RADIAN CORPORATION

FINAL DRAFT
INVESTIGATION REPORT, PHASE II
GROUNDWATER CONTAMINATION
INDUSTRIAL TRANSFORMER SUPERFUND SITE
HOUSTON, TEXAS

Prepared in Cooperation with
Texas Water Commission
U.S. Environmental Protection Agency

July 1988

Prepared By:

Riaz Ahmed, Ph.D., P.E., Program Manager
Thomas Hoskings, Ph.D., P.E., Project Director
Mary McGill, Geologist

The preparation of this report was financed by grants from the U.S. Environmental Protection Agency through the Texas Water Commission.

001471

1016383

000137

001471

RADIAN
CORPORATION

21 July 1988

Ms. Sherry Fuerst
U.S. Environmental Protection Agency
1445 Ross Avenue
Dallas, Texas 75202-2733

Dear Sherry:

Enclosed please find one final draft copy of each of the following reports pertaining to Phase II at the Industrial Transformer Superfund site:

- RI,
- FS, and
- QA/QC Report.

Please call me if you have any questions.

Sincerely,

Thomas W. Hoskings, Ph.D., P.E.
Department Head

TWH:pmb

Enclosure

001472

10675 Richmond Ave., Suite 190 / Houston, Texas 77042 / (713) 785-9225

RADIAN CORPORATION

TABLE OF CONTENTS

Page No.

Executive Summary

1.0 INTRODUCTION..... 1-1

1.1 Site Definition..... 1-2
1.2 Site History..... 1-6
1.3 Statement of the Problem..... 1-7
1.4 Objectives of the RI Phase II..... 1-9

2.0 FIELD PROGRAM..... 2-1

2.1 Monitor Well Installation Procedures..... 2-1

2.1.1 Construction of the Intermediate Depth (101) Wells..... 2-1
2.1.2 Analytical Parameters and Procedures..... 2-4
2.1.3 Well Development Procedures..... 2-5

2.2 Electric Logging..... 2-5
2.3 Plugging and Abandoning Monitor Well 3..... 2-6
2.4 Potentiometric Surface Determination..... 2-6
2.5 Water Sampling..... 2-7
2.6 Hydraulic Conductivity..... 2-8
2.7 Cone-Penetrometer Use..... 2-9

3.0 SITE GEOLOGY..... 3-1

3.1 Data Sources..... 3-1
3.2 Depositional Setting..... 3-3

4.0 CHEMICAL DATA RESULTS AND INTERPRETATION..... 4-1

4.1 Polychlorinated Biphenyls (PCBs)..... 4-1
4.2 Trichloroethene (TCE) in Soils..... 4-4

4.2.1 Phase II Data..... 4-4
4.2.2 Comparison with Phase I Data..... 4-8

4.3 Trichloroethene (TCE) in the Shallow Water-Bearing Zone..... 4-13

4.3.1 Phase II Data..... 4-14
4.3.2 Comparison with Phase I Data..... 4-21

4.4 Trichloroethene (TCE) in the Intermediate Water-Bearing Zone..... 4-24

001473

RADIAN CORPORATION

TABLE OF CONTENTS
(Continued)

		Page No.
4.5	General Aquifer Parameters	4-27
5.0	HYDROGEOLOGIC TESTING	5-1
5.1	Slug Tests	5-1
5.2	Static Water Level Measurements and Hydraulic Gradients	5-4
5.3	Estimate of Yield	5-12
5.4	Location of Plume in Uppermost Water-Bearing Zone	5-12
5.5	Rate of Movement of Plume	5-14
5.6	Plume Volume	5-16
6.0	CONCLUSIONS	6-1

References

Appendix A	Organic Vapor Analyzer (OVA) and Trichloroethene Data
Appendix B-1	Well Completion Forms
Appendix B-2	Monitor Well Construction Details
Appendix B-3	Determination of Screen Slot Size and Sand Pack Analysis
Appendix C	Summary of Analytical Methods and Preservation Requirements
Appendix D	Geotechnical Analysis
Appendix E	Cone-Penetrometer Soundings
Appendix F	Gamma Ray Logs
Appendix G-1	Determination of Hydraulic Conductivity
Appendix G-2	Static Water Level Measurements

001474

RADIAN CORPORATION

LIST OF FIGURES

Figure No.	Description	Page No.
1-1	Location of Industrial Transformer Superfund Site within the City of Houston	1-3
1-2	Summary Diagram of Soil Samples >25 ppm PCBs	1-4
1-3	Summary of TCE Values in Soil Samples - Phase I	1-8
2-1	Cone Penetrometer Locations	2-10
3-1	TCE Values for Shallow Depth Wells and Cone Penetrometer	3-2
3-2	Cross-Section A-A'	3-4
3-3	Cross-Section B-B'	3-5
3-4	Cross-Section C-C'	3-6
3-5	Cross-Section D-D'	3-7
3-6	Cross-Section E-E'	3-8
3-7	Cross-Section F-F'	3-9
4-1	Summary Diagram of Soil Samples >25 ppm PCBs	4-3
4-2	TCE Values for Monitor Well Soil Samples (ppm) - Phase II	4-7
4-3	Summary of TCE Values in Soil Samples - Phase I	4-11
4-4	TCE Values for Shallow Depth, Monitor Well Water Samples (First Round)	4-16
4-5	TCE Values for Shallow Depth, Monitor Well Water Samples (Second Round)	4-16
4-6	TCE Values for Shallow Depth (1st Round) and Cone Penetrometer Locations	4-19
4-7	TCE Values - Water Samples from Uppermost Aquifer - Phase I	4-23
4-8	TCE Values for Intermediate Depth - Monitor Well Water Samples	4-26

001475

RADIAN CORPORATION

LIST OF FIGURES
(Continued)

Figure No.	Description	Page No.
5-1	Hydraulic Conductivity and Transmissivity	5-3
5-2	Shallow Depth Monitor Wells	5-5
5-3	Shallow Depth Monitor Wells	5-6
5-4	Shallow Depth Monitor Wells	5-7
5-5	Shallow Depth Monitor Wells	5-8
5-6	Shallow Depth Monitor Wells	5-9
5-7	Intermediate Depth Monitor Wells	5-10
5-8	Intermediate Depth Monitor Wells	5-11
5-9	TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit	5-13
6-1	TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit	6-2

001476

RADIAN CORPORATION

LIST OF TABLES

Table No.	Description	Page No.
1-1	Water Well Inventory	1-5
4-1	Polychlorinated Biphenyls (PCBs) Data - Intermediate Depth - Soil Samples	4-2
4-2	Trichloroethene (TCE) Data - Intermediate Depth - Soil Samples	4-5
4-3	Trichloroethene (TCE) Data - Phase I	4-9
4-4	Trichloroethene (TCE) Data - Monitor Well Water Samples	4-15
4-5	Trichloroethene (TCE) Data - Cone-Penetrometer Water Samples	4-18
4-6	Trichloroethene (TCE) Data - Monitor Well Water Samples (Phase I)	4-22
4-7	Trichloroethene (TCE) Data - Monitor Well Water Samples	4-25
4-8	General Aquifer Parameters	4-28
5-1	Hydraulic Conductivity and Transmissivity Data	5-2
5-2	Groundwater Velocities at each Monitor Well Location	5-15

001477

RADIAN CORPORATION

EXECUTIVE SUMMARY
REMEDIAL INVESTIGATION, PHASE II
INDUSTRIAL TRANSFORMER SUPERFUND SITE
HOUSTON, TEXAS

Introduction

Radian Corporation is under contract to the Texas Water Commission (TWC) to perform a Remedial Investigation/Feasibility Study (RI/FS) (Phase II work) at the Industrial Transformer Superfund (ITS) site. The work is being financed through Cooperative Agreement No. V-0066416 between the U.S. Environmental Protection Agency (EPA) and the Texas Water Commission (TWC). The consultant for the remedial investigation phase, Radian Corporation, was selected on May 27, 1986. The RI/FS contract was executed on June 30, 1986. Amendment No.1, authorizing Phase II work was executed on October 28, 1987.

The Phase I RI/FS was primarily directed at the near surface polychlorinated biphenyls (PCBs) contamination. During that investigation it was determined that trichloroethene (TCE) from the site had migrated into the shallow and intermediate water-bearing zones. The objective of the Phase II RI/FS is to assess the extent of TCE contamination in the uppermost and intermediate water-bearing zones underlying the ITS site. Site sampling and investigation activities were performed from January 1988 to March 1988. The purpose of this report is to document the results of the Phase II RI.

Separate FS and Quality Assurance/Quality Control reports were prepared as part of this contract amendment.

