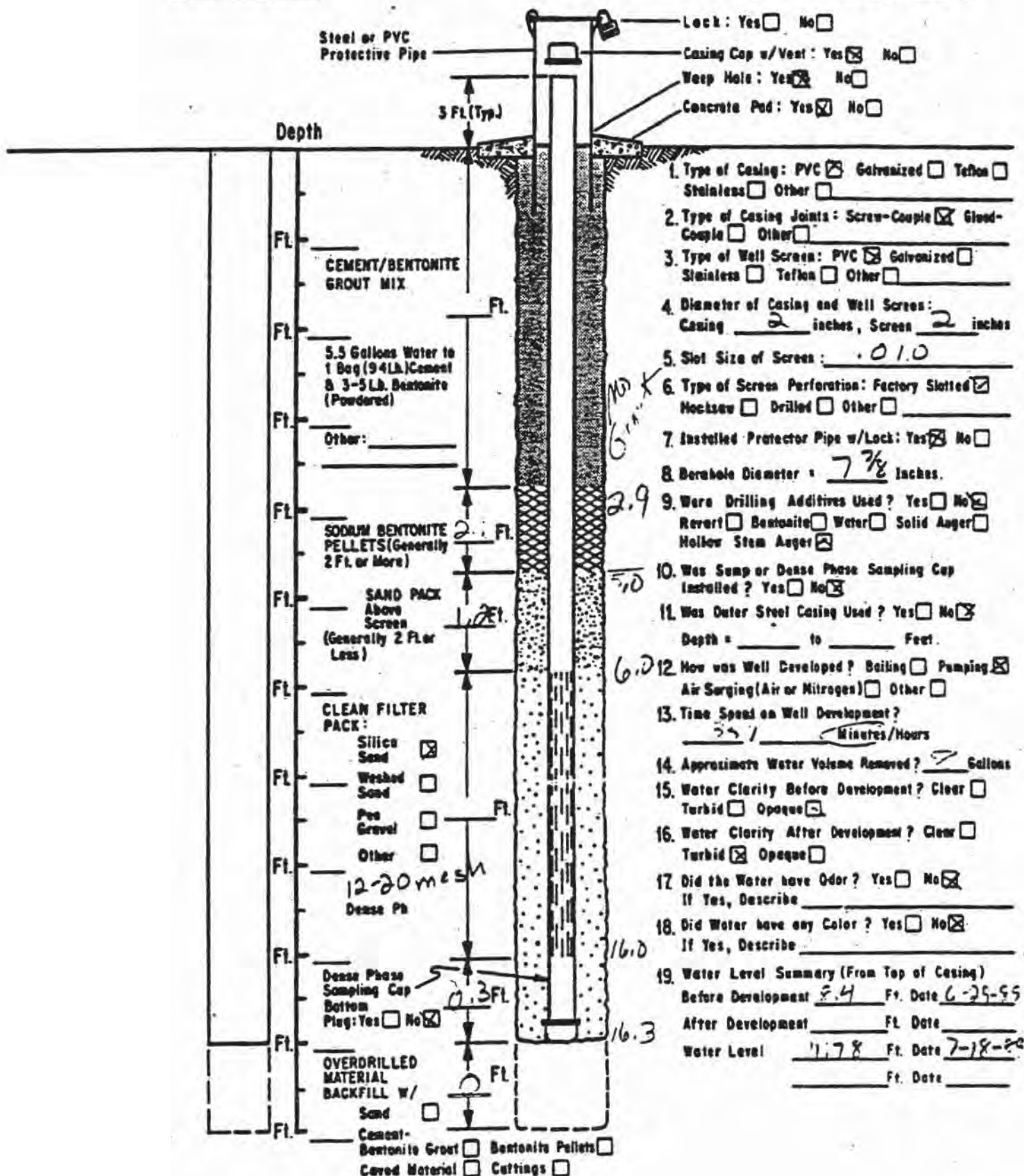
KERR-McGEE CORPORAT. N
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

WELL LABEL SMW4

LITHOLOGY

WELL

SPECIFICATIONS



Well No. SMW-4

Date Installed 6-29-89

Drill Rig Type MOBILE 2-41

Driller/Firm T. HINER

Drill Crew C. WALEN/R. KERN

Kerr-McGee Hydrologist UX

KERR-McGEE CORPORATION Hydrology Dept. Engineering Services			REFINING		LOCATION WYNNWOOD, OK		BORING NUMBER SMW-5				
DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE				REMARKS OR FIELD OBSERVATIONS	
						NO.	TYPE	DEPTH	REC.		
0	LIGHT BROWN SILT AND GRAVEL FILL, DRY, CRUMBLY		GM								
	DARK BROWN CLAYEY SILT, SLIGHTLY MOIST, NO PLAST.		ML			1		4	3.5		
5	BROWN SILTY FINE SAND, SLIGHTLY MOIST, WELL-GRADED SMW-5A FROM 6-8'		SW- SM			2			3.8		
10	GRAY BROWN AND BROWN SILTY FINE SAND/SANDY SILT, MOIST, WELL-GRADED SAMPLE SMW-5B FROM 12-13'		SM- SW			3		9	5.6		
15	LIGHT GRAY BROWN SAND, FINE TO MED. GRAIN, SATURATED PERC. 15, SILT BELOW 12' - SMW-5C FROM 12-15'					4		14	2.0		
20						5		19	1.0		
								24			
<p>TD = 24'</p> <p>RANSAMPLER TO 25 FEET TO TAKE 6 FT SAND SAMPLE</p>											

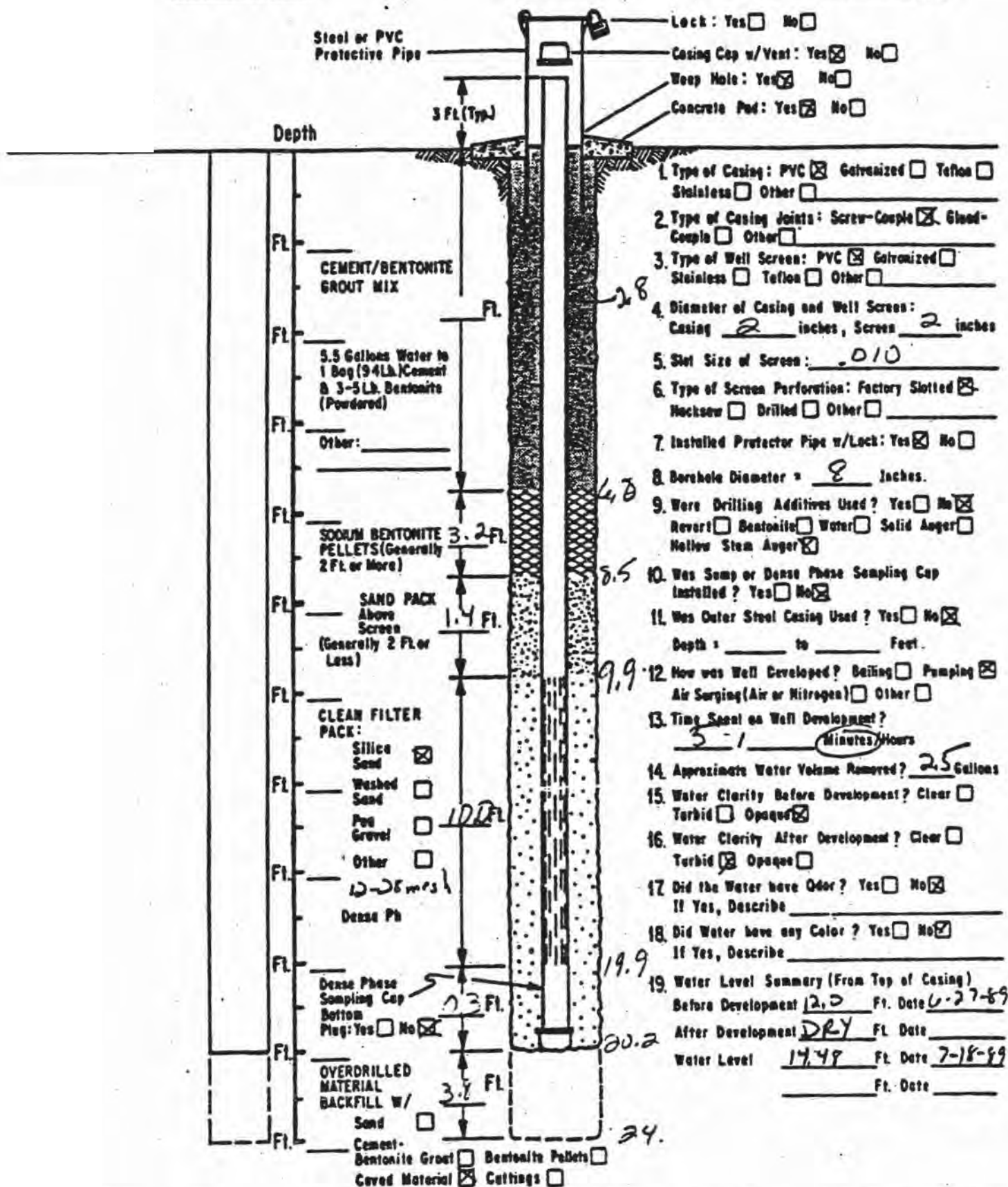
KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM

WELL LABEL SMW5

LITHOLOGY

WELL

SPECIFICATIONS



Well No. SMW-5
 Driller/Firm JIM WINNER

Date Installed 6-27-89 Drill Rig Type Mobile 2-111
 Drill Crew C. WALKER / M. POWELL Kerr-McGee Hydrologist J. L. W.

SOIL BORING LOG KM-3635-A

KERR-McGEE CORPORATION Hydrology Dept. Engineering Services		KM SUBSIDIARY REFINING		LOCATION WYNNEWOOD, OK		BORING NUMBER SMWG			
DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE			REMARKS OR FIELD OBSERVATIONS
						NO.	TYPE	DEPTH	
0.5	GRAVEL FILL		GW		16				PID READING 40 UNITS BACKGROUND- PROBABLY DUE TO HIGH HUM- IDITY (NO ODORS)
	SILT, BAN. & RD.-BRN., CLAY., SL. SDY., DRY IN TOP 1 FT., MOIST BELOW, FIRM, FRI., NO ODOR				20				
					18				
					17				
5	DRY, HARD, FRIABLE FROM 5-6 1/2 FT.		ML		18	1	4.5	4.0	RAINING - PUT PID AWAY
	AS ABOVE, MOIST, FIRM, FRI., NO ODOR, SCATTERED BLACK SPECKS								
	BECOMING V. SDY.								
10	SILTY SAND, GRAY & BAN. MTD., V.F. GR., LOOSE, MOIST TO SAT., NO ODOR		SM			2	9.5	5.0	
15	GRADING TO :								
	SAND, V.F. - F. GR., RD.-BRN., SAT., LOOSE, MOD. P. GRD., NO ODOR		SP			3	14.5	5.0	▽ 15.3 SWITCH TO CENTER BIT- TO PREVENT SAND LOCK
20									

EXPLANATION		GRAPHIC LOG LEGEND		DATE DRILLED	PAGE
▽	Water Table (24 Hour)		CLAY	5/25/90	1 of 2
▽	Water Table (Time of Boring)		SILT	DRILLING METHOD HSA/cont. sampler	
PID	Photoionization Detection (ppm)		SAND	DRILLED BY Winnek/Kingsley	
NO.	Identifies Sample by Number		GRAVEL	LOGGED BY T. Bent	
TYPE	Sample Collection Method		SILTY CLAY	EXISTING GRADE ELEVATION (FT. AMSL)	
	SPLIT-BARREL		CLAYEY SAND	LOCATION OR GRID COORDINATES	
	THIN-WALLED TUBE		DEBRIS FILL		
	AUGER		NIGHT ORGANIC (PEAT)		
	ROCK CORE		SANDY CLAY		
	CONTINUOUS SAMPLER		CLAYEY CLAY		
	NO RECOVERY				
DEPTH Depth Top and Bottom of Sample			CLAYEY SILT		
REC. Actual Length of Recovered Sample in Feet					

SOIL BORING LOG KM-9655-A

KERR-McGEE CORPORATION Hydrology Dept. Engineering Services		KM SUBSIDIARY REFINING	LOCATION WYNNEWOOD, OK		BORING NUMBER SMW6				
DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE			REMARKS OR FIELD OBSERVATIONS
						NO.	TYPE	DEPTH	
20	SAND, PD, BRN., CLR., FEW BLK. GRAINS, F.-CRS. GR., W. GRD., SAT., LOOSE, NO ODOR		SW						
25	T. D. 24.5'								

EXPLANATION	Water Table (24 Hour)			Water Table (Time of Boring)			PID			NO.			TYPE		
	Water Table (24 Hour)				Water Table (Time of Boring)				PID				NO.		
	Photoionization Detection (ppm)				Identifies Sample by Number				Sample Collection Method				SPLIT-BARREL		
	AUGER				ROCK CORE				THIN-WALLED TUBE				CONTINUOUS SAMPLER		
	NO RECOVERY				DEPTH				REC.				GRAPHIC LOG LEGEND		

DATE DRILLED		PAGE	
5/25/90		2 of 2	
DRILLING METHOD HSA/center bit			
DRILLED BY Winick/Kingsley			
LOGGED BY T. Bent			
EXISTING GRADE ELEVATION (FT AMSL)			
LOCATION OR GRID COORDINATES			

KERR-McGEE CORPORATION Hydrology Dept. Engineering Services			KM SUBSIDIARY REFINING	LOCATION WYNNEWOOD, OK.		BORING NUMBER SMW-9			
DEPTH IN FEET	LITHOLOGIC DESCRIPTION	GRAPHIC LOG	UNIFIED SOIL FIELD CLASS.	BLOWS PER FOOT	PID (ppm)	SOIL SAMPLE			REMARKS OR FIELD OBSERVATIONS
						NO.	TYPE	DEPTH	
	TOP SOIL - GRAVELLY LOAM DARK BROWN - MOIST							0	
2	CLAYEY SILT MED-BROWN - C DARK TAN SLT. MOIST		ML			1		3.5'	EARTH ODOUR
5	SILT BECOMING SATURATED @ 9' LIGHT GRAY-TAN COLOR MORE PREVALENT		SM			2		2.3'	
10	SILT SAND MED. GRAY-TAN SATURATED OCCASIONAL MED GRAY-GREEN SILTY CLAY LENS							2.1'	
15								15	
20								20	NO RECORD! LITHOLOGIST INTERFERED FROM CUTTINGS
	TO 20'								

EXPLANATION

- Water Table (24 Hour)
- Photoionization Detection (ppm)
- PID NO. TYPE Identifies Sample by Number Sample Collection Method
- SPLIT-BARREL
- AUGER
- ROCK CORE
- THIN-WALLED TUBE
- CONTINUOUS SAMPLER
- NO RECOVERY

DEPTH Depth Top and Bottom of Sample
REC. Actual Length of Recovered Sample in Feet

GRAPHIC LOG LEGEND

CLAY	DEBRIS FILL
SILT	HIGHLY ORGANIC (PEAT)
SAND	SANDY CLAY
GRAVEL	CLAYEY SAND
SILTY CLAY	
CLAYEY SILT	

DATE DRILLED
11/23/92

PAGE
1 of 1

DRILLING METHOD
HOLLOW STEM AUGER

DRILLED BY
TERRACON

LOGGED BY
T. REED

EXISTING GRADE ELEVATION (FT AMSL)

LOCATION OR GRID COORDINATES

**KERR-McGEE CORPORATION
HYDROLOGY DEPARTMENT
MONITORING WELL INSTALLATION DIAGRAM**

Protective Pipe
Yes ☒ No ☐
Steel ☒ PVC ☐
Surveying Pin? Yes ☒ No ☐

Casing Cap Vent? Yes ☒ No ☐
Lock? Yes ☒ No ☐
Weep Hole? Yes ☐ No ☒
Concrete Pad 3 Ft. x 3 Ft. x 3.5 Inches

DEPTH FROM TOP OF CASING
BELOW GRADE

Cement/Bentonite Grout Mix
Yes ☐ No ☐
5.5 Gallons Water to
94Lb. Bag Cement &
3-5 Lb. Bentonite
Powder
Others: CONCRETE
MERGED INTO
PAD

Bentonite Seal
Pellets ☒ Slurry ☐
Filter Pack Above Screen
1.7 Ft.