001478

001478

RADIAN CORPORATION

Background

The ITS site is located less than a mile east of the Astrodome/Astroworld complex on I-610 South Loop West, inside the City of Houston. Access to the ITS site is gained by the freeway access road to the north, Knight Street to the west, Mansard Street to the south and South David Street to the east (Figure 1). The site area includes residential, commercial and light industrial facilities. Within a one-mile radius, a light industrial/commercial business area is located most closely to the site, then the recreational complexes of Astroworld and Astrodome, and finally, a mix of private, single and multi-family dwellings further away from the site. The residential population is about 2,000, and a maximum daily traffic of 100,000 persons may move within the 1-mile radius due to recreational activities associated with the Astrodome and Astroworld.

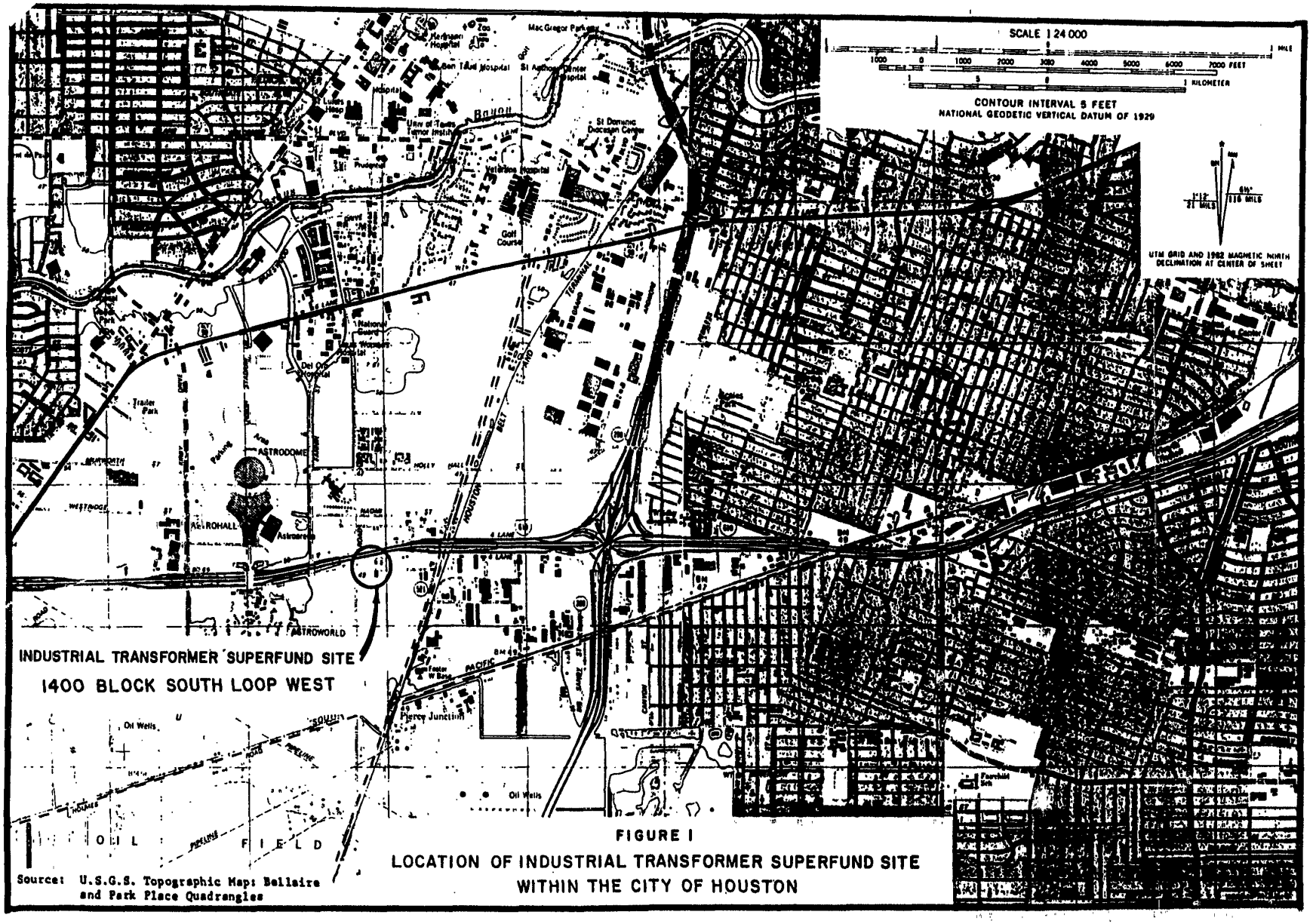
Site History

The site is contaminated principally with PCBs and TCE. A detailed summary of the site history concerning PCBs and TCE is presented in the Remedial Investigation report (Radian, 1988). The results of Phase I work and the previous site investigations by various regulatory agencies prior to the Remedial Investigation conducted by Radian Corporation are also presented in that report.

In the fall of 1981, a City of Houston work crew noted strong chemical odors while installing a waterline adjacent to the Industrial Transformer Company. This property is owned by Mr. Sol Lynn, but at that time was leased to Mr. Ken James, owner of Sila-King, a chemical-supply house. An inspection later that day by representatives of both the TWC and the City of Houston Department of Health showed about 75 empty drums scattered about on the property at 1415, 1417 and 1419 South Loop West. Most of the drums, labeled trichloroethene, were empty and punctured.

001479

001479



Source: U.S.G.S. Topographic Map: Bellaire and Park Place Quadrangles

FIGURE I

LOCATION OF INDUSTRIAL TRANSFORMER SUPERFUND SITE WITHIN THE CITY OF HOUSTON

001480

RADIAN CORPORATION

As part of the Remedial Investigation (Phase I), various soil and water samples were analyzed for PCBs and TCE. Because Phase II work was conducted specifically to further investigate TCE contamination, only Phase I TCE results are summarized here (Table 1). The Remedial Investigation report (Radian, 1988) documents the complete investigation and findings concerning PCBs as well as TCE.

During Phase I activities, four surface soil samples were chosen for TCE analysis, based on their proximity to known locations of TCE-contaminated soil. Values ranged from 0.02 to 2 ppm TCE.

The shallow boring program consisted of 19 boreholes. Each of 18 shallow boreholes were sampled in the 0 to 2 foot interval and then again in the 2 to 4 foot interval while the nineteenth borehole comprised a composite sample. TCE values ranged from 0.0051 to 150 ppm.

A total of eight soil samples were collected for TCE analysis from deep soil boreholes and monitor wells. Concentrations ranged from 0.0077 ppm to 2000 ppm. Two samples selected for Priority Organics Pollutants analyses (POP) confirmed the presence of TCE.

In Phase I work, a total of seven groundwater monitor wells were installed, six in the uppermost water-bearing zone and one in the intermediate water-bearing zone. The latter well was later plugged and abandoned.

Water samples were collected twice from the uppermost water-bearing zone and analyzed for TCE. Although individual values varied between the first and second rounds for a given well, the overall ranking of wells in terms of TCE concentration remained the same in both rounds (Figure 2). Highest TCE concentrations were observed in MW-2 (430 ppm/500 ppm, for Rounds 1 and 2, respectively) followed by MW-4 (250 ppm/400 ppm), then MW-5 (190 ppm/300 ppm), then MW-7 (46 ppm/72 ppm), MW-6 (25 ppm/26 ppm) and lastly, MW-1 (0.003 ppm/0.0007 ppm). All six of these wells showed consistently higher values in

001481

001481

RADIAN CORPORATION

TABLE 1. SUMMARY OF TCE SAMPLE TYPES AND RESULTS FROM PHASE I

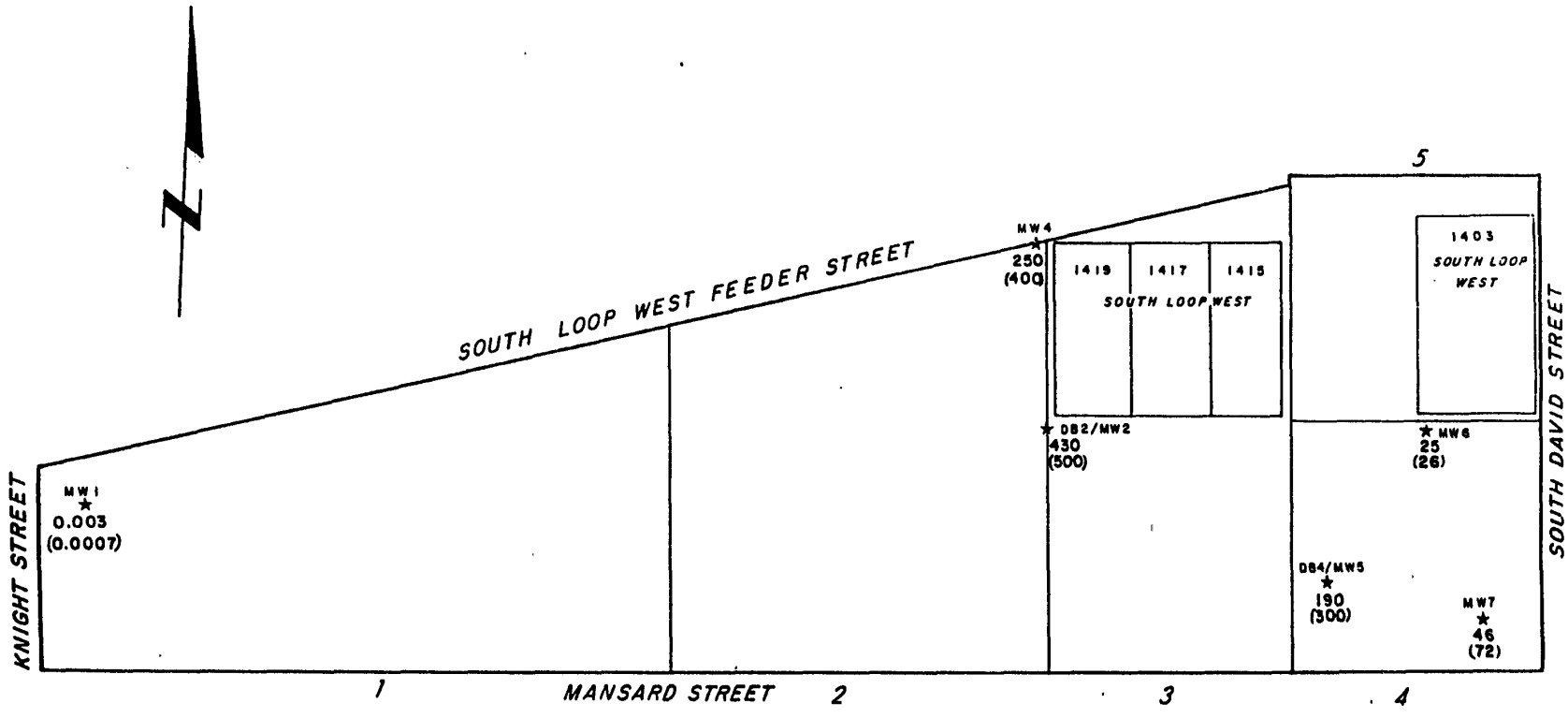
Sample	Sample Type	No.	Parameter	Range of Concentrations (ppm)**	Comments
Soil & Sediment	Soil	4 1	TCE POP	0.02-2	TCE: 0.0018 ppm
Shallow Soil Boring	Soil	18 4	TCE POP	0.0051-150	TCE: 0.003-57
Deep Soil Boring	Soil	4 1	TCE POP	0.0077-43	TCE: 240
Monitor Well	Soil	4 1	TCE POP	15-2000	TCE: 12
Groundwater	Water	15 4	TCE VPOP	0.0007-500 1.5-320	
Stormwater	Water	2	POP		TCE: 0.0026

Key: TCE - trichloroethene
POP - priority organic pollutants
VPOP - volatile priority organic pollutants

** Values have been rounded.

001482

001482



LEGEND

DB2/MW2	WELL NUMBER
★	WELL LOCATION
430	SAMPLE VALUE FIRST ROUND
(500)	SAMPLE VALUE SECOND ROUND

FIGURE 2

TCE VALUES (PPM)
WATER SAMPLES FROM
UPPERMOST AQUIFER
(FIRST & SECOND ROUND) PHASE I

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

FOR THE PURPOSE OF PRESENTATION,
ALL VALUES ARE ROUNDED OFF.

001483

the second round of sampling compared to the first. Volatile Priority Organic Pollutant (VPOP) analyses confirmed the presence of TCE as the contaminant present in the groundwater.

Four complete sets and one incomplete set of water level measurements established a north-northwesterly groundwater flow for the uppermost water-bearing sand, with a gradient ranging from 0.0030 ft/ft to 0.0036 ft/ft. Static water level averages 3 to 4 feet below ground level for the shallow wells, while static water level in the intermediate well averages about 25.68 feet below ground level.

001484

Statement of Problem

TCE is the principal known contaminant in deep subsurface soils and in groundwater at the site. The EPA has classified TCE as a possible carcinogen. The major concern is that exposure to TCE may impact human health and the environment. The potential exposure pathway includes ingestion of groundwater.

This Phase II RI is to define the extent and magnitude of TCE in the uppermost and intermediate water-bearing units. Contamination may enter and migrate through either of these via:

- Vertical migration from the surface through intermediate soil horizons and underlying water-bearing zones; and
- Horizontal migration once introduced to water-bearing sands.

The investigation has been divided into 3 steps:

Step 1 Presampling Activities include:

- Review of Phase I (and prior) investigation activities and results, data gaps and insufficiencies;
- Propose responses and remedial technologies to clean up TCE contaminated deep subsurface soils and groundwater in the uppermost and intermediate water-bearing zones;

001484

RADIAN CORPORATION

- Assess existing conditions at the site; and
- Prepare work plans including Health and Safety Plan, Quality Assurance/Quality Control Plan, Sampling Plan and Project Management Plan.

Step 2 Field Sampling Activities include:

- Collecting soil samples from depth in the three monitor wells (101 foot depth) and analyzing them for TCE;
- Collecting composite cores from the 0 to 2 foot depth at each of the three monitor wells;
- Completing the three monitor wells in the intermediate water-bearing zone;
- Measuring static water levels in all wells and determining hydraulic gradients;
- Collecting groundwater samples from the uppermost and intermediate water-bearing zones and analyzing them for TCE;
- Conducting slug tests on the three intermediate depth wells to determine hydraulic conductivity;
- Collect cone-penetrometer "soundings" or logs from twenty locations on and surrounding the perimeter of the site; and
- Collect water samples from each of the locations defined by the cone-penetrometer.

Step 3 Site characterization/analyses include:

- Site-specific geology and hydrology;
- Nature, magnitude and extent of the TCE-contaminated deep subsurface soils at the site;
- Nature, magnitude and extent of TCE-contaminated groundwater in the upper and intermediate water-bearing zone;
- Volume of contaminated soils and water;
- Contaminant pathways and rates;
- Gathering of data sufficient to evaluate potential remedial activities; and
- Collection of water-bearing zone sediments for grain-size analyses.

001485

001485

RADIAN CORPORATION

Site Geology

As summarized in the Phase I RI (Radian, 1988), the site is located on the Beaumont (Clay) Formation of Pleistocene age. Two major aquifers underlying the site are the Chicot and, underlying it, the Evangeline. The uppermost water-bearing unit appears to be a crevasse-splay. The site-stratigraphy consists of clays, extending from the surface down to a depth of about 15 feet. This is followed by a series of alternating clays, silty clays and silty sands at varying depths from 15 to 30 feet.

The top of the water-bearing sand ranges from about 30 to 34 feet below ground surface. On-site, the water-bearing sand varies from about one foot thick at the western end to about 7.5 feet at the eastern end (and just off-site). The sand content increases from west to east across the site.

The cone-penetrometer soundings or logs form a series of cross-sections both on-site and around the perimeter of the site. In general, these cross-sections indicate that this water-bearing zone pinches out stratigraphically to the northwest (off-site) and possibly to the southeast (off-site). To the north of the ITS site, several cone soundings indicate another silty sand lies immediately below the defined uppermost water-bearing zone and is separated by a silty clay and clay up to approximately one foot thick.

These types and changes in lithology are consistent with depositional models of overbank deposits, that is, crevasse splays from a nearby Pleistocene fluvial channel. The uppermost water-bearing zone appears to be limited in area extending just beyond the western boundaries of the site and may continue to thicken and extend to unknown limits beyond the eastern end.

The uppermost water-bearing sand is separated from the next lower, "intermediate" water-bearing sand by alternating stiff clays and clayey-silty beds, as interpreted from core samples and gamma-ray logs. The separating layers range in thickness from 45 to 52 feet.

001486

001486

RADIAN CORPORATION

The intermediate water-bearing zone varies in thickness from 5 to 6.5 feet and is comprised of about 50% sand, 50% silts and clays. It may also be the product of overbank flooding. This zone is underlain by clay.

PCB Analyses

Composite samples from the 0 to 2 foot depth were collected from each of the three newly installed wells and analyzed for PCBs. Values were less than 0.5 ppm. This sampling was conducted in response to Phase I findings that PCBs were highly localized and random and that amounts greater than 25 ppm were restricted to the uppermost two feet.