FILTER PACK MATERIAL
Silica Sand ☒
Washed Sand ☐
Pea Gravel ☐
Others: _____
Sand Size 10-20

Dense Phase Sampling Cup
Bottom Plug
Yes ☒ No ☐
Overdrilled Material
Backfill
Grout ☐ Sand ☐
Caved Material ☒
Others: _____

3 Ft.
3 Ft.
2 Ft.
5
1.7 Ft.
6.7
10 Ft.
16.7
3 Ft.
17
3 Ft.
20

DRILLING INFORMATION:

- Borehole Diameter = 8.5 Inches.
- Were Drilling Additives Used? Yes ☐ No ☒
Revert ☐ Bentonite ☐ Water ☐
Solid Auger ☐ Hollow Stem Auger ☒
- Was Outer Steel Casing Used? Yes ☐ No ☒
Depth = _____ to _____ Feet.
- Borehole Diameter for Outer Casing _____ Inches.

WELL CONSTRUCTION INFORMATION:

- Type of Casing: PVC ☒ Galvanized ☐ Teflon ☐
Stainless ☐ Other _____
- Type of Casing Joints: Screw-Couple ☒ Glue-Couple ☐ Other _____
- Type of Well Screen: PVC ☒ Galvanized ☐
Stainless ☐ Teflon ☐ Other _____
- Diameter of Casing and Well Screen:
Casing 2 Inches, Screen 2 Inches.
- Slot Size of Screen: .010
- Type of Screen Perforations: Factory Slotted ☒
Hacksaw ☐ Drilled ☐ Other _____
- Installed Protector Pipe w/Lock: Yes ☒ No ☐

WELL DEVELOPMENT INFORMATION:

- How was Well Developed? Bailing ☐ Pumping ☒
Air Surging (Air or Nitrogen) ☐ Other _____
- Time Spent on Well Development?
10 / 1 Minutes/Hours
- Approximate Water Volume Removed? 28 Gallons
- Water Clarity Before Development? Clear ☐
Turbid ☐ Opaque ☒
- Water Clarity After Development? Clear ☒
Turbid ☐ Opaque ☐
- Did Water have Odor? Yes ☒ No ☐
If Yes, Describe SULFUR?
- Did Water have any Color? Yes ☐ No ☒
If Yes, Describe _____

WATER LEVEL INFORMATION:

Water Level Summary (From Top of Casing)

During Drilling ~ 9 Ft. Date 11/23
Before Development _____ Ft. Date _____
After Development 10.3 (BG) Ft. Date 11/23

Driller/Firm M. JOHNSON / TERRACON Drill Rig Type CME 75 Date Installed 11/23/92
Drill Crew M. JOHNSON / J. WARD Well No. SMW-9 Kerr-McGee Hydrologist T. REED

APPENDIX A-2

ANALYTICAL DATA FOR WELLS SMW-5 AND SMW-9

KERR-McGEE REFINING CORPORATION
 WYNNEWOOD, OKLAHOMA REFINERY
 TREND CHARTING: GROUNDWATER ANALYTICAL DATA

WELL SMW5

DATE	BARIUM ug/l	CHROMIUM ug/l	LEAD ug/l	SELENIUM ug/l	ARSENIC ug/l	COBALT ug/l	NICKEL ug/l	VANADIUM ug/l
Aug-89	160	ND	ND	ND	ND	ND	ND	ND
Sep-92	305	ND	ND	ND				
Dec-92	295	ND	5.3	ND				
Mar-93	341	15.1	13.2	ND				
Jun-93	538	51.2	28.3	ND				

ND - Not detected above quantitation limit

KERR-McGEE REFINING CORPORATION
 WYNNEWOOD, OKLAHOMA REFINERY
 TREND CHARTING: GROUNDWATER ANALYTICAL DATA

WELL SMW5

DATE	BENZENE ug/l	TOLUENE ug/l	ETHYLBENZ. ug/l	XYLENES ug/l	TOTAL BTEX ug/l	TOTAL SEMIVOLATILES ug/l	TPH ug/l
Aug-89	ND	ND	ND	ND	ND	ND	ND
Sep-92	ND	ND	ND	ND	ND		2350
Dec-92	ND	ND	ND	ND	ND		
Mar-93	ND	ND	ND	0.8	0.8		72.6
Jun-93	ND	ND	ND	ND	ND		76.8

ND - Not detected above quantitation limit

KERR-MCGEE REFINING CORPORATION
 WYNNWOOD, OKLAHOMA REFINERY
 TREND CHARTING: GROUNDWATER ANALYTICAL DATA

WELL 8MW9

DATE	BARIUM ug/l	CHROMIUM ug/l	LEAD ug/l	SELENIUM ug/l	BENZENE ug/l	TOLUENE ug/l	ETHYLBENZ. ug/l	XYLENES ug/l	TOTAL BTEX ug/l	TPH ug/l
Dec-82	356	10	11	ND	ND	ND	ND	2.9	2.9	453
Mar-83	920	23	56	ND	ND	ND	ND	3.5	3.5	506
Jun-83	ND	ND	36	ND	ND	ND	ND	3.1	3.1	

ND - Not detected above quantitation limit

ATTACHMENT B

**SAMPLING AND ANALYSIS PLAN
KERR-McGEE REFINING CORPORATION
WYNNEWOOD, OKLAHOMA**

MONITOR WELL LOCATIONS

The RCRA Interim Status Post-Closure Plan for the Kerr-McGee Refining Corporation's (KMRC's) Wynnewood Refinery Storm Water Retention Pond (SWRP), was submitted to the U.S. EPA on August 31, 1993. The plan was approved by EPA on December 14, 1993. The groundwater compliance monitor well network described in the plan consists of a total of four (4) shallow alluvial wells. At the time of the Plan's submittal, two (2) of the compliance monitor wells, SMW-5 upgradient and SMW-9 downgradient, were already constructed. Then, two (2) additional downgradient compliance wells, SMW-11 AND SMW-21, were installed in February 1994. In order to cover the entire groundwater saturation zone, four (4) deeper wells were also installed in February 1994. The observation well proposed in the Post-Closure Plan to be located between SMW-5 and SMW-9, on the east side of the SWRP, could not be installed due to physical constraints. These constraints include the proposed location being within the capped area of the closed SWRP and on the edge of the No-Name Creek.

Thus, the SWRP monitor compliance well network now consists of four (4) nested well locations (8 wells total) shown below. The "D" designation after the well numbers specifies the deep well.

Upgradient
SMW-5
SMW-5D

Downgradient
SMW-11
SMW-11D
SMW-21
SMW-21D
SMW-9
SMW-9D

Revised 6/17/94

After the removal of Asphalt Pit I, which is adjacent to the SWRP, KMRC may add one new downgradient compliance monitor well set to the SWRP compliance well network. A general location of the proposed monitor well set is shown on the attached map. The exact location will be determined prior to drilling based upon groundwater elevation data which will be used to determine groundwater flow direction. This well set may be either an additional or replacement compliance monitor well(s), depending on the conclusions made from the groundwater flow direction determination. KMRC anticipates this proposed location will require a well set as the other SWRP monitoring well locations have required two wells (i.e. shallow and deep), to adequately screen the aquifer.

Revised 6/17/94

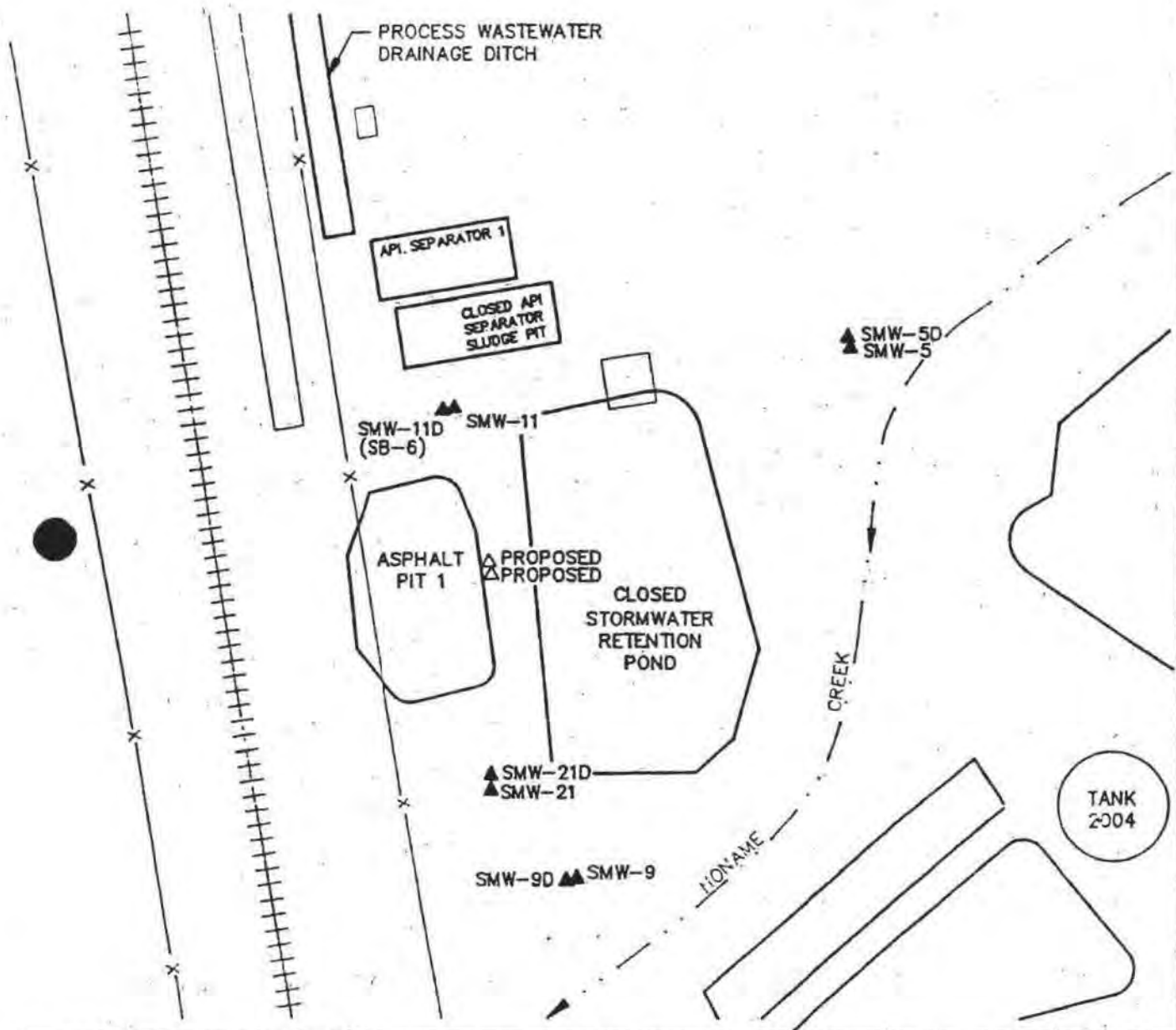


SCALE

**LEGEND**

SMW-5 ▲ POST-CLOSURE MONITOR WELL LOCATION

PROPOSED ▲ PROPOSED POST-CLOSURE MONITOR WELL LOCATION



Project Title:
CLOSED STORMWATER RETENTION POND
MONITOR WELL LOCATION MAP

Client:
KERR-McGEE REFINING CORP.
WYNNEWOOD

Document Title:

Location:

WYNNEWOOD, OKLAHOMA

**ROBERTS/SCHORNICK
& ASSOCIATES, INC.**

Environmental Consultants
3700 West Robinson, Suite 200
Norman, Oklahoma 73072
(405) 321-3895

REVISED
6/17/94

DATE:
5/12/94

PREPARED BY: B.J.S.

SCALE:
1"=80'

CHECKED BY: B.J.S.

PROJECT NO:
94002.01 M53

FIGURE NO.:

12.2 GROUNDWATER MONITORING

The information contained in this section is submitted in accordance with Oklahoma Hazardous Waste Management Regulations and 40 CFR 270.14 as adopted by the OSDH.

12.1 Exemption From Groundwater Protection Requirements

KMRC is not requesting an exemption from the groundwater protection requirements of the regulations.

12.2 Interim Status Period Groundwater Monitoring Data

12.2.1 Location of Interim Status Groundwater Monitoring Wells

December, 1980, as part of interim status requirements (40 CFR 265) and in order to provide necessary background information for the Refinery's Part B permit application, KMRC initially installed five RCRA groundwater monitoring wells (LMW1, LMW2, LMW3, LMW4, and LMW5) around the Land Treatment Facility (LTF). The location of these wells in relation to the LTF is shown in Figure 12-1.

In September, 1984, KMRC installed 3 additional monitor wells (LMW6, LMW7, and LMW8) for the purpose of providing better definition of the water table configuration and direction of groundwater flow beneath the LTF. Changes in the presence of fluid hydrocarbons from an

upgradient source in monitor well LMW1 prompted KMRC to install monitor well LMW6 as a replacement upgradient monitor well. Since LMW1 contains liquid phase hydrocarbon from an upgradient source, it was removed from the RCRA groundwater monitoring system.

In March, 1985, two monitor wells were installed near the LTF. Continuous water level recorders were installed in these wells in May, 1986. These water level recorders are no longer necessary for water level recording at the LTF and will be removed from the wells.

The RCRA groundwater monitoring system at the LTF was expanded in 1986 to include additional downgradient groundwater monitor wells LMW2-O, LMW3-O, LMW4-O, LMW5-O, and LRW1-O, as well as two additional upgradient monitor wells, LMW6-O and LRW2-O. These wells were screened across the top of the water table, without extending to the bottom of the shallow alluvial aquifer, to monitor the quality of "shallow" groundwater. The locations of all RCRA groundwater monitor wells for the LTF are shown on Figure 12-1.

Subsequent to the Storm Water Retention Pond (SWRP) becoming newly-regulated as a hazardous waste surface impoundment, a RCRA groundwater

MW-4, SMW-5, SMW-6, and SMW-9. Wells SMW-4 and SMW-9 are crossgradient/downgradient wells, well SMW-5 is an upgradient well, and well MW-6 is an upgradient/crossgradient well. The locations of these wells are shown on Figure 12-2. These wells will be monitored during the post-closure care period for the SWRP. The monitoring program consists of quarterly monitoring of the above listed wells for calendar year 1993 and semi-annual monitoring thereafter, beginning in June 1994 and continuing until completion of the post-closure care monitoring period.