Extent of TCE Migration

A program of soil and water sampling was conducted to determine the lateral and vertical extent, concentration level and volume of TCE-contaminated materials at the site. Table 2 summarizes sample types and range of TCE concentrations.

A total of fifty two (52) soil samples were collected from three monitor wells, one with a total depth of 100.5 feet and two with a total depth of 101 feet. These samples were initially screened using field analyses. Thirty samples with the greatest field headspace TCE concentrations were selected for laboratory analyses. TCE values ranged from 0.009 to 600 ppm (Figure 3).

Water samples were collected in two rounds from all nine wells (six shallow-depth and three intermediate-depth). The overall ranking of wells in terms of TCE concentration remained the same in both rounds, even though individual values varied. In the uppermost water-bearing zone, highest TCE concentration (for both rounds) have been observed in MW-4 (470 ppm/550 ppm, Rounds 1 and 2 respectively), MW-2 (340 ppm/410 ppm), MW-5 (220 ppm/160 ppm), MW-6 (55 ppm/56 ppm), MW-7 (100 ppm/54 ppm) and finally MW-1, with no TCE detected in either round. Figure 4 illustrates the distribution of TCE values in Round 1 and Round 2.

001487

001487

RADIAN CORPORATION

TABLE 2
SUMMARY OF TCE SAMPLE TYPES AND RESULTS

Sample Source	Sample Type	No.	Parameter	Range (ppm)
Monitor Well	Soil	30	TCE	0.009 - 600
		3	PCB	< 0.75
Groundwater	Water	38	TCE	0.0005 - 790

Key: PCB - polychlorinated biphenyls
TCE - trichloroethene

001488

001488

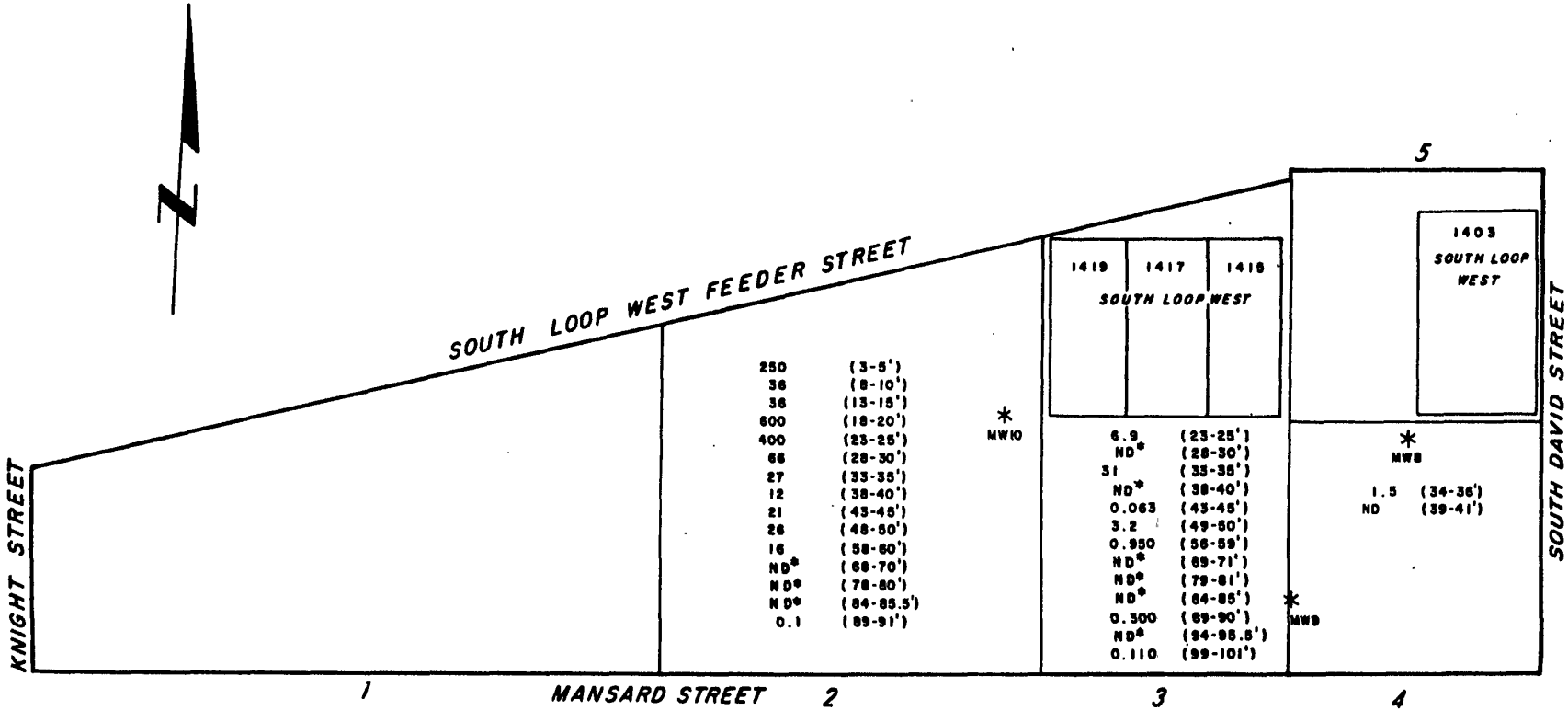


FIGURE 3

TCE VALUES FOR MONITOR WELL SOIL SAMPLES (PPM) PHASE II

LEGEND

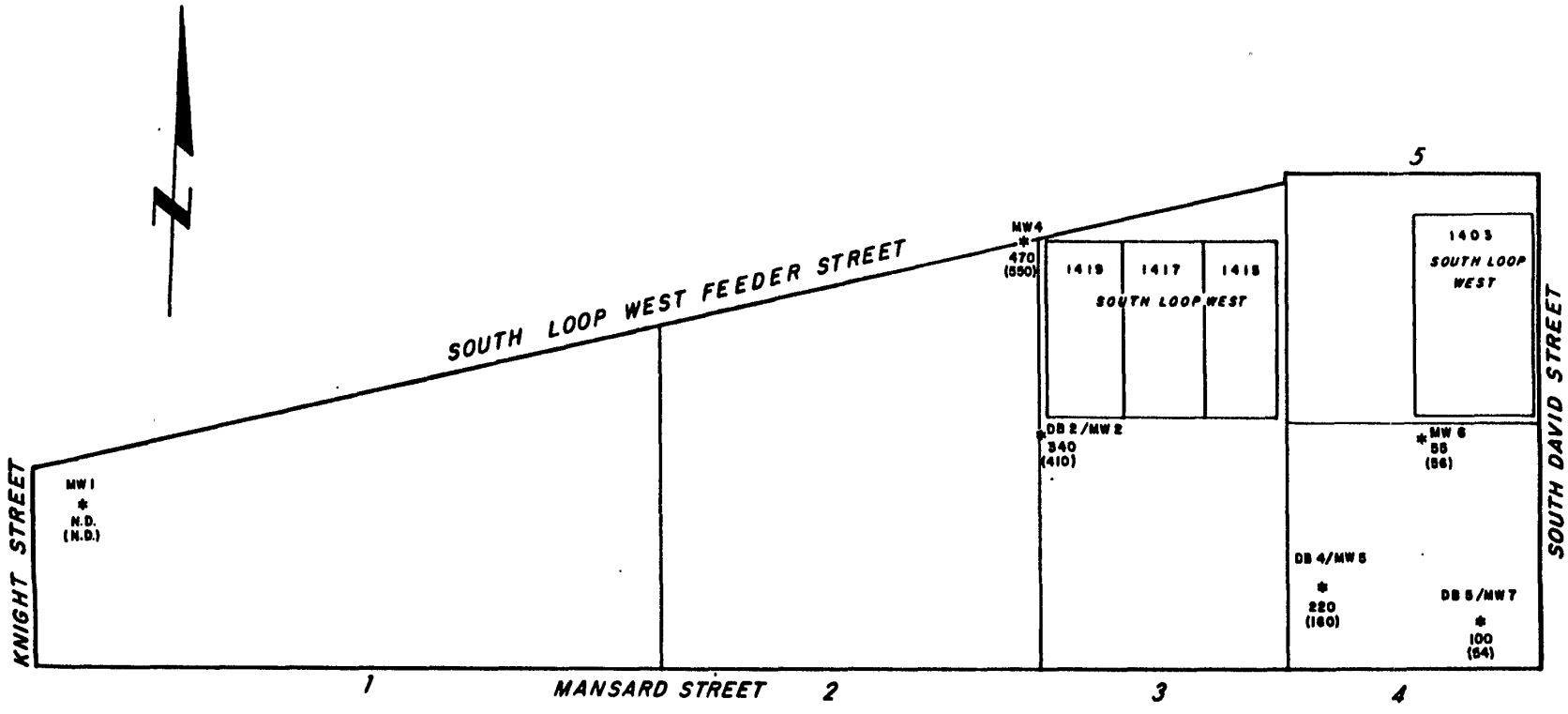
MW8	MONITOR WELL NUMBER
*	MONITOR WELL LOCATION
69(23-25')	SAMPLE VALUE; WITH DEPTH IN PARENTHESIS
ND	NOT DETECTED
ND*	NOT DETECTED; LESS THAN 0.04 PPM