2.2.2 Description of Statistical Procedures During LTF Interim Status Monitoring

Groundwater monitoring data for pH, Specific Conductance (SC), Total Organic Carbon (TOC), and Total Organic Halogens (TOX) obtained from downgradient LTF monitor wells have been statistically compared with background data obtained from upgradient monitor wells. In accordance with interim status regulations [40 CFR 265.93(b)], the student's t-test at the 0.01 level of significance was used to determine statistically significant increases (and decreases, in the case of pH) over first year background levels. Appendix H describes the student's t-test and gives an example of calculations using sample TOC data and pH data.

The groundwater monitoring program for the SWRP will be conducted under the alternate groundwater monitoring program.

nsist of statistical evaluation of the analytical data. The SWRP groundwater monitoring program will be initiated in 1993, as described above.

12.3 Interim Status LTF Groundwater Monitoring Data Summary.

12.3.1 Upgradient Background Groundwater Data

After installation, RCRA upgradient monitor wells LMW1, LMW6, and LMW6-O are sampled quarterly for one year. Groundwater samples were analyzed in quadruplicate for the groundwater indicator parameters pH, Specific Conductivity, TOC, and TOX in accordance with interim status requirements (Appendix H). In addition, interim status drinking water and groundwater quality parameters listed in Table 12-1 were monitored on a quarterly basis during the first

LMW6-O.

Table 12-2 presents the results of the first year of groundwater analysis for upgradient monitor well LMW1. The arithmetic mean of each parameter is listed for each quarter. The resultant annual arithmetic mean, variance, and standard deviation based on quarterly means for each parameter for the year are listed beneath the table of quarterly means. This same data for the placement upgradient monitor well, LMW6, is presented in Table 12-3. Table

After the initial year of sampling for all the interim status parameters listed in 40 CFR 265.92, KMRC continued to perform semi-annual groundwater sampling. Analyses for the groundwater quality parameters listed in Table 12-1 were performed on an annual basis. Analyses for the indicator parameters for groundwater contamination were performed on a semi-annual basis.

Appendix I presents a summary of interim status data generated for upgradient monitor wells LMW1, LMW6, and LMW6-O.

2.2.3.2 Downgradient Groundwater Monitoring Data

After installation, RCRA downgradient monitor wells LMW3, LMW4, LMW5, LMW3-O, LMW4-O, and LMW5-O were sampled quarterly for one year. In June, 1986, monitor wells LRW1 and LRW1-O were added to the RCRA program. These monitor wells were sampled quarterly for one year beginning in July, 1987. Groundwater samples were analyzed in quadruplicate for the groundwater contamination indicator parameters pH, Specific Conductivity, TOC, and TOX in accordance with interim status requirements (the data is presented in Appendix I). In addition, interim status drinking water and groundwater quality parameters listed in Table 12-1 were monitored on a quarterly basis during the first year of groundwater monitoring for the above-listed downgradient monitor wells.

bles 12-5 through 12-12 present the results of the first year of groundwater analysis for the downgradient monitor wells. The arithmetic mean of each parameter is listed for each quarter. The resultant annual arithmetic mean, variance, and standard deviation based on quarterly means for each

After the initial year of sampling for all the interim status parameters listed in 40 CFR 265.92, KMRC continued to perform semi-annual groundwater sampling for these downgradient monitor wells. Analyses for the groundwater quality parameters listed in Table 12-1 were performed on an annual basis. Analyses for the indicator parameters were performed on a semi-annual basis.

Appendix I presents a summary of interim status data generated for downgradient monitor wells LMW5-O, LRW1, and LRW1-O.

2.2.3.3 Discussion of Interim Status Groundwater Monitoring Data

The initial groundwater assessment for the LTF consisted of the installation of the monitoring wells on the

ita from these wells, KMRC reported a statistical increase in pH in monitor wells LMW3, LMW4, and LMW5 to the OSDH in February, 1984. KMRC simultaneously requested Kerr-McGee's Hydrology Department to develop a groundwater assessment program. A three-phase Groundwater Assessment Plan was submitted in May, 1984. Phase I consisted of determination of true upgradient direction for placement of an upgradient monitor well. Phase II consisted of a study of the pH and specific conductance profiles of existing groundwater monitor wells. Phase III consisted of the determination of the source of impact, if Phase II determined that the observed deviations in pH and conductivity were not inherent results of sampling procedures.

Phase I and Phase II results were submitted to the OSDH in September, 1984. A layer of liquid hydrocarbon was discovered in upgradient monitor well LMW1. A new upgradient monitor well, LMW6, was installed north of the LTF.

Phase III Groundwater Assessment Plan was submitted in November, 1984, designed to determine the source of the hydrocarbon and the reason for the changes in pH and conductivity observed in the interim status monitoring program. As part of the groundwater assessment program, monitor wells RW1 and LRW2 were installed both up and downgradient of the LTF. The Groundwater Assessment Report of Phase III Results, submitted to the OSDH in June, 1985, stated that the upgradient hydrocarbon plume discovered in

downgradient

Appendix I presents annual groundwater monitoring reports that show statistically significant increases in pH and specific conductance in downgradient LTF monitor wells. These statistical changes are apparent in monitor wells installed after the Phase III groundwater assessment report was completed. These changes were reported annually to the OSDH, in accordance with State regulations. A Groundwater Quality Assessment Plan, designed to determine the cause of these statis

2.3 Aquifer Identification

2.3.1 Uppermost Aquifer

The uppermost aquifer at the Wynnewood LTF and SWRP is the alluvial aquifer found within the present day flood-plain of the Washita River. This aquifer ranges in thickness from 20 to 25 feet at the Refinery site and consists principally of sand and gravel. Hydrogeologic properties of the alluvial aquifer at the LTF and S

12.3.2 Underlying Bedrock Aquifer.

There are no aquifers underlying the Refinery that are hydraulically interconnected with the Alluvial Aquifer. The bedrock units underlying the LTF and SWRP consist principally of shale with thin sandstone beds and lenses. There are no known water wells completed within these bedrock units in the area. These bedrock units are capable of yielding only minor quantities of fresh to slightly saline water to drilled wells. A more thorough description of these bedrock water-bearing units can be found in the hydrogeologic characterizations for the LTF and SWRP presented in Appendices J and K, respectively.

12.3.3 Hydrogeologic Properties.

The groundwater at the Refinery generally flows in a west-southwesterly direction at a rate of approximately 0.33 feet/day. The hydraulic gradient is approximately 1.05×10^{-3} feet/foot or about 5.5 feet/mile. A more detailed description of the flow rates and direction can be found in the hydrogeologic characterization presented in Appendices J and K.

12.4 Contaminant Plume Description

No plume of groundwater contamination originating from the LTF has been identified at this site. As explained in Section 12-2, a hydrocarbon plume from an upgradient source has impacted upgradient monitor well LMW-1 and has resulted in statistical changes in the LTF's groundwater monitoring data. KMRC

conducted both a Land Treatment Demonstration (in accordance with the mission of a No Migration Petition) and a Groundwater Assessment (also included in the No Migration Petition) for the LTF. The results of these investigations were submitted to the EPA and the OSDH in June, 1990. Further investigation showed the LTF to be the source of contamination covered in downgradient monitor wells. The executive summary of the Groundwater Assessment Report is included in this application as Appendix L. The executive summary of the Land Treatment Demonstration Report is included in this permit application as Appendix M. The post-closure groundwater monitoring program for the SWRP will be initiated in the first quarter of 1993. At this time, no releases from the SWRP are known. If monitoring results indicate that a release has occurred from the SWRP, then RC will initiate the appropriate response action.

5 Groundwater Monitoring Program

A groundwater monitoring program currently being performed at the KMRC Annwood LTF was developed after the completion of the Groundwater Assessment conducted from November, 1988 through November, 1989. IRC is currently installing a hydrocarbon recovery system upgradient of the LTF that will contain and capture the upgradient source of contamination. This recovery system will effectively cut off the upgradient source of impact to the LTF.

the groundwater monitoring program for the SWRP will be initiated in the first quarter of 1993 and will consist of quarterly monitoring of each specified upgradient and downgradient well through the 1993 calendar year. Beginning in June 1994, groundwater samples will be obtained on a semi-annual schedule from each specified upgradient and downgradient well until completion of the post-closure care monitoring period.

2.5.1 Description of Groundwater Monitoring Wells

In order to provide necessary background information for the Refinery's Part B permit application, KMRC initially installed four groundwater monitoring wells (LMW1, LMW3, LMW4, and LMW5) at the LTF (Figure 12-1). Monitor well LMW1 was installed as an upgradient monitor well, and wells LMW3, LMW4, and LMW5 were installed as downgradient monitor wells. In addition to these four water quality monitoring wells, KMRC installed 3 monitor wells (LMW7, LMW8, and LMW2) to further define the groundwater flow and configuration beneath the LTF. The discovery of a liquid phase hydrocarbon in upgradient well LMW1, along with incomplete definition of groundwater flow directions, prompted KMRC to install replacement "upgradient" well LMW6 in September, 1984. Since LMW1 is not representative of upgradient background conditions it was removed from the RCRA groundwater monitoring system.

The RCRA groundwater monitoring system was expanded in 1986 to include several additional downgradient groundwater monitoring wells: LMW3-O, LMW4-O, LMW5-O, LRW1, and LRW1-O, as well as one additional upgradient well LMW6-O (Figure 12-1). These wells were installed with the well screens intersecting the water table, but including only a short interval of the saturated aquifer, in an effort to isolate the effects of the LTF on the groundwater from the effects of the upgradient hydrocarbon plume.

The Washita River alluvial sand and gravel aquifer extends from a depth of 0 to 62 feet beneath the LTF and SWRP. Only about the upper 28-33 feet consist of permeable sands and gravels. The lower 33-62 feet consist of a very low permeability (7.0×10^{-9} cm/sec average vertical permeability) clay which overlies the Pennsylvanian shale bedrock. Wells LMW1 through LMW6 are screened through the entire thickness of the sands and gravels of the Alluvial Aquifer, with the screened section extending above the saturated zone to allow for seasonal water-level fluctuations. Piezometer wells LMW7 and LMW8 were installed to more precisely monitor the water table configuration and flow regime beneath the LTF. These wells (LMW7 and LMW8) are each 10 feet deep and extend 5 feet into the zone of saturation in the Alluvial Aquifer. KMRC included monitor wells LMW2, LMW2-O, LRW2, and LRW2-O (Figure 12-1) in the RCRA monitoring system for the Groundwater Assessment Program proposed to the OSDH in July, 1987.

The monitoring well network for the SWRP consists of two (2) crossgradient/downgradient wells SMW-4 and SMW-9; one (1) upgradient well SMW-5, and one (1) upgradient/crossgradient well SMW-6. All of these wells are screened within the upper portion of the alluvial aquifer. This monitoring well network for the SWRP was in place in December 1992, and quarterly groundwater monitoring will be performed in calendar year 1993 (semi-annual monitoring beginning in June, 1994).

The locations of all RCRA groundwater monitoring wells installed at the LTF are shown in Figure 12-1, and the location of wells at the SWRP are shown in Figure 12-2. Soil boring lithologic logs and monitor well completion diagrams for these wells, the three piezometer wells (LMW7, LMW8, and LMW2), and the SWRP wells are included in Appendices J and K.

12.5.2 Representative Samples.

The waste management area at the Wynnewood LTF previously included the area on which wastes were applied during the active life of the regulated unit. It included the horizontal space taken up by the earthen dikes which are designed to contain the applied wastes and prevent runoff from leaving or run-on from entering the site. The point of compliance at the Wynnewood LTF corresponded only to the downgradient portions of the previous waste

management area. The previous waste management area and point of compliance for the LTF are shown on Figure 3-2.

The depths and locations of the RCRA monitor wells allowed collection of representative samples of the underlying Alluvial Aquifer. Monitor wells LMW3, LMW4, and LMW5, LMW3-O, LMW4-O, LMW5-O, LRW1, and LRW1-O are all located outside of the waste management area but immediately adjacent to the point of compliance on the west and southwest sides of the LTF, as shown in Figure 12-1. Upgradient wells LMW6 and LMW6-O are located several tens of feet north of the LTF, as shown in Figure 12-1.

The data presented in Section 12-3 and Appendix J substantiates the locations of LMW6 and LMW6-O as appropriate for background water quality monitoring. This site was chosen based upon the available groundwater flow data and the fact that it is removed from the waste management area in an upgradient (or cross-gradient) direction. Wells LMW3, LMW4, LMW5, LMW3-O, LMW4-O, LMW5-O, LRW1 and LRW1-O are appropriately located downgradient along the point of compliance.

The waste management area of the SWRP previously corresponded to the physical outline of the SWRP. The point of compliance at the SWRP

corresponds only to the downgradient portions of the previous waste management area, as shown on Figure 12-2.

Representative groundwater samples are obtained from each monitoring well by evacuating each well by pumping or by bailing with a dedicated bailer. A groundwater sample is then extracted by pumping or using a dedicated bailer. The Sampling and Analysis Plan, submitted to the OSDH in November, 1990, is attached as Appendix N and discusses the monitor well evacuation and sampling procedures in detail. This plan may be updated as necessary and incorporated into the sampling activities. All procedures are designed to produce groundwater samples representative of groundwater in the interval screened by the monitor well.

12.5.3 Sampling and Analysis Procedures.

The Wynnewood Refinery has established sampling and analysis procedures for groundwater samples taken from the LTF and SWRP monitoring wells. These procedures are listed in the Sampling and Analysis Plan included in Appendix N. Both the monitor well sampling technician and the analytical laboratory observe these procedures when sampling and analyzing groundwater from the LTF and SWRP groundwater monitoring wells.

Sampling and Analysis Plan includes methodology and criteria for the following areas:

Sample Collection Method.

Sample Preservation, Packaging, and Shipment.

Analytical Procedures and Quality Control

Chain-of-Custody Procedures

5.4 Groundwater Elevation Determination

RCRA groundwater monitor wells at the Wynnewood Refinery have been surveyed by a professional licensed surveyor for location on the Refinery coordinate grid and for Mean Sea Level (MSL) elevation. Horizontal control is within 1.0 feet and vertical elevation control is within 0.01 feet MSL. A summary of the RCRA groundwater monitor wells' coordinates and elevations is presented in Table 12-13.

Procedures for measuring groundwater elevation are included in the Sampling and Analysis Plan, Appendix N. Annual potentiometric surface maps are drawn for the LTF based on the water level data generated from several of the quarterly sampling events. Annual potentiometric surface maps for the LTF are shown in Figures 12-3a through 12-3h. Potentiometric surface maps for the WRP area for January, 1992 and April, 1992 are shown on Figure 12-4a and

12-4b. A Refinery-wide potentiometric surface map for November, 1992 is shown on Figure 12-5.