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001489



LEGEND

DB4/MW 5 – DEEP BORING/MONITOR WELL NUMBER
* – WELL LOCATION
220 – SAMPLE VALUE 1st ROUND
N. D. – NONE DETECTED
(160) – SAMPLE VALUE 2nd ROUND

FIGURE 4

TCE VALUES FOR SHALLOW DEPTH MONITOR WELL WATER SAMPLES (PPM).
(FIRST & SECOND ROUND) PHASE II

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

001490

RADIAN CORPORATION

Water samples were collected in two rounds from all nine wells (six shallow-depth and three intermediate-depth). The overall ranking of wells in terms of TCE concentration remained the same in both rounds, even though individual values varied. In the uppermost water-bearing zone, highest TCE concentration (for both rounds) have been observed in MW-4 (470 ppm/550 ppm, Rounds 1 and 2 respectively), MW-2 (340 ppm/410 ppm), MW-5 (220 ppm/160 ppm), MW-6 (55 ppm/56 ppm), MW-7 (100 ppm/54 ppm) and finally MW-1, with no TCE detected in either round. Figure 4 illustrates the distribution of TCE values in Round 1 and Round 2.

In the intermediate water-bearing zone, highest TCE concentrations (for both rounds) have been observed in MW-9 (14 ppm/5.2 ppm), MW-10 (0.160 ppm/0.085 ppm) and finally MW-8 (0.0008 ppm/ 0.0005 ppm). Round 1 and Round 2 values are illustrated in Figure 5.

A total of twenty water samples were collected on-site and off-site from the uppermost water-bearing zone utilizing a cone-penetrometer. Values ranged from 0.0015 ppm to 790 ppm (Figure 6). Highest TCE values of any water sample collected to date, were found in several of the cone-penetrometer locations. While highest TCE values were found in MW-2 during Phase I activities, the highest values during Phase II were found to the north-northwest and off-site. The off-site high concentration is located on the median strips between the ITS site and South Loop 610 West and is 790 ppm TCE.

Four sets of water level measurements were collected from the uppermost water-bearing zone and two sets on the intermediate-depth wells. These measurements defined the site-potentiometric surface and the direction and hydraulic gradient of groundwater flow. A north-northwesterly flow was established for the uppermost water-bearing zone. The observed gradients ranged from 0.0031 ft/ft to 0.0039 ft/ft. The static water level in the shallow wells averaged 39 to 41 feet above mean sea level. A southeasterly flow was established for the intermediate water-bearing zone. Static water level in the intermediate water-bearing zone averaged about 20 to 22 feet above mean sea level.

001491

001491

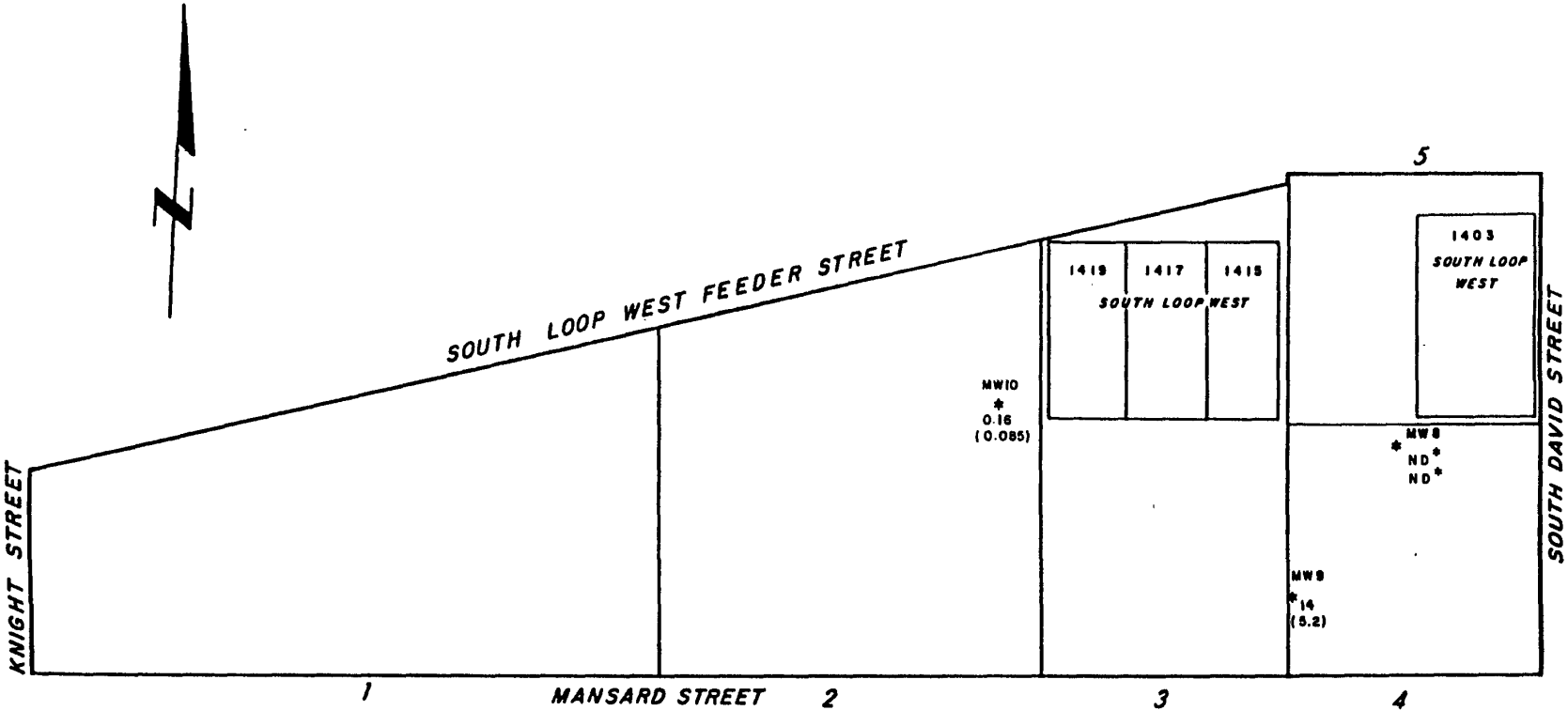


FIGURE 5

TCE VALUES FOR INTERMEDIATE DEPTH (101 Foot) MONITOR WELL WATER SAMPLES (PPM).

(FIRST & SECOND ROUNDS) PHASE II

LEGEND

MW10 – MONITOR WELL NUMBER

* – MONITOR WELL LOCATION

0.160 – SAMPLE VALUE

ND* – NOT DETECTED; LESS THAN 0.0021 PPM

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001492

RADIAN CORPORATION

In the intermediate water-bearing zone, highest TCE concentrations (for both rounds) have been observed in MW-9 (14 ppm/5.2 ppm), MW-10 (0.160 ppm/0.085 ppm) and finally MW-8 (0.0008 ppm/ 0.0005 ppm). Round 1 and Round 2 values are illustrated in Figure 5.

A total of twenty water samples were collected on-site and off-site from the uppermost water-bearing zone utilizing a cone-penetrometer. Values ranged from 0.0015 ppm to 790 ppm (Figure 6). Highest TCE values of any water sample collected to date, were found in several of the cone-penetrometer locations. While highest TCE values were found in MW-2 during Phase I activities, the highest values during Phase II were found to the north-northwest and off-site. The off-site high concentration is located on the median strips between the ITS site and South Loop 610 West and is 790 ppm TCE.

Four sets of water level measurements were collected from the uppermost water-bearing zone and two sets on the intermediate-depth wells. These measurements defined the site-potentiometric surface and the direction and hydraulic gradient of groundwater flow. A north-northwesterly flow was established for the uppermost water-bearing zone. The observed gradients ranged from 0.0031 ft/ft to 0.0039 ft/ft. The static water level in the shallow wells averaged 39 to 41 feet above mean sea level. A southeasterly flow was established for the intermediate water-bearing zone. Static water level in the intermediate water-bearing zone averaged about 20 to 22 feet above mean sea level.

Hydraulic conductivity (K) data for the intermediate water-bearing zone ranged from 0.31 to 0.87 feet/day. Thickness of this unit ranges from 5 to 6.5 feet. The hydraulic conductivity varies because of heterogeneities in porosity, grain size, shape, sorting and packing. Transmissivity is a function of hydraulic conductivity and thus follows the same patterns as hydraulic conductivity.

In comparision, hydraulic conductivity (K) data for the uppermost water-bearing unit ranged from approximately 0.63 to 2.0 feet/day.

001493

001493

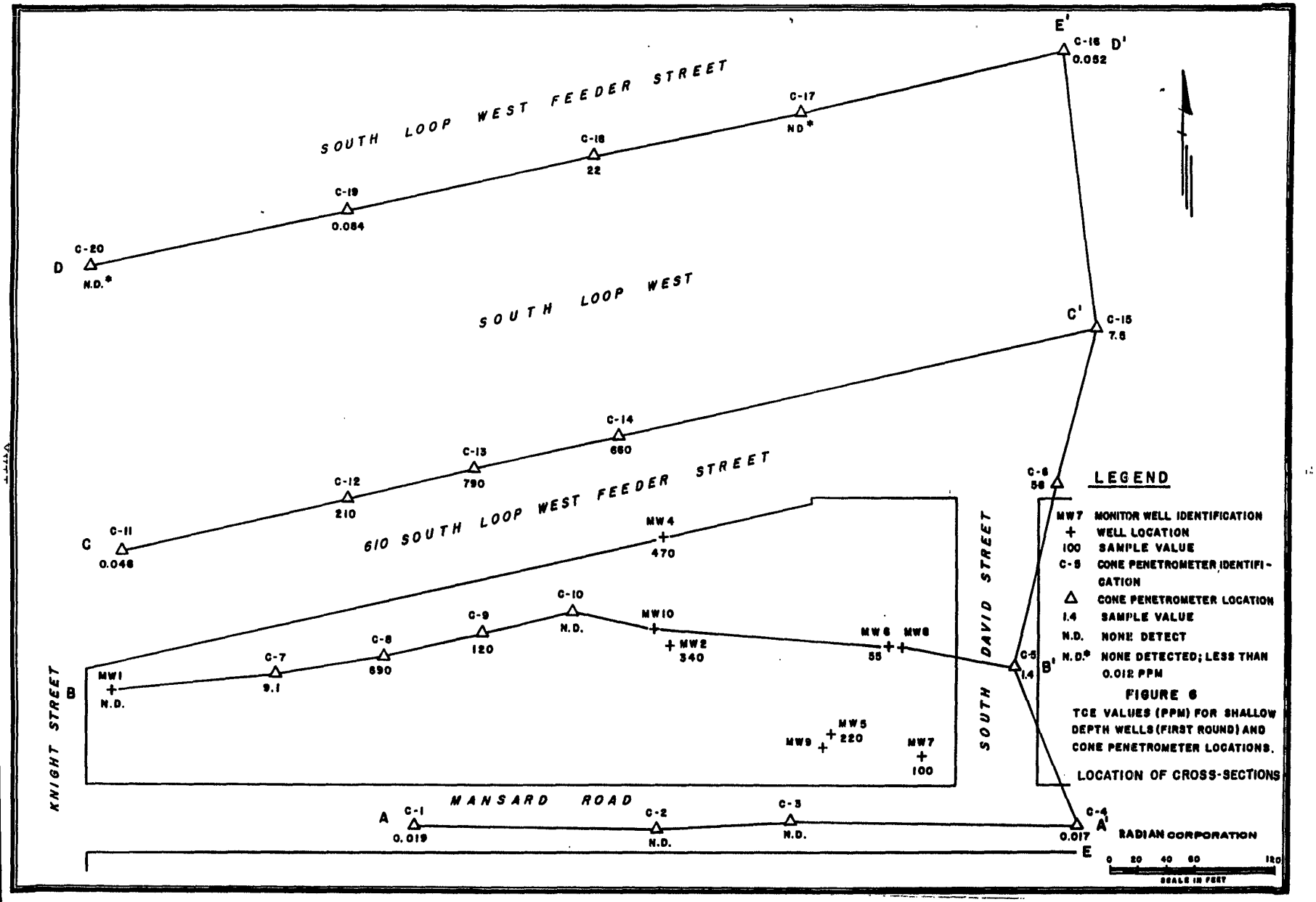


FIGURE 6
TCE VALUES (PPM) FOR SHALLOW DEPTH WELLS (FIRST ROUND) AND CONE PENETROMETER LOCATIONS.

001494

RADIAN CORPORATION

The uppermost water-bearing sand contains approximately 3.2 million gallons of water contaminated above the EPA and TWC action limit of 5 ppb TCE. Approximate extent of the plume is shown in Figure 7.

Conclusion

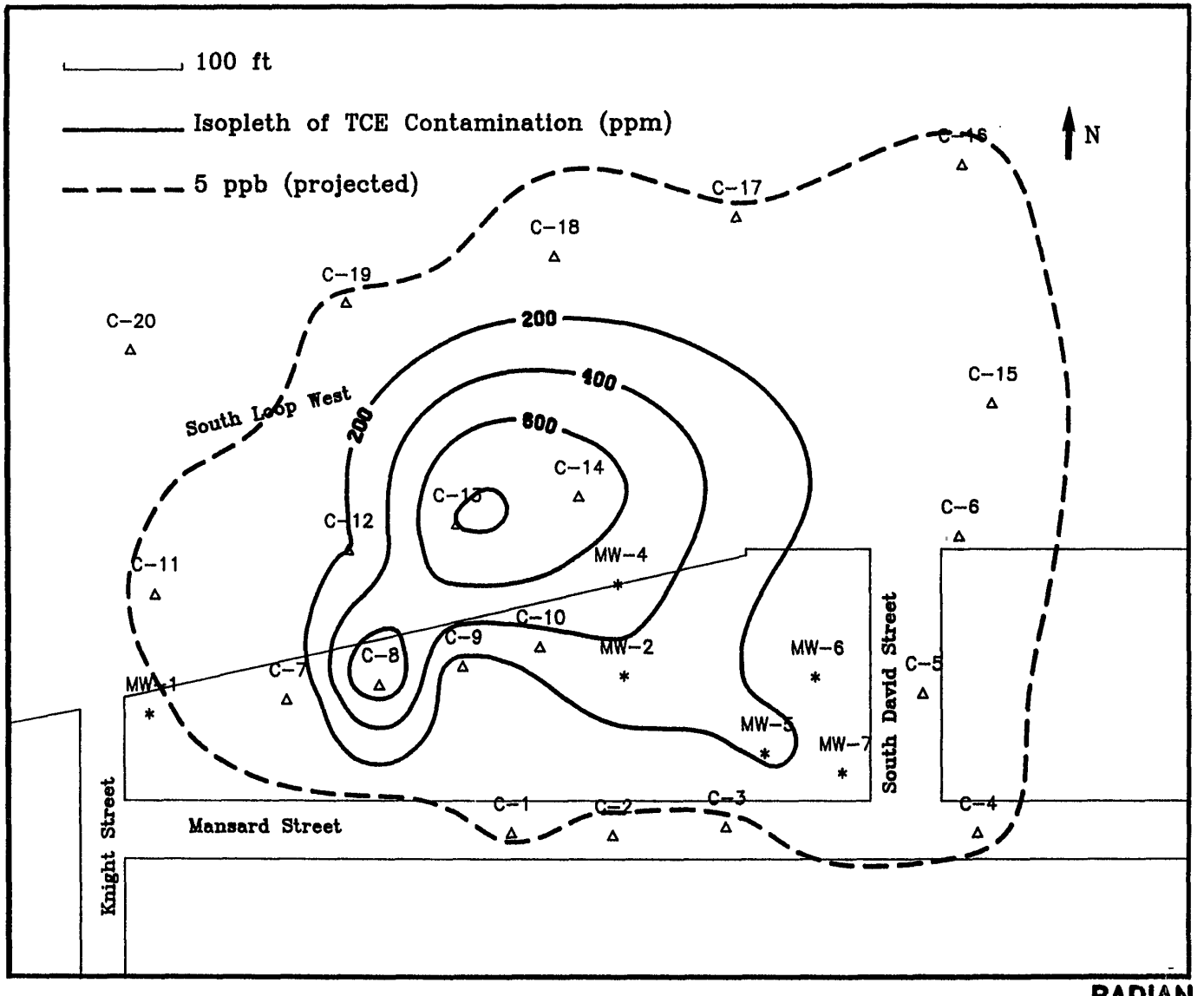
These observations together with those from Phase I indicate that a TCE plume exists in the uppermost water-bearing zone and that it is moving in the direction of groundwater flow to the northwest. Figure 7 illustrates the location of the plume.