12.5.5 Groundwater Quality Data Interpretation

In accordance with the Long-Term Groundwater Assessment Plan proposed in June, 1990 (attached as Appendix O), the fourteen LTF RCRA monitor wells were proposed to be sampled on a quarterly basis for the following parameters: total metals, barium, chromium, lead, and selenium; benzene, ethylbenzene, toluene, and total xylenes (BTEX); and total petroleum hydrocarbons (TPH). KMRC is amending their analytical list proposed in the June, 1990 Long-Term Groundwater Assessment Plan to include total barium, chromium, lead, and selenium; and benzene, ethylbenzene, toluene, and total xylenes. Total petroleum hydrocarbons will no longer be analyzed from the RCRA well network. The four (4) metal parameters and BTEX will be monitored in the 14 LTF monitor wells and the four (4) SWRP monitor wells during the post-closure care monitoring period. The concentrations of each metal and total BTEX will be monitored and charted with time for each well. This will enable KMRC to monitor the impact of the upgradient hydrocarbon recovery system on the aquifer, and to see changes in metal and organic concentrations in wells upgradient from the LTF and SWRP. This program will also enable KMRC to establish trends in concentration in both upgradient and downgradient monitor wells. Charts of these constituents (where data was available) are enclosed in

Appendix P, along with a tabulation of the historical analytical data (metals and BTEX) for the fourteen (14) LTF wells.

Groundwater sampling will continue in accordance with the existing Long-Term Groundwater Assessment Plan until the assessment is complete, in 1995. At that time, a long-term monitoring program will be developed for the LTF.

12.6 Post-Closure and Long-Term Groundwater Monitoring Requirements

The LTF is closed and closure of the SWRP will proceed upon OSDH approval of the interim status closure plan submitted to the OSDH and EPA on November 30, 1992. Groundwater monitoring requirements for the LTF will be performed in accordance with the Long-Term Groundwater Assessment Plan (Appendix O) submitted in June, 1990. The SWRP groundwater monitoring requirements will also be performed in accordance with the Long-Term Groundwater Assessment Plan and the interim status post-closure groundwater monitoring program discussed below.

12.6.1 LTF Post-Closure Monitoring Requirements

Groundwater monitoring for the LTF will continue in accordance with the existing Long-Term Groundwater Assessment Plan, which was submitted to the OSDH on June 22, 1990. This Long-Term Groundwater Assessment Plan will

be conducted for a period of five (5) years. Upon completion of this assessment, a post-closure monitoring program will be developed for the LTF.

12.6.2 SWRP Post-Closure Monitoring Requirements

12.6.2.1 Introduction

Groundwater monitoring at the SWRP will be performed during the post-closure care period to monitor the groundwater quality beneath the SWRP and to provide assurance that groundwater quality goals applicable to analytical parameters monitored in groundwater are achieved. KMRC proposes that post-closure groundwater monitoring will be performed in accordance with the Long-Term Groundwater Assessment Plan proposed for the Wynnewood Refinery in June 1990 and the groundwater monitoring program described in the November 30, 1992 Interim Status Post-Closure Plan for the SWRP. An alternate groundwater monitoring system (pursuant to 40 CFR 265.90(d)) is being utilized for the SWRP, and these documents (the Long-Term Groundwater Assessment Plan and the Interim Status Post-Closure Plan) constitute a Groundwater Assessment Plan in accordance with 40 CFR 265.93(d)(3). The anticipated duration of the post-closure groundwater monitoring period for the SWRP is 30 years, unless approval for a shorter post-closure care period is granted in accordance with 40 CFR 264.117(a)(2)(i).

12.6.2.2 Groundwater Monitoring System Description

A discussion of key components of the post-closure care groundwater monitoring system is presented in the following subsections.

12.6.2.3 Monitor Well Network

The proposed post-closure monitoring well network is shown on Figure 12-2. This well network consists of four (4) shallow alluvial wells (SMW-4, SMW-5, SMW-6, and SMW-9). All of these wells monitor the upper ten (10) feet of the zone of saturation in the alluvial terrace aquifer. Monitor well SMW-5 is the upgradient monitoring well for the SWRP area. Monitor well SMW-6 can also be considered as either an upgradient well or crossgradient well, depending upon seasonal changes in groundwater flow direction. Monitor wells SMW-4 and SMW-9 may serve as downgradient wells and/or crossgradient wells, depending upon seasonal changes in groundwater flow direction. A listing of the post-closure monitor wells for the SWRP are shown on Table 12-14. A summary of monitor well construction details, including well survey information, is included on Table 12-15.

12.6.2.4 Analytical Parameters

Groundwater quality data has been collected from numerous monitor wells installed at the Refinery since about 1980. RCRA related groundwater sampling and analysis programs have been conducted under the approval of the

OSDH. Based upon extensive analyses of groundwater, KMRC has identified the following principal hazardous waste constituents (PHCs) which have been detected in groundwater at the Refinery at levels of concern. These parameters are:

- Benzene
- Total Barium
- Total Chromium
- Total Lead
- Total Selenium

In addition, in the Long-Term Groundwater Assessment Plan submitted to the OSDH in June 1990, KMRC added the following parameters to the groundwater analytical list:

- Toluene
- Ethylbenzene
- Total Xylenes
- Total Petroleum Hydrocarbons

During post-closure groundwater monitoring, all of the above-listed parameters, other than total petroleum hydrocarbons, will be analyzed in groundwater samples collected from each specified upgradient and downgradient well. A

summary of the post-closure groundwater sampling parameters, analytical test methods, sample containers, sample preservatives, and holding times are presented on Table 12-16. A map showing the location of the monitoring well network is shown on Figure 12-2.

12.6.2.5 Sample Frequency

In accordance with the Long-Term Groundwater Assessment Plan (June 1990), representative groundwater samples will be obtained quarterly from each specified upgradient and downgradient well through the 1993 calendar year. Beginning in June 1994, groundwater samples will be obtained on a semiannual schedule from each specified upgradient and downgradient well until completion of the post-closure care monitoring period.

12.6.2.6 Groundwater Sampling Plan Description

A Sampling and Analysis Plan has been prepared by KMRC. This Plan is included in Appendix N and details sampling and analytical testing procedures which will be followed in the field during post-closure groundwater sampling activities.

12.6.2.7 Data Evaluation and Response Activities

The execution of the groundwater monitoring program will require the frequent review and assessment of monitoring results. Anomalous and unanticipated

results may be obtained from the program. Review and assessment activities must, therefore, be able to identify these anomalous occurrences and initiate the proper response to the monitoring results.

In the event a significant change in groundwater quality is detected, the first step will be a careful review of the laboratory analytical results for errors (such as calculation errors, reporting errors, instrument errors). If no errors are found, the KMRC may resample and analyze the groundwater in an effort to resolve any apparent discrepancies in the data.

In accordance with the Long-Term Groundwater Assessment Plan, the laboratory analytical data will be plotted in concentration versus time diagrams. This procedure will enable the analytical data to be reviewed to assess the chemical quality changes of groundwater beneath the SWRP over time. The concentration versus time diagrams will be prepared for total barium, total chromium, total lead, total selenium, benzene, and total BTEX. In addition, all analytical parameters will be compared to any applicable groundwater quality standards and this comparison will be presented in the annual data report. If significant groundwater deterioration is indicated from the concentration versus time diagrams or groundwater quality standard comparison, the OSDH will be notified of this finding within seven (7) days.

Groundwater level data will also be collected from each monitoring well in the post-closure monitoring well network. Groundwater potentiometric maps will be prepared for each sampling event to define the groundwater flow direction. The potentiometric surface map will be evaluated to insure that there has been no change in the groundwater flow direction which could affect the ability of a monitor well to properly monitor groundwater conditions beneath the SWRP.

Should a significant change in groundwater flow direction occur, KMRC will remeasure water levels in all wells and prepare a new potentiometric surface map to insure that no errors were made during the initial water level measurements.

If the groundwater still shows a significant difference from past flow maps, then KMRC will notify the OSDH within seven (7) days of this finding. KMRC will then initiate appropriate measures to insure that a post-closure care monitoring network is properly in place to monitor groundwater quality in the SWRP area. These measures may include additional water level monitoring, installation of additional wells, or a re-evaluation of the existing well network as to well placement.

The depths of each well will also be measured to insure that no excessive silt buildup occurs. If the monitor wells experience siltation problems, then additional well development will be conducted.

12.6.2.8 Data Reporting

KMRC will prepare and submit to the OSDH an annual report summarizing the past year's sampling activities, analytical results, and groundwater flow data. This report will be submitted within 45 days of the receipt of the fourth quarter analytical data in 1993, and within 45 days of receipt of the December analytical data in subsequent years. In addition to presenting a summary of the sample analytical results, the annual report will include the laboratory analytical reports and an assessment of the data relative to the objectives and approach of post-closure groundwater monitoring. The assessment section of the report is organized in the following manner:

- Discussion of Site History
- Sampling and Analytical Procedures
- Variations in Groundwater Flow Pattern
 - Direction of Flow and Gradient
 - Velocity of Flow
- Variation in Groundwater Quality
 - Extent of Constituents

- Concentration of Constituents
- Direction and Rate of Constituent Movement
- Immiscible Phase Evaluation
- Trends Identified in Data
 - Groundwater Flow and Seasonal Groundwater Level Fluctuations
 - Constituent Concentration
 - Constituent Movement
- Comparison of Water Quality Data to Appropriate Standards
- Recommendation for Continuation or Modification of Program
- Appendices
 - Water Quality Data
 - Water Level Data

12.6.2.9 Aquifer Characterization Data

A Hydrogeological Characterization of the uppermost groundwater system beneath the SWRP is provided in Appendix K. This Hydrogeological Characterization Report provides a detailed summary of hydrogeological conditions in the SWRP area. The information provided in this report provides technical information that is necessary to properly evaluate groundwater quality and flow data generated during the post-closure groundwater monitoring program.

12.6.3 Contingent Post-Closure Groundwater Program for Tank 2007

12.6.3.1 Introduction

KMRC desires to close Tank 2007 in accordance with the closure plan described in Section 9.1. However, in the event such closure is not practicable or possible and it becomes necessary to implement the contingent closure plan, KMRC is providing this contingent post-closure groundwater program in accordance with 40 CFR 264.197(b) and 40 CFR 264.310(6)(3).

Currently, there is no groundwater monitor well system required at Tank 2007 under the 40 CFR Subpart J rules. In order to satisfy the financial requirements of 40 CFR 264.197(c)(3), a conceptual post-closure groundwater monitoring program is described in the following sections.

12.6.3.2 Conceptual Groundwater Monitoring System Description

Groundwater monitoring at Tank 2007 will be performed during the post-closure care period to monitor the groundwater quality beneath Tank 2007 and to provide assurance that groundwater quality goals applicable to analytical parameters monitored in groundwater are achieved. The anticipated duration of the post-closure groundwater monitoring period for Tank 2007 is 30 years, unless approval for a shorter post-closure care period is granted in accordance with 40 CFR 264.117(a)(2)(i). A discussion of key components of the post-closure care groundwater monitoring system is presented below.

12.6.3.3 Monitor Well Network

The conceptual post-closure monitoring well network will consist of at least one (1) background monitoring well and two (2) detection monitoring wells. The number of detection monitoring wells is appropriate due to the small size (34 feet diameter) of the potential source area. All installed wells will monitor the upper ten (10) feet of the zone of saturation in the alluvial terrace aquifer. Existing monitoring wells will be evaluated to determine if incorporation or adaption into this post-closure monitoring program is appropriate. If new monitoring wells are to be installed, all construction methods will be in accordance with applicable OWRB rules and EPA guidance criteria existing at the time of installation.

12.6.3.4 Analytical Parameters

Groundwater quality data has been collected from numerous monitor wells installed at the Refinery since about 1980. RCRA related groundwater sampling and analysis programs have been conducted under the supervision of the OSDH. Based upon extensive analyses of groundwater, KMRC has identified the following principal hazardous waste constituents (PHCs) which have been detected in groundwater at the Refinery at levels of concern. These parameters are:

- Benzene
- Total Barium

- Total Chromium
- Total Lead
- Total Selenium

In addition, in the Long-Term Groundwater Assessment Plan submitted to the OSDH in June 1990, KMRC added the following parameters to the groundwater analytical list:

- Toluene
- Ethylbenzene
- Total Xylenes
- Total Petroleum Hydrocarbons

During post-closure groundwater monitoring, all of the above-listed parameters, other than total petroleum hydrocarbons, will be analyzed in groundwater samples collected from each specified upgradient and downgradient well. These parameters are appropriate because K049, K051, and F037 wastes, previously stored in Tank 2007, include these parameters as shown by waste analysis. A summary of the conceptual post-closure groundwater sampling parameters, analytical test methods, sample containers, sample preservatives, and holding times are presented on Table 12-16.

12.6.3.5 Sample Frequency

Groundwater samples will be obtained on a semiannual schedule from each specified upgradient and downgradient well until completion of the post-closure care monitoring period. The semi-annual sampling frequency is consistent with the Long-Term Groundwater Assessment Plan (June, 1990) and the ongoing monitoring program which encompasses the Tank 2007 area.

12.6.3.6 Groundwater Sampling Plan Description

A detailed Groundwater Sampling and Analysis Plan dated November 30, 1990, has been prepared by KMRC and is enclosed in Appendix N. This Plan details sampling and analytical testing procedures which will be followed in the field during post-closure groundwater sampling activities for Tank 2007.

12.6.3.7 Data Evaluation and Response Activities

The execution of the groundwater monitoring program will require the frequent review and assessment of monitoring results. Anomalous and unanticipated results may be obtained from the program. Review and assessment activities must, therefore, be able to identify these anomalous occurrences and initiate the proper response to the monitoring results.

In the event a significant change in groundwater quality is detected, the first step will be a careful review of the laboratory analytical results for errors (such as calculation errors, reporting errors, instrument errors). If no errors are found,

the KMRC may resample and analyze the groundwater in an effort to resolve any apparent discrepancies in the data.

In accordance with the Long-Term Groundwater Assessment Plan, the laboratory analytical data will be plotted in concentration versus time diagrams. This procedure will enable the analytical data to be reviewed to assess the chemical quality changes of groundwater beneath the closed Tank 2007 over time. The concentration versus time diagrams will be prepared for total barium, total chromium, total lead, total selenium, benzene, and total BTEX. In addition, all analytical parameters will be compared to any applicable groundwater quality standards and this comparison will be presented in the annual data report. If significant groundwater deterioration is indicated from the concentration versus time diagrams or groundwater quality standard comparison, the OSDH will be notified of this finding within seven (7) days.

Groundwater level data will also be collected from each monitoring well in the post-closure monitoring well network. Groundwater potentiometric maps will be prepared for each sampling event to define the groundwater flow direction. The potentiometric surface map will be evaluated to insure that there has been no change in the groundwater flow direction which could affect the ability of a monitor well to properly monitor groundwater conditions beneath the closed Tank 2007.

Should a significant change in groundwater flow direction occur, KMRC will remeasure water levels in all wells and prepare a new potentiometric surface map to insure that no errors were made during the initial water level measurements.

If the groundwater still shows a significant difference from past flow maps, then KMRC will notify the OSDH within seven (7) days of this finding. KMRC will then initiate appropriate measures to insure that a post-closure care monitoring network is properly in place to monitor groundwater quality in the closed Tank 2007 area. These measures may include additional water level monitoring, installation of additional wells, or a re-evaluation of the existing well network as to well placement.

The depths of each well will also be measured to insure that no excessive silt buildup occurs. If the monitor wells experience siltation problems, then additional well development will be conducted.