TCE has been verified to exist in upgradient locations. Possible explanations include reversal of groundwater gradient over time or several scattered sources of TCE at or close to the surface which have vertically migrated down to the uppermost water-bearing zone. TCE may have migrated vertically down through the clay until reaching a more silty clay lens, then moving laterally along these lenses as well as continuing to migrate vertically.

The extent of the TCE plume in the intermediate water-bearing unit cannot be determined based on available information.

001495

001495



RADIAN CORPORATION

Figure 7
TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit

RADIAN CORPORATION

SECTION 1
INTRODUCTION

Radian Corporation is under contract to the Texas Water Commission (TWC) to perform a Remedial Investigation/Feasibility Study (RI/FS) at the Industrial Transformer Superfund (ITS) site. A Remedial Investigation/Feasibility Study report (Radian, 1988) has been issued on the first phase of the RI/FS and a public hearing on that report has been conducted by the U.S. Environmental Protection Agency (EPA). That report and the subsequent public hearing focused on surface and shallow subsurface (0 to 4 feet) contamination. However, deeper contamination was discovered during the field investigation and this report (Phase II) addresses that contamination.

The objectives of the Remedial Investigation Phase II are to assess the nature, extent and magnitude of TCE contamination at the site, specifically in the deeper soil horizons and groundwater within the uppermost (30 feet to 35 feet deep) and intermediate (85 feet to 87 feet deep) water-bearing sands. The information generated in this Phase II RI is to be used in the Phase II FS to evaluate remedial action alternatives. Work conducted in both Phase I and Phase II has been financed through Cooperative Agreement No. V-0066416 between the EPA and the TWC. The RI/FS contract was executed June 30, 1986 and Amendment No. 1, which authorizes Phase II work at the site, was executed on October 28, 1987.

Both Phase I and Phase II RI/FS work at the ITS site is being performed as a CERCLA or Superfund project following evaluation by the Hazard Ranking System and inclusion on the National Priority List (NPL). CERCLA is an acronym for Comprehensive Environmental Response, Compensation and Liability Act, more popularly known as Superfund. It was enacted in 1980 to remediate hazardous substances at uncontrolled or abandoned hazardous waste sites and to provide funding and procedures for the federal government together with state governments to ensure remediation of hazardous substance locations, whether a responsible party has been identified or not.

001497

001497

RADIAN CORPORATION

The Superfund Amendments and Reauthorization Act (SARA), a five-year extension of CERCLA, was signed into law October 17, 1986. SARA provides a number of additions to existing law but among the most important are:

- New emphasis is placed on risk reduction, using techniques that allow destruction/detoxification of waste, rather then preventing exposure. More pointedly, permanent solutions and treatments to permanently and significantly reduce the toxicity, mobility and/or volume of hazardous substances are preferred.
- Remediation must attain Federal applicable or relevant and appropriate requirements (ARARs) and more stringent State ARARs.

001498

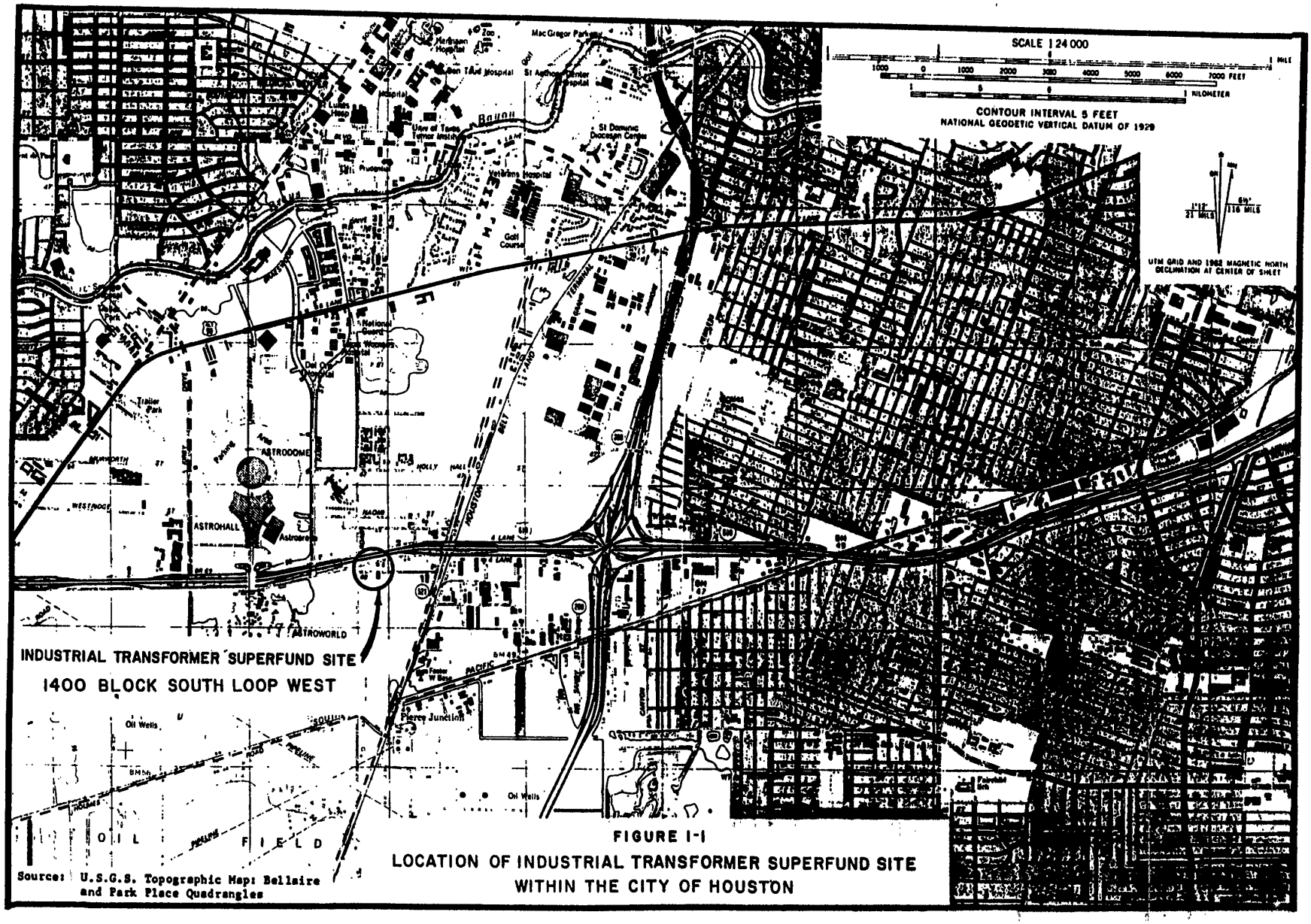
1.1 SITE DEFINITION

The Industrial Transformer Superfund site is located within the city limits of Houston, Texas. The specific lots and other contiguous lots within this block of land are bounded by Knight Street on the west, Mansard Street to the south, South David Street to the east, and the feeder road for I-610 South Loop West, to the north (Figure 1-1 and Figure 1-2).

A detailed description is given in the Remedial Investigative Report (Radian, 1988), Section 1.1 Site Definition and Appendix A-1 Property Description.

An inventory of water wells within a one-mile radius shows 24 wells. Where information on total depth is available, the inventory shows that the wells are completed at a variety of depths, from 77 to 844 (Table 1-1). The inventory did not determine the use of this water.

While no wells appear to be screened in the uppermost water-bearing unit, all water wells are not necessarily registered with the state. TCE appears to be migrating vertically through the aquitards, putting deeper aquifers at risk. Thus, various populations stand the risk of possible exposure to TCE via the route of ingestion of contaminated groundwater. Furthermore, the State of Texas does not have the authority to implement institutional controls for groundwater use.

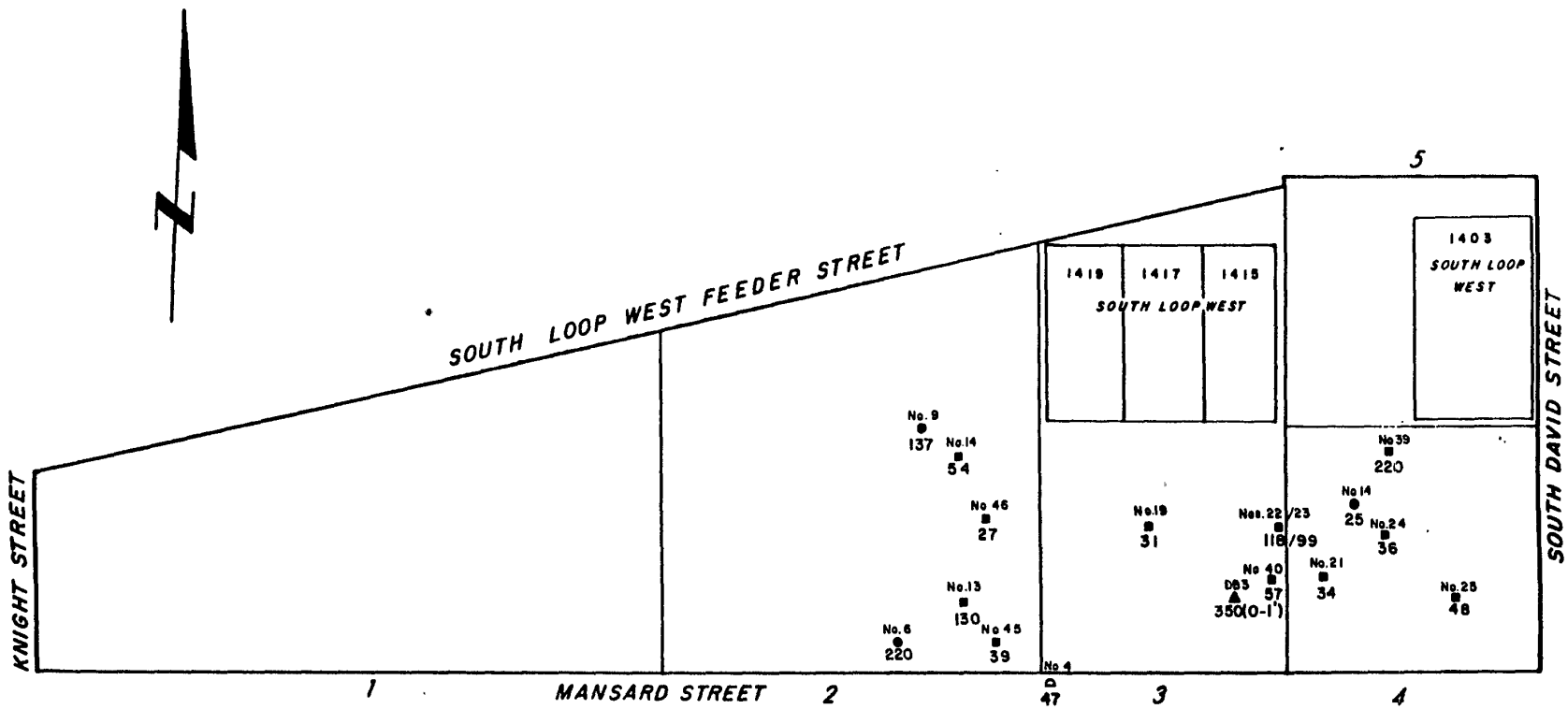


Source: U.S.G.S. Topographic Map: Bellaire and Park Place Quadrangles

FIGURE I-1

LOCATION OF INDUSTRIAL TRANSFORMER SUPERFUND SITE WITHIN THE CITY OF HOUSTON

001499



LEGEND

No.9 SAMPLE NUMBER

■ SURFACE SOIL LOCATION

● SHALLOW BOREHOLE LOCATION (0-2' DEPTH)

▲ DEEP BOREHOLE LOCATION (DEPTH IN PARENTHESIS)

SEDIMENT LOCATION

31 SAMPLE VALUE

FOR THE PURPOSES OF PRESENTATION, ALL VALUES HAVE BEEN ROUNDED OFF.

FIGURE 1-2
SUMMARY DIAGRAM OF SOIL SAMPLES >25 PPM PCB'S (INCLUDING SURFACE, SHALLOW AND DEEP SUBSURFACE SAMPLES)

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

001500

RADIAN CORPORATION

TABLE 1-1
WATER WELL INVENTORY
(Within 1 Mile Radius from Industrial Transformer Site)

Owner's Name	Source	Well No.	Total Depth	Year Drilled
Exxon Corporation	Houston Galveston Subsidence Dist.	3429	77	1979
Dresser Magcobar-Almeda Plant	"	1626	542	1956
International Tool & Supply Co.	"	3174	542	1956
International Tool & Supply Co.	"	2787	468	1962
International Tool & Supply Co.	"	2786	N/A	1981
International Tool & Supply Co.	"	3928	N/A	1981
Southwestern Bell Telephone Co.	"	3223	N/A	1968
Texaco, Inc.	"	2807	289	1967
Exxon Company, U.S.A.	"	2992	N/A	N/A
Harris County c/o County Judge	"	3298	150	1966
Black-Broiler Co.	U.S.G.S.	LJ-65-21-601	329	1952
Institute Place	"	LJ-65-21-605	310	1928
Magcobar Mud Co.	"	LJ-65-21-610	320	1946
Magcobar Mud Co.		LJ-65-21-611	542	1956
Metal Arts Co.	"	LJ-65-21-614	468	1962
Metal Arts Co.	"	LJ-65-21-615	540	1966
Star-Tex Oil Co.	"	LJ-65-21-616	292	1966
Signal Oil Company	"	LJ-65-21-617	290	1966
Houston Gulf Gas Co.	"	LJ-65-21-618	211	1929
Harris County Flood Control Dist.	"	LJ-65-21-620	432	1960
International Tools	"	LJ-65-21-624	337	1978
Charles W. Patronella	"	65-2-6K	321	1975
Wanda Petroleum Corp.	"	65-21-9L	844	1974
Metal Arts	"	65-21-6L	337	1978

001501

001501

RADIAN CORPORATION

1.2 SITE HISTORY

A detailed summary of the sequence of events surrounding the contamination at the ITS site is given in the Remedial Investigation Report (Radian, 1988), Section 1.2 Site History.

As early as 1971, the Industrial Transformer Company, owned and operated by Mr. Sol Lynn, was located at 1415, 1417, and 1419 South Loop West in Houston, Texas. During the fall of that year, the first documented investigation of the site occurred when the City of Houston Water Pollution Control Division noted that workers of the Industrial Transformer Company poured oil out of electrical transformers onto the ground as they were dismantling the transformers. Oil and grease were observed lying on the soil and floating on standing water on-site and in the ditch adjacent to the property.

Further inspections yielded different results. An inspection of the ITS site on November 10, 1978 by a representative of the TWC showed no signs of oil spills or unauthorized discharges. Another representative of the TWC observed on January 13, 1980, old drums and an oily discharge from a drum storage area behind Sila-King, Inc., a chemical supply company operating at 1419 South Loop West. Samples collected by the City of Houston Department of Health on September 11, 1981 showed the major soil and water contaminant to be TCE. After City of Houston work crews noticed strong chemical vapors on November 14, 1981 while installing a water line along the north side of Mansard Road, representatives of the TWC and the City of Houston Department of Health investigated the site and noticed a strong TCE smell. The representatives also observed approximately 75 empty, punctured drums prominently labelled "trichloroethene" that were scattered across Mr. Lynn's property. These drums disappeared from the site between March 16 and March 29, 1982. Finally, the Solid Waste Enforcement Unit of the TWC requested in 1984 that the EPA rank the ITS site for corrective action through the Superfund program.

001502

001502

RADIAN CORPORATION

1.3 STATEMENT OF THE PROBLEM

The Phase I Remedial Investigation report (Radian, 1988) determined the extent and magnitude of contamination by polychlorinated biphenyls (PCBs) and trichloroethene (TCE) in the shallow subsurface soils at the site. A summary of the conclusions includes:

- PCB contamination is localized and random in Areas 3 and 4 and the eastern portion of Area 2 (Figure 1-2). Surface soil and sediment samples range from 0.08 to 220 parts per million (ppm) PCBs. The shallow boring (0 to 4 feet) samples range from 0.05 to 137 ppm PCBs. Soil borehole and monitor well soil samples range from 0.08 to 350 ppm (the highest value, 350 ppm, was observed in the uppermost foot of soil). One sample of ponded water was found to contain 0.17 ppm PCBs. No PCBs were found during air sampling.

- TCE contamination is also random due in part to its high volatility and ability to move in soil and groundwater. Figure 1-3 illustrates the distribution of TCE. Surface soil and sediment samples range from 0.02 to 1.6 ppm TCE. The shallow boring (0 to 4 foot) soil samples range from none detected to 150 ppm TCE. Soil boring and monitor well soil samples range from none detected to 2000 ppm TCE.

- In the uppermost water-bearing unit, two rounds of sampling yielded TCE values ranging from 0.0007 to 500 ppm. An intermediate water-bearing unit (84 to 89 feet) yielded indeterminate values of TCE.