12.6.3.8 Data Reporting

KMRC will prepare and submit to the OSDH an annual report summarizing the past year's sampling activities, analytical results, and groundwater flow data. This report will be submitted within 45 days of receipt of the December analytical data in subsequent years. In addition to presenting a summary of the sample analytical results, the annual report will include the laboratory analytical

reports, and an assessment of the data relative to the objectives and approach of post-closure groundwater monitoring. The assessment section of the report will be organized in the following manner:

- Discussion of Site History
- Sampling and Analytical Procedures
- Variations in Groundwater Flow Pattern
 - Direction of Flow and Gradient
 - Velocity of Flow
- Variation in Groundwater Quality
 - Extent of Constituents
 - Concentration of Constituents
 - Direction and Rate of Constituent Movement
 - Immiscible Phase Evaluation
- Trends Identified in Data
 - Groundwater Flow and Seasonal Groundwater Level Fluctuations
 - Constituent Concentration
 - Constituent Movement
- Comparison of Water Quality Data to Appropriate Standards
- Recommendation for Continuation or Modification of Program
- Appendices
 - Water Quality Data
 - Water Level Data

12.6.3.9 Aquifer Characterization Data

A Hydrogeological Characterization of the uppermost groundwater system, including the area near Tank 2007, is provided in Appendix J. This Hydrogeological Characterization Report provides a detailed summary of hydrogeological conditions near the Tank 2007 area. The information provided in this report provides technical information that is necessary to properly evaluate groundwater quality and flow data generated during the post-closure groundwater monitoring program.

**Table 12-1: Interim Status Detection Monitoring Program
Groundwater Monitoring Parameters**

Indicator Parameters for Groundwater Contamination:

pH - standard units
Specific Conductance C - umhos
Total Organic Carbons - mg/l
Total Organic Halogens - mg/l

Groundwater Quality Parameters:

Chloride - mg/l
Iron - mg/l
Manganese - mg/l
Phenols - mg/l
Sodium - mg/l
Sulfate - mg/l

Interim Primary Drinking Water Standards:

<u>Parameter (unit)</u>	<u>Maximum Level</u>
Arsenic - mg/l	0.05
Barium - mg/l	1.0
Cadmium - mg/l	0.01
Chromium - mg/l	0.05
Fluoride - mg/l	1.4 - 2.4
Lead - mg/l	0.05
Mercury - mg/l	0.002
Nitrate - mg/l	10
Selenium - mg/l	0.01
Silver - mg/l	0.05
Endrin - mg/l	0.0002
Lindane - mg/l	0.004
Methoxychlor - mg/l	0.1
Toxaphene - mg/l	0.005
2,4,-D - mg/l	0.1
2,4,5,-TP Silvex - mg/l	0.01
Gross Alpha - pCi/l	15
Gross Beta - millirem/yr	4
Radium - pCi/l	5
Coliform Bacteria - /100 ml	1

Groundwater Elevation is recorded to within 0.01 feet MSL.

Table 12-2: Background Data for Monitor Well LMW1
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>ARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
st (11-12-81)	6.44	1406	57	<1
cond (3-9-82)	6.32	1444	44	<1
rd (6-29-82)	6.30	1394	90	0.54
urth (4-28-82)	6.33	1231	19	<1
thmetic Mean Year	6.39	1369	52.5	0.172*
riance	0.0099	0.069	874	0.060*
andard eviation	0.0629	94.3	29.6	0.245
efficient of variation	0.004	8887	0.563	1.42

Mean and variance for TOX was based upon inputting a value of 0.05 mg/l for each analysis yielding < 1 mg/l for first year.

le 12-3: Background Data for Monitor Well LMW6
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>ARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
t (12-4-84)	6.45	875	15.2	0.037
ond (3-15-85)	6.58	842	8.7	0.228
d (3-12-85)	6.65	1125	15.8	0.04
rth (9-24-85)	6.40	1250	17.5	0.09
hmetic Mean r Year	6.52	1023	14.3	0.099
iance	0.0177	38,866	14.89	0.0080
ndard eviation	0.115	197.1	3.86	0.089
efficient of variation	0.018	0.193	0.27	0.904

Table 12-4 Background Data for Monitor Well LMW6-0
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>QUARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
First (9-9-86)	6.60	425	3.0	0.023
Second (12-12-86)	6.30	371.5	2.5	0.03
Third (3-19-87)	6.26	332	3.75	0.03
Fourth (9-16-87)	6.0	391.3	18	3.0
Arithmetic Mean for Year	6.29	379.9	6.81	0.77
Variance	0.060	1509	55.9	2.21
Standard Deviation	0.246	38.9	7.48	1.49
Coefficient of Variation	0.039	0.102	1.10	1.93

* Mean and variance for TOC was based upon inputting a value of 2.50 mg/l for each analysis yielding <5 mg/l for first year.

ble 12-5: Background Data for Monitor Well LMW3
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>JARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
st (11-17-81)	6.55	1131	44	<1
cond (3-9-82)	6.34	1231	24	<1
ird (6-29-82)	8.52	1175	30	<1
urth (9-28-82)	6.56	1050	11	<1
ithmetic Mean or Year	6.99	1147	27	0.5
ariance	1.05	5835	187	0.0
andard Deviation	1.02	76.4	13.7	0.0
efficient of /ariation	0.146	0.067	.507	0.0

Table 12-6: Background Data for Monitor Well LMW4
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>QUARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
First (11-17-81)	7.10	1050	43	<1
Second (3-9-82)	7.27	1081	29	<1
Third (6-29-82)	8.75	775	25	<1
Fourth (9-28-82)	7.30	1000	78	<1
Arithmetic Mean for Year	7.61	976	43.7	0.5
Variance	0.59	19,159	581	0.0
Standard Deviation	0.768	138	24.1	0.0
Coefficient of Variation	0.101	0.142	0.55	0.0

le 12-7: Background Data for Monitor Well LMW5
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>ARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
t (11-17-81)	6.87	775	44	< 1
ond (3-9-82)	6.64	831	26	< 1
rd (6-29-82)	9.20	1120	46	2
irth (9-28-82)	6.67	775	49	< 1
thmetic Mean r Year	7.35	875	41.2	0.875
riance	1.54	766,062	107	0.56
ndard eviation	1.24	165.3	10.3	0.75
efficient of variation	0.169	0.189	0.25	0.857

Table 12-8: Background Data for Monitor Well LMW3-0
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>QUARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
First (9-9-86)	6.13	445	7.7	33
Second (12-12-86)	6.12	501	8	34
Third (3-19-87)	6.56	499	11	<30
Fourth (7-16-87)	6.24	493	7.7	23
Arithmetic Mean for Year	6.26	484	8.6	26.2
Variance	0.042	705	2.58	81
Standard Deviation	0.206	26.5	1.61	9.0
Coefficient of Variation	0.033	0.055	0.187	0.34

Table 12-9: Background Data for Monitor Well LMW4-0
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>DATE</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
Start (9-9-86)	6.23	951	11.2	61
End (12-12-86)	6.10	940	84	39
Mid (3-19-87)	6.14	846	12	40
Birth (7-16-87)	6.00	1056	12.8	40
Arithmetic Mean for Year	6.12	948	30	45.0
Variance	0.009	7380	1296	114
Standard Deviation	0.095	85.9	36	10.7
Coefficient of				

Table 12-10:

Background Data for Monitor Well LMW5-0
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>QUARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
First (9-9-86)	6.48	774	11.2	41.6
Second (12-12-86)	6.23	667	65	2.2
Third (3-19-87)	6.40	640	10	<30
Fourth (7-16-87)	6.13	720	11	35
Arithmetic Mean for Year	6.31	700	24.3	23.4
Variance	0.025	3521	736	0.775
Standard Deviation	0.159	59.3	27.1	18.1
Coefficient of Variation	0.025	0.085	1.17	328

le 12-11:

Background Data for Monitor Well LRW1
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>ARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
(7-16-87)	6.29	1083	16.6	34
ond (10-2-87)	6.26	965	18.9	46
d (11-18-87)	6.35	982	16.3	26
rth (3-7-88)	*	*	28	32
hmetic Mean r Year	6.3	1010	20	34.5
ance	0.002	4069	30.1	70.3
ndard viation	0.046	63.8	5.49	8.39
fficient of riation	0.007	0.063	0.275	0.243

Table 12-12

Background Data for Monitor Well LR -0
Means, Variance, Standard Deviation,
and Coefficient of Variation

<u>QUARTER</u>	<u>pH</u> <u>Standard Units</u>	<u>CONDUCTIVITY</u> <u>umhos/cm</u>	<u>TOC</u> <u>mg/l</u>	<u>TOX</u> <u>mg/l</u>
First (7-16-87)	5.91	895	13.2	24
Second (10-2-87)	5.92	858	14.6	52
Third (11-18-87)	5.89	797	15.2	27
Fourth (3-7-88)	*	*	19	25
Arithmetic Mean for Year	5.91	850	15.5	32
Variance	0.0002	2449	6.15	179
Standard Deviation	0.015	49.5	2.48	13.4
Coefficient of Variation	0.003	0.058	0.16	0.42

* - not measured

TABLE 12-13

MONITOR WELL COORDINATES AND ELEVATIONS

<u>LL ME</u>	<u>NORTH COORDINATE</u>	<u>EAST COORDINATE</u>	<u>TOP OF CASING ELEVATION</u>
<u>Wells</u>			
W1	-1638	-103	852.09
W2	-2494	-106	852.40
W2-O	-2502	-106	851.39
W3	-2916	-958	850.70
W3-O	-2922	-965	849.61
W4	-1891	-1138	850.75
W4-O	-1900	-1136	850.19
W5	-1108	-966	850.53
W5-O	-1105	-976	850.07
W6	-627	-512	851.15
W6-O	-619	-511	851.01
W7	-2092	-770	851.71
W8	-2154	-189	852.36
W9	-1804	-291	853.11
W10	-1526	-375	853.02
W11	-1851	-96	852.53
W12	-944	-98	852.09
W13	-1289	-62	854.62
W14	-1371	-236	853.42
IW1	-2569	-1243	849.57
IW1-O	-2578	-1245	849.31
IW2	-1068	-102	852.11
IW2-O	-1077	-101	853.16
<u>MRP Wells</u>			
W-4	-3383	-63	851.40
W-5	-3300	+325	854.42
W-6	-3465	+363	854.07
W-9	-3542	+52	852.16

Table 12-14: List of SWRP Post-Closure Monitor Wells
 Kerr-McGee Refining Corporation
 Wynnewood, Oklahoma

MONITOR WELL IDENTIFICATION	WELL DESIGNATION
SMW-5	UPGRADIENT WELL
SMW-6	UPGRADIENT WELL/CROSSGRADIENT WELL
SMW-4	CROSSGRADIENT/DOWNGRADIENT WELL
SMW-9	CROSSGRADIENT/DOWNGRADIENT WELL

Table 12-15:

WELL
NUMBERDATE
DRILLED"DRILLED
DEPTH,
FEET

**(2) GROUND
LEVEL ELEV.
FEET, AMSL**

**(2) TOP OF
WELL CASING
ELEVATION
FEET, AMSL**

(2) TOTAL
WELL DEPTH,
FEET

1" PVC
CASING
STICKUP,
FEET

"WELL
SCREEN
INTERVAL,
FEET

SMW-4

29-JUN-89

16.3

848.81

851.40

18.89

2.59

60.160

SMW-5

27-JUN-89

24.0

852.16

854.42

22.46

2.26

9.9-19.9

SMW-6

25-MAY-90

24.5

852.00

854.07

22.07

2.07

5.0-20.0

SMW-9

23-NOV-92

20.0

849.39

852.16

22.77

2.77

6.7-16.7

NOTES:

ALL MONITOR WELLS DRILLED UTILIZING HOLLOW STEM AUGER DRILLING TECHNIQUES.

ALL MONITOR WELLS CONSTRUCTED OF TWO (2) INCH DIAMETER SCHEDULE 40 PVC CASING AND SCREEN.

ALL MONITOR WELL SCREEN INTERVALS CONSTRUCTED OF 0.01 INCH SLOT SCREEN

¹¹¹: DENOTES DEPTH IN FEET BELOW GROUND.

⁽²⁾: DENOTES ELEVATION IN FEET ABOVE MEAN SEA LEVEL (AMSL).

(3). DENOTES DEPTH IN FEET FROM TOP OF PVC WELL CASING.

Table 12-16: SWRP Post-Closure Groundwater Sampling Parameters
Analytical Methods and Sample Handling
Kerr-McGee Refining Corporation
Wynnewood, Oklahoma

PARAMETER	ANALYTICAL METHOD	CONTAINER	PRESERVATION	MAXIMUM HOLDING TIME
TOTAL BARIUM	208.1	GLASS OR PLASTIC	COOL 4°C HNO ₃ TO PH<2	6 MONTHS
TOTAL CHROMIUM	218.1	GLASS OR PLASTIC	COOL 4°C HNO ₃ TO PH<2	6 MONTHS
TOTAL LEAD	239.1	GLASS OR PLASTIC	COOL 4°C HNO ₃ TO PH<2	6 MONTHS
TOTAL SELENIUM	270.3	GLASS OR PLASTIC	COOL 4°C HNO ₃ TO PH<2	6 MONTHS
BTEX	8020	GLASS, TEFLON LINED SEPTUM ZERO HEADSPACE	COOL 4°C HCL TO PH<2	14 DAYS
NOTES: REFERENCE: TEST METHODS FOR EVALUATING SOLID WASTE, EPA-SW-846, NOVEMBER 1986.				

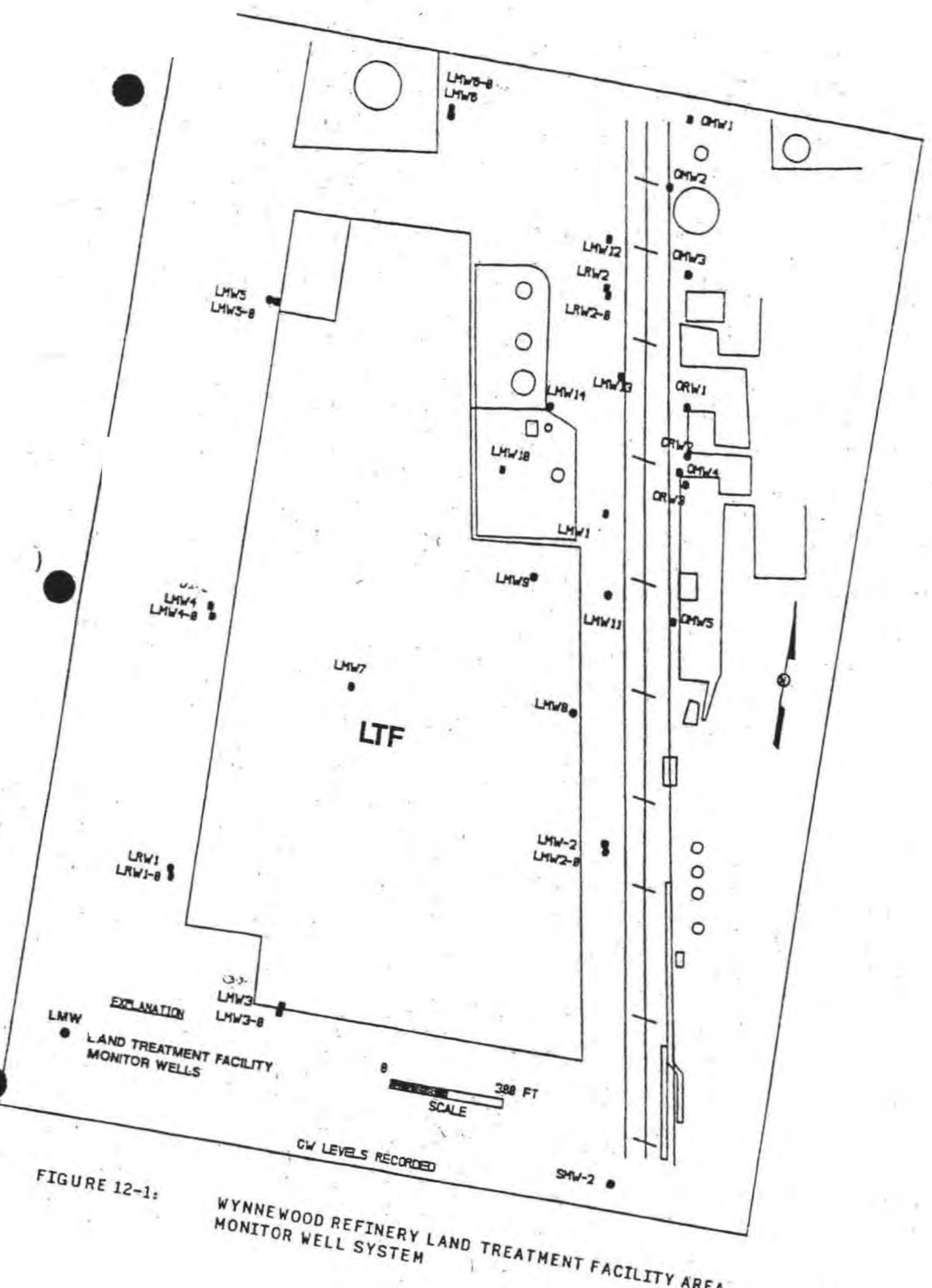


FIGURE 12-1:

WYNNEWOOD REFINERY LAND TREATMENT FACILITY AREA
MONITOR WELL SYSTEM



SCALE
0' 100' 200' 300'

LEGEND

SMW-3 ● MONITOR WELL LOCATION
--- POINT OF COMPLIANCE

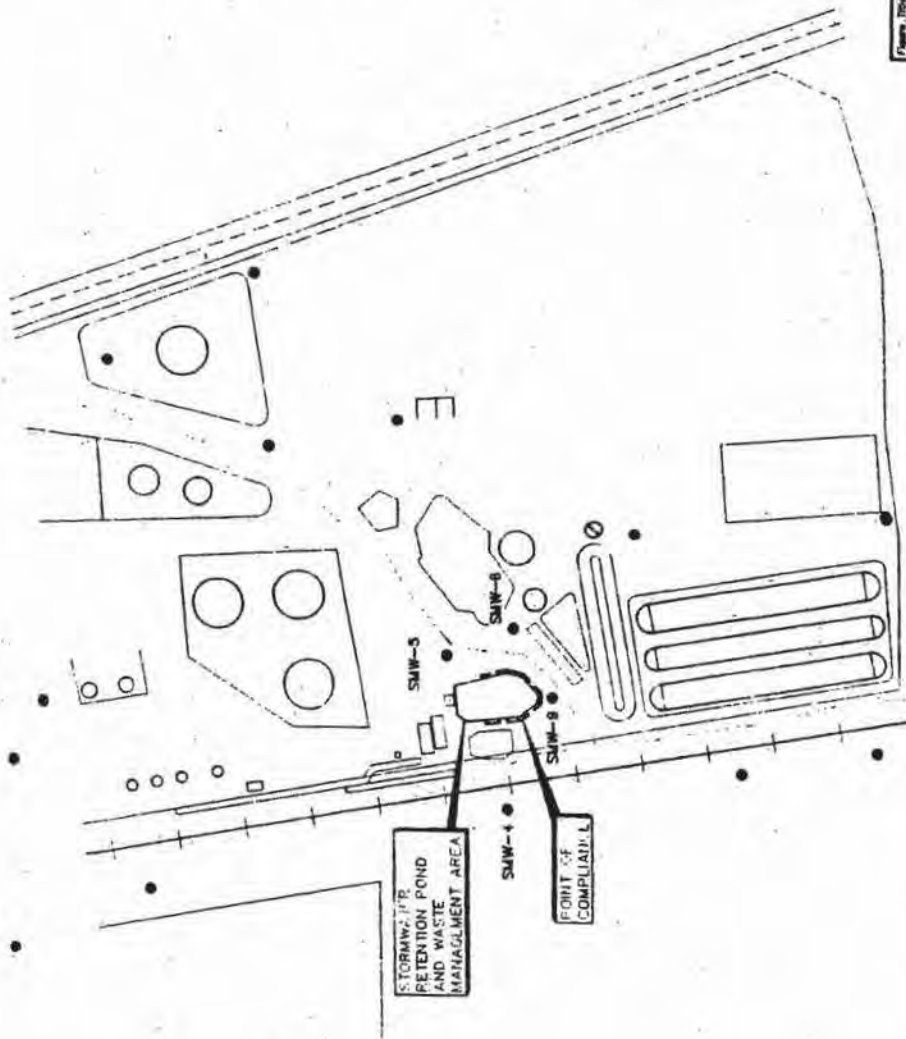


Figure Title	SWRP FACILITY LAYOUT AND POINT OF COMPLIANCE	Client	KERR-MCGEE REFINING CORPORATION
Document Title		Location	WYNNWOOD, OKLAHOMA
ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants 1000 West 10th Street Tulsa, Oklahoma 74103		DATE	1/2/83
		PREPARED BY	MIL
		CHECKED BY	BUS
		ADOPTED BY	TH
		PROJECT NO.	PROJECT NO.
		ATTACHMENT	12-2

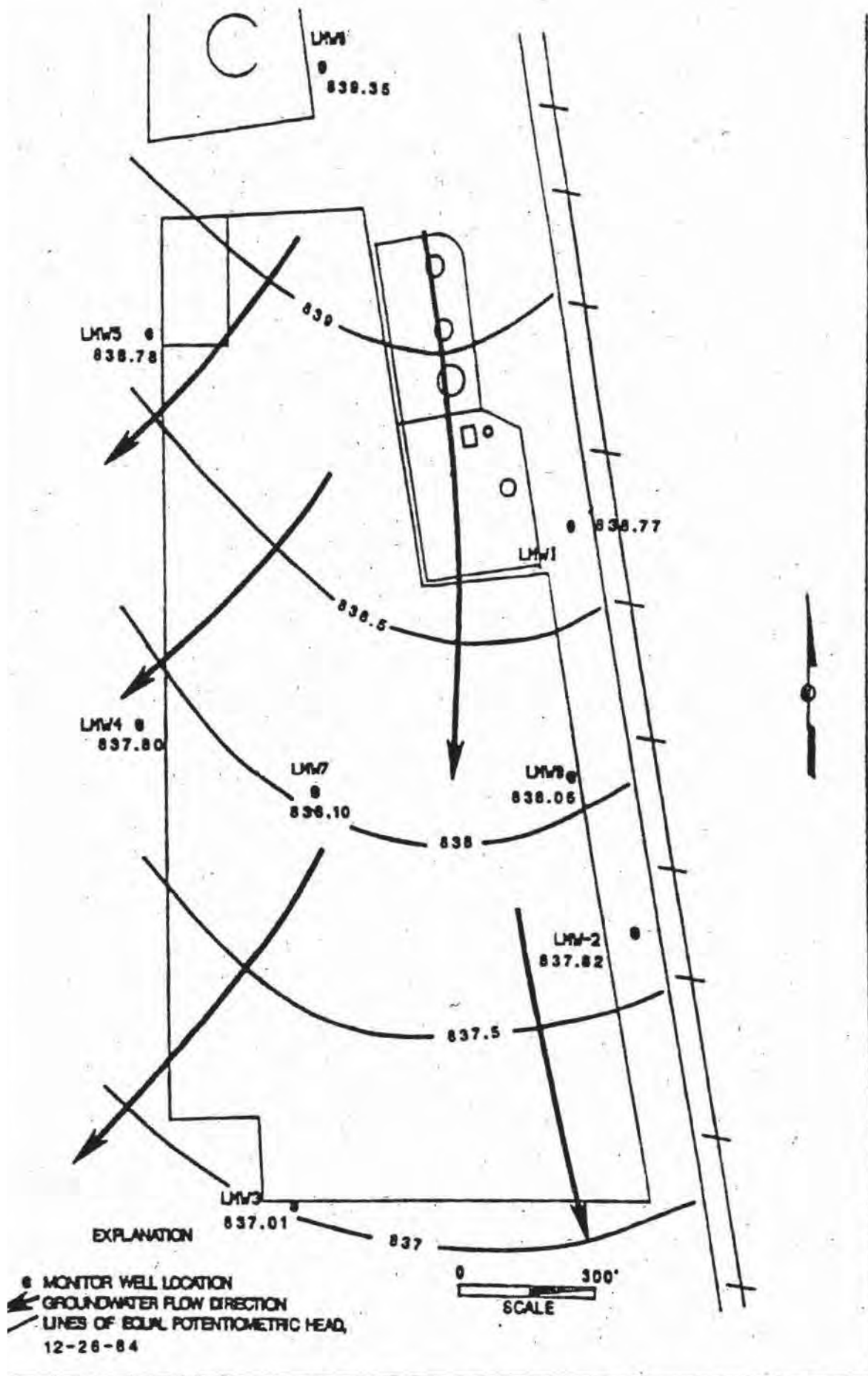


FIGURE 12-3A POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,
KMRC, WYNNEWOOD, OK

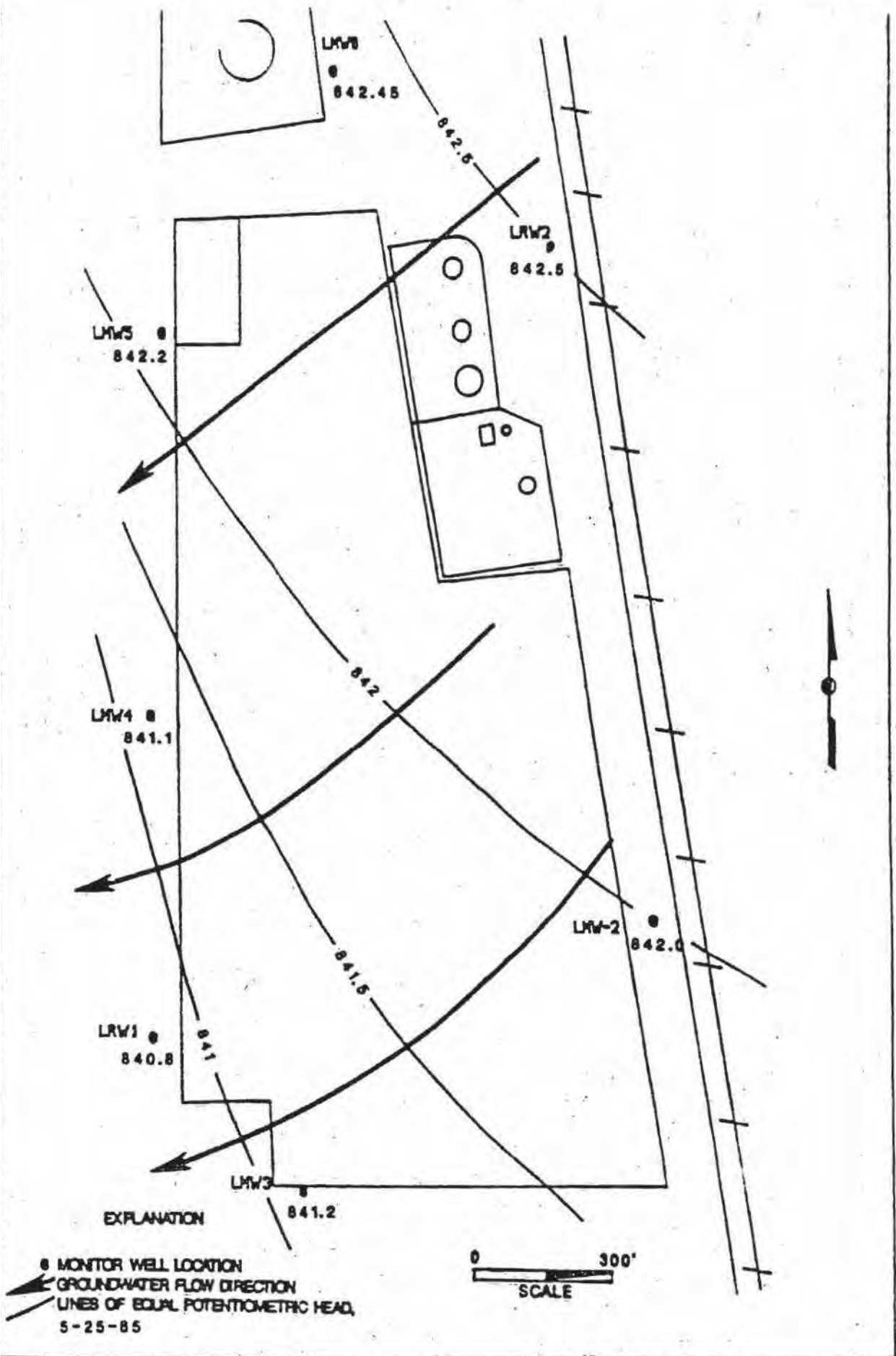


FIGURE 12-3B POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,
KMRC, WYNNEWOOD, OK

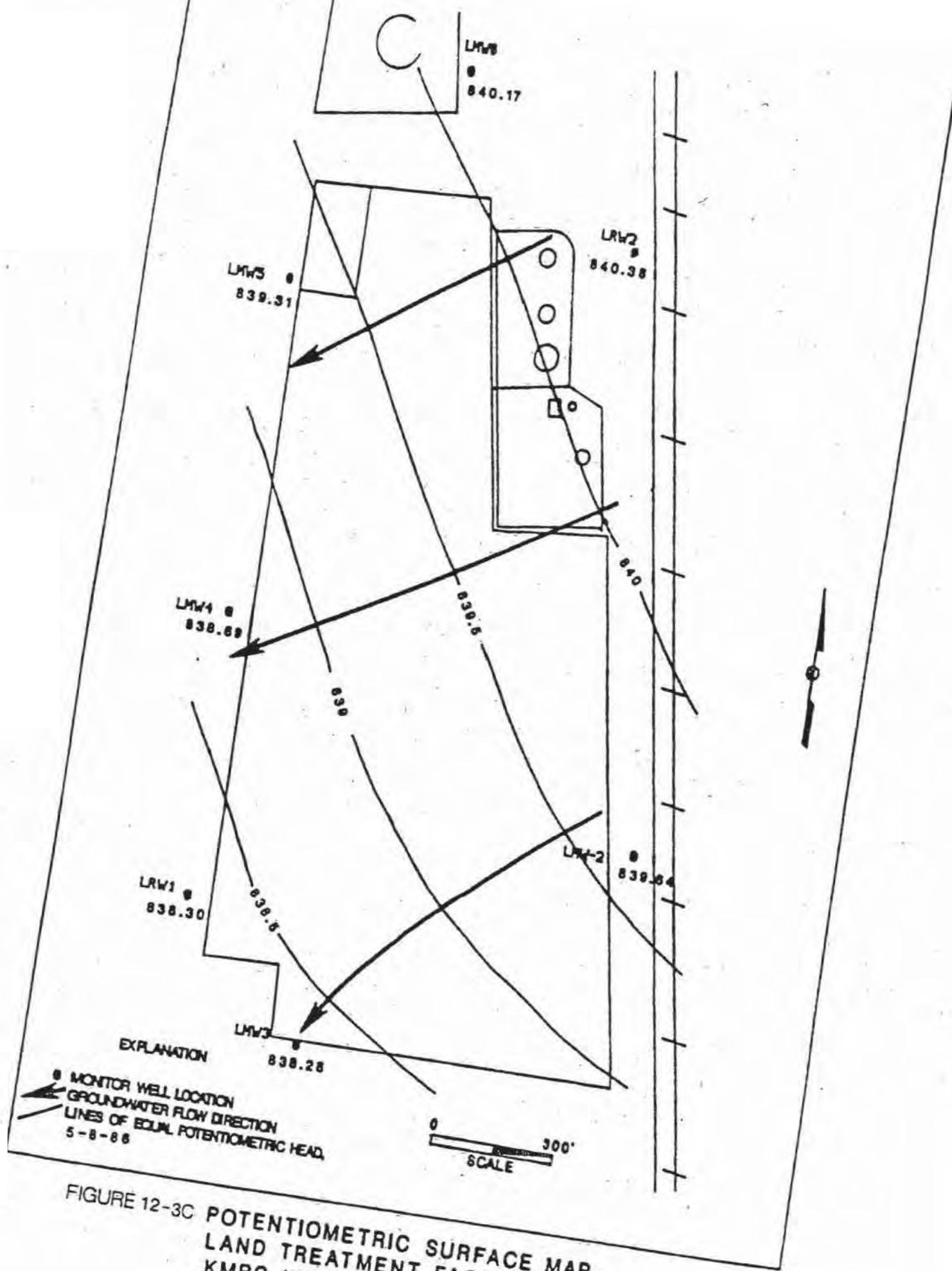


FIGURE 12-3C POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,
KMRC, WYNNEWOOD, OK

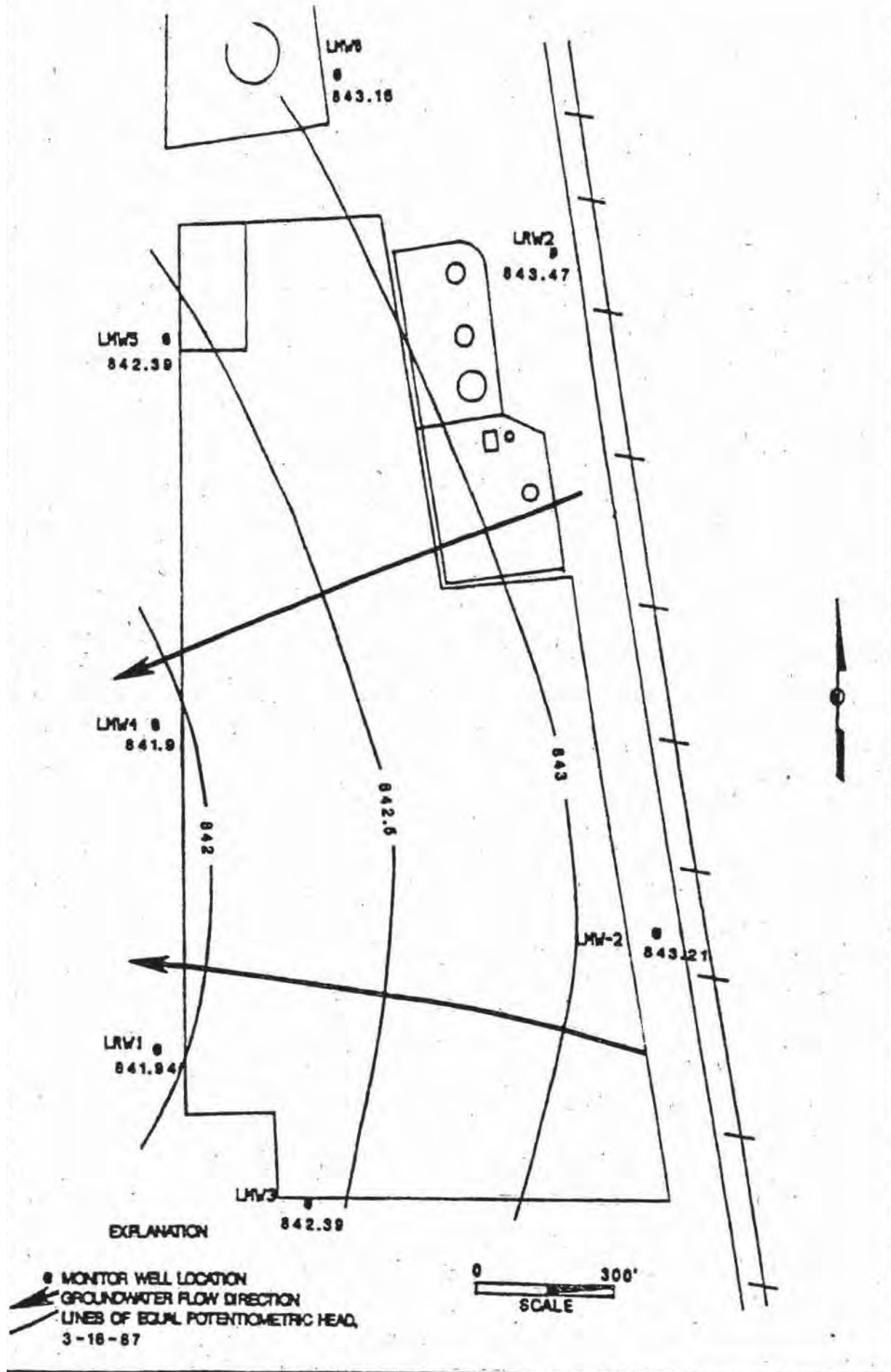


FIGURE 12-3D POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,
KMRC, WYNNEWOOD, OK

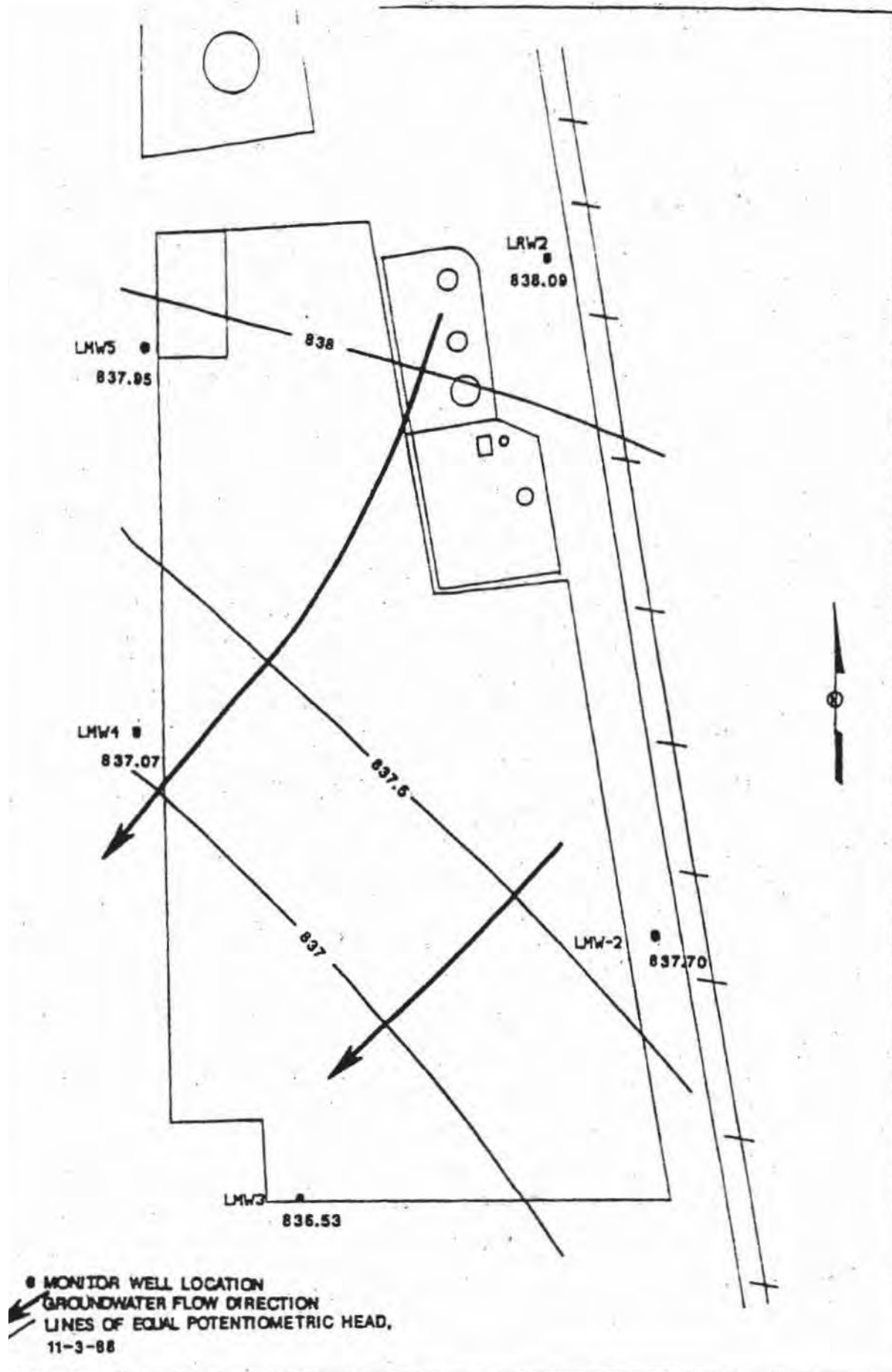


FIGURE 12-3E POTENTIOMETRIC SURFACE MAP
 LAND TREATMENT FACILITY,
 KMRC, WYNNEWOOD, OK

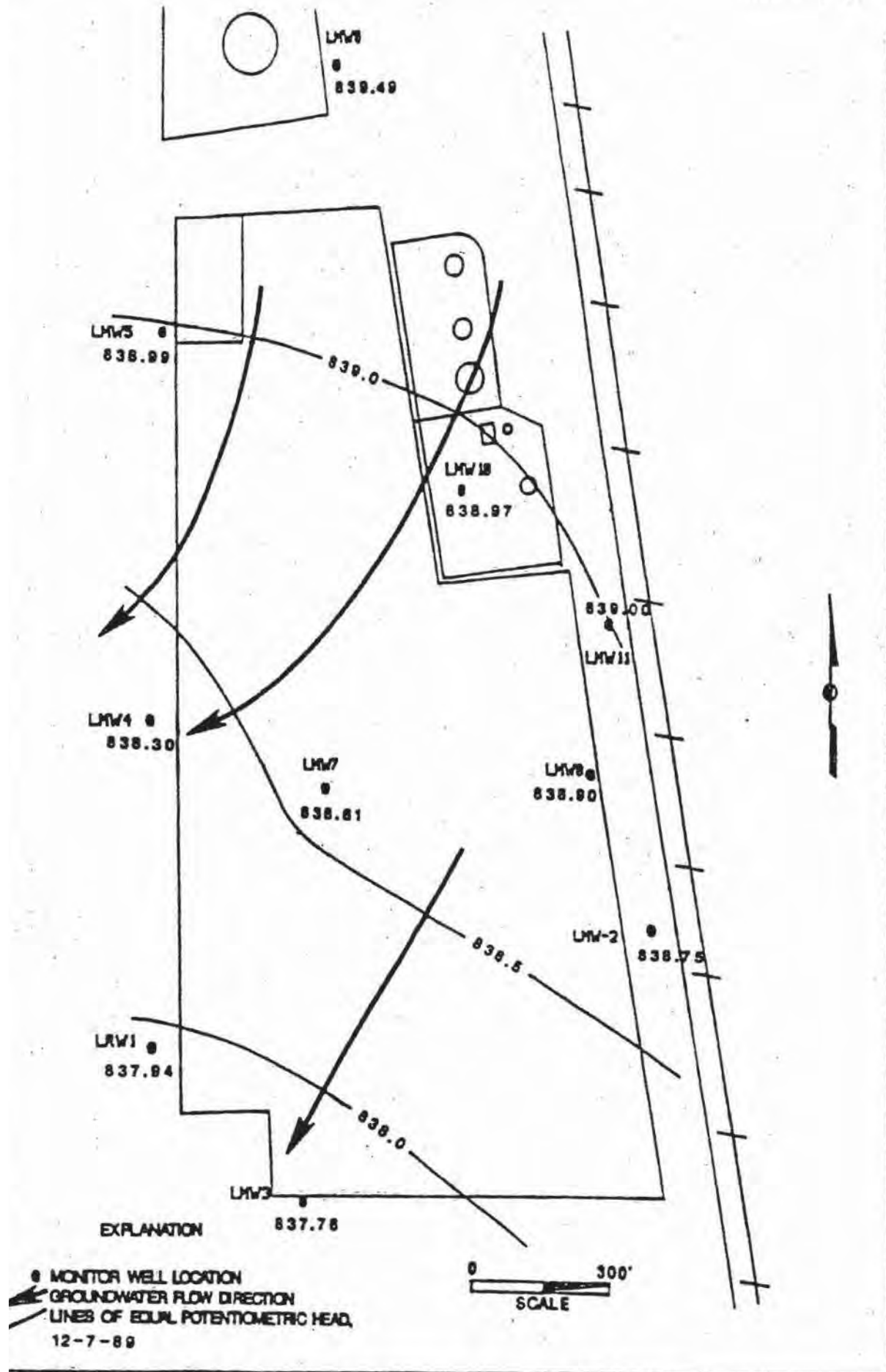


FIGURE 12-3F POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,
KMRC, WYNNEWOOD, OK

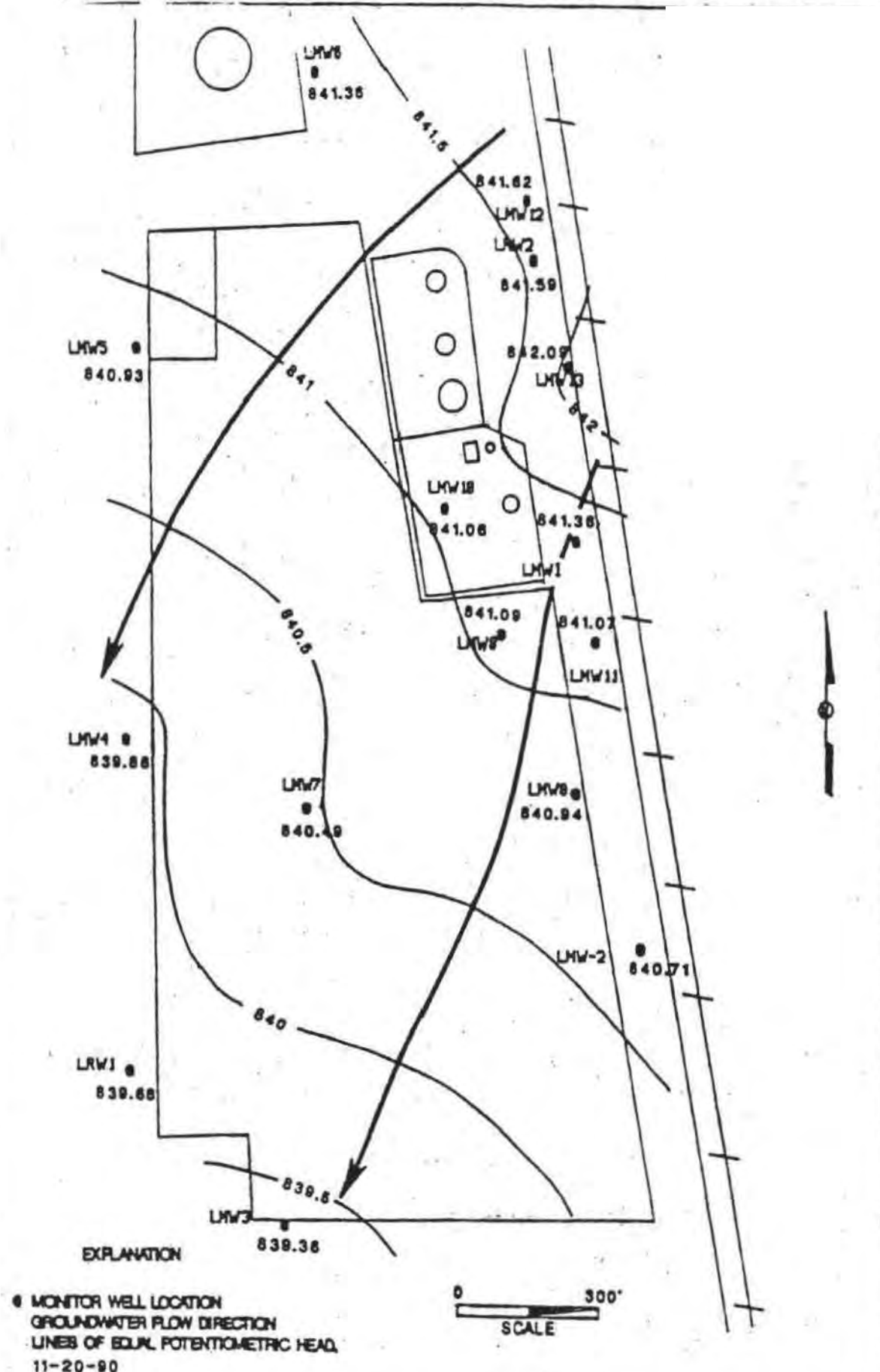


FIGURE 12-3G POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,

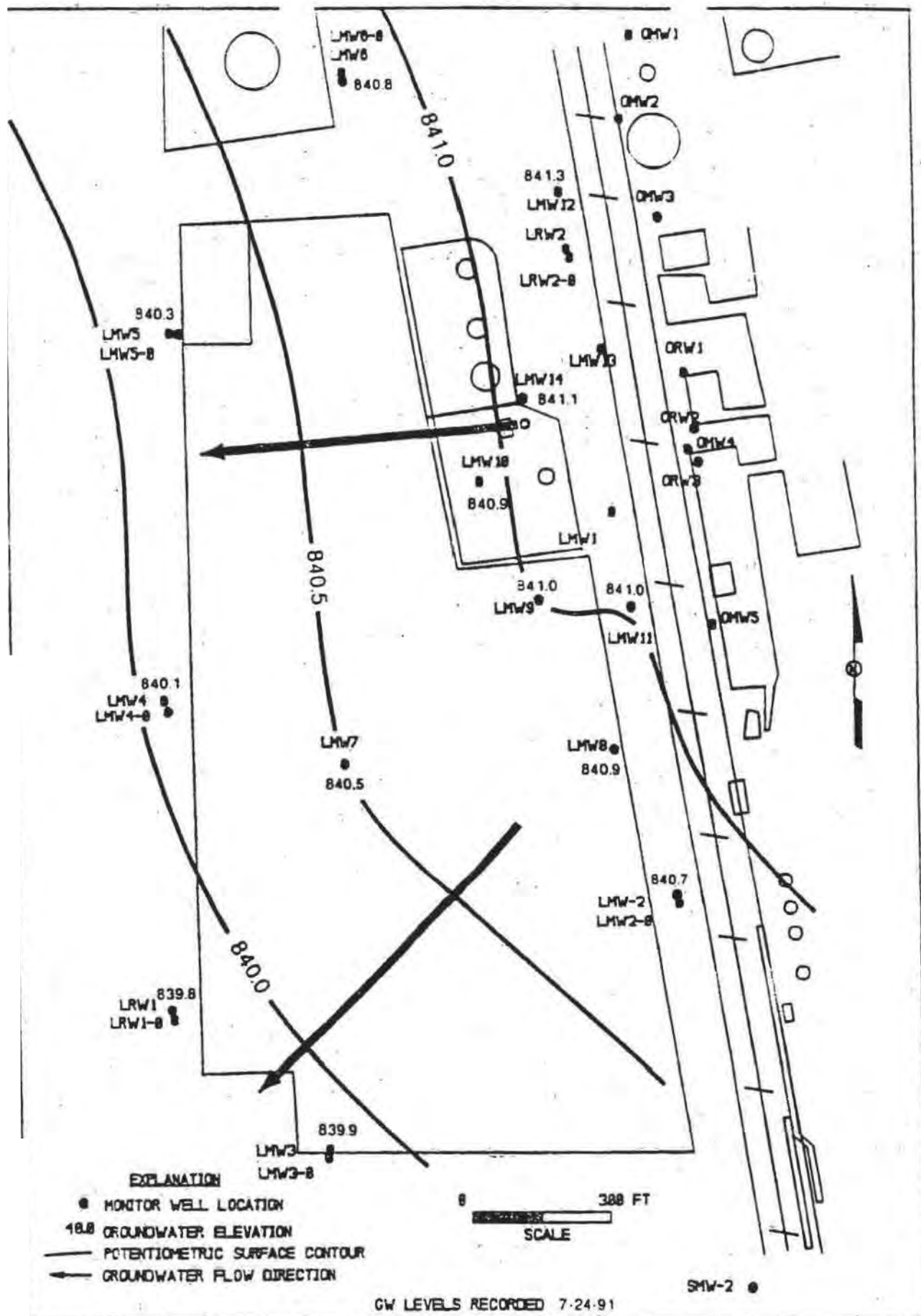
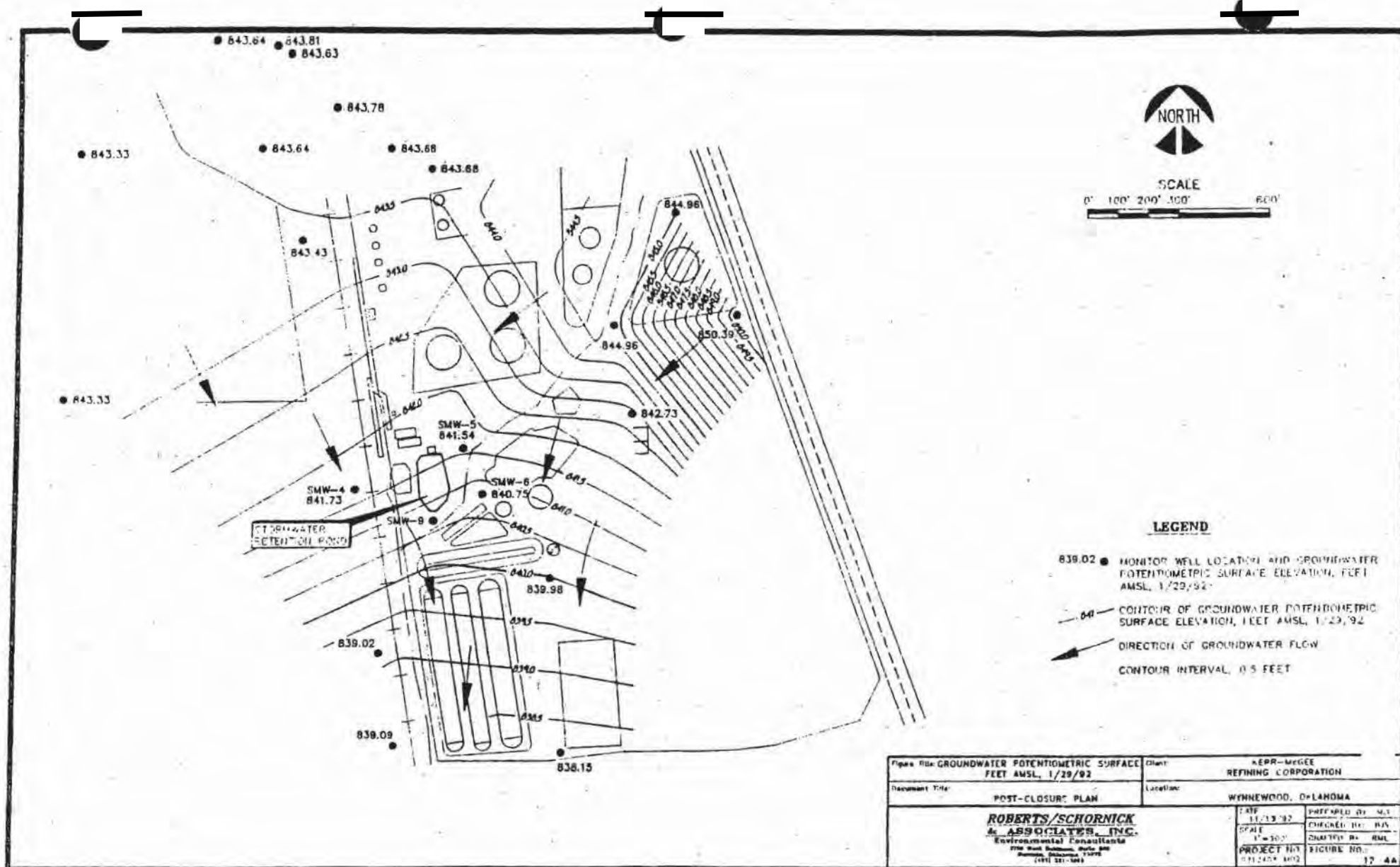
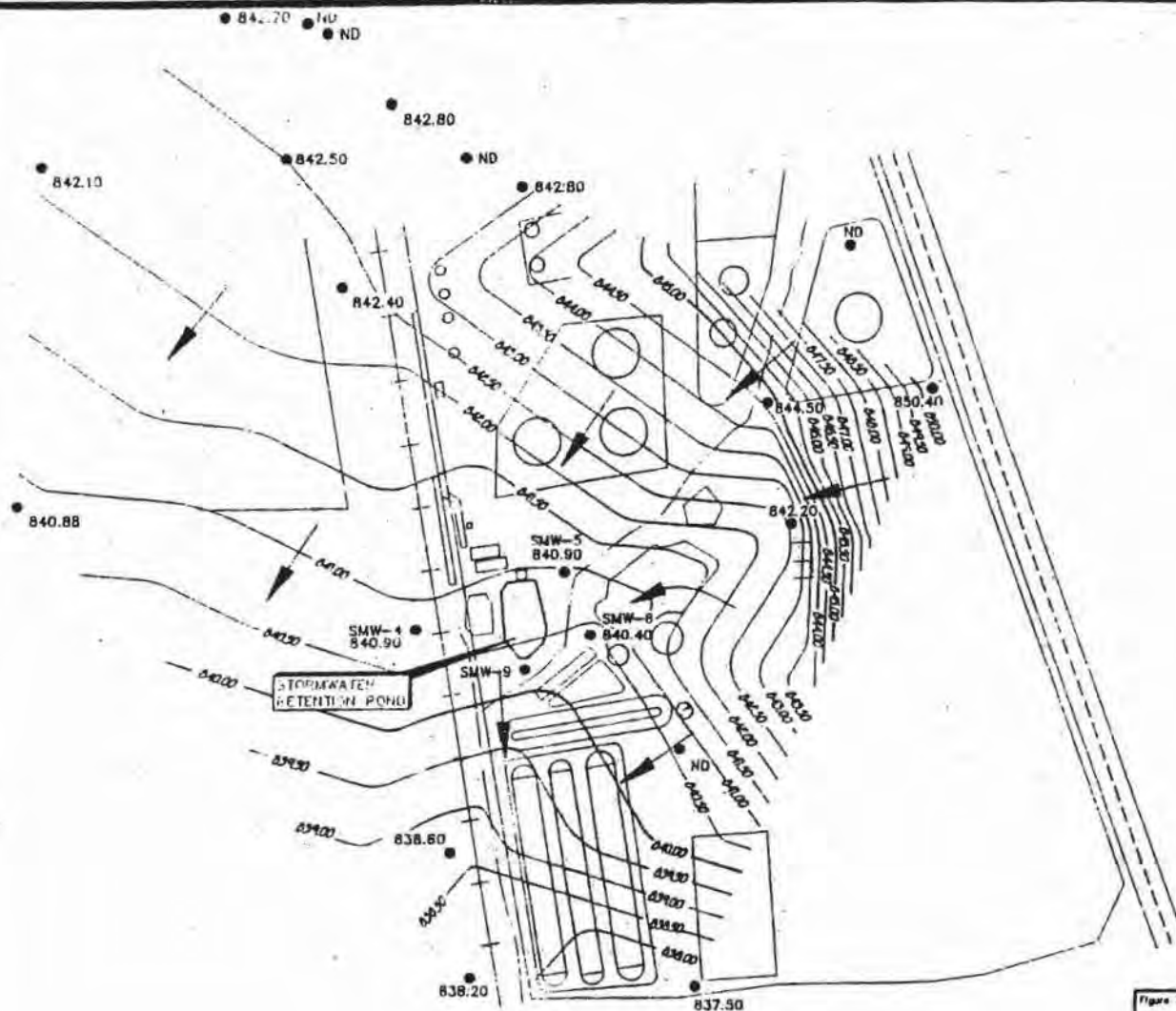


FIGURE 12-3H POTENTIOMETRIC SURFACE MAP
LAND TREATMENT FACILITY,
KMRC, WYNNEWOOD, OK



File: R10: GROUNDWATER POTENTIOMETRIC SURFACE FEET AMSL, 1/29/92	Client: KBR-MEGEE REFINING CORPORATION
Document Title: POST-CLOSURE PLAN	Location: WYNEWOOD, OKLAHOMA
ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants 700 West Oklahoma, Suite 200 Oklahoma City, Oklahoma 73106 (405) 521-1000	DATE: 11/13/92 SCALE: 1"=50' PROJECT NO: 011245X-0102
	PREPARED BY: MJS CHECKED BY: RJS DRAWN BY: RML
	FIGURE NO: 17-4A



SCALE
0' 100' 200' 300' 400'

LEGEND

838.60 ● MONITOR WELL LOCATION AND GROUNDWATER POTENTIOMETRIC SURFACE ELEVATION, FEET AMSL, 4/23/92

— 8410 — CONTOUR OF GROUNDWATER POTENTIOMETRIC SURFACE ELEVATION, FEET AMSL, 4/23/92

← DIRECTION OF GROUNDWATER FLOW

CONTOUR INTERVAL 0.5 FEET

Figure Title: GROUNDWATER POTENTIOMETRIC SURFACE, FEET AMSL, 4/23/92	Client: KERR-McGEE REFINING CORPORATION
Document Title: POST-CLOSURE PLAN	Location: WINNEWOOD, OKLAHOMA
ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants 2101 Van Hook Road, Suite 200 Tulsa, Oklahoma 74119	DATE: 11/13/92
	PREPARED BY: MJH
	CHECKED BY: BJS
	DRAWN BY: PMH
PROJECT NO:	FIGURE NO:

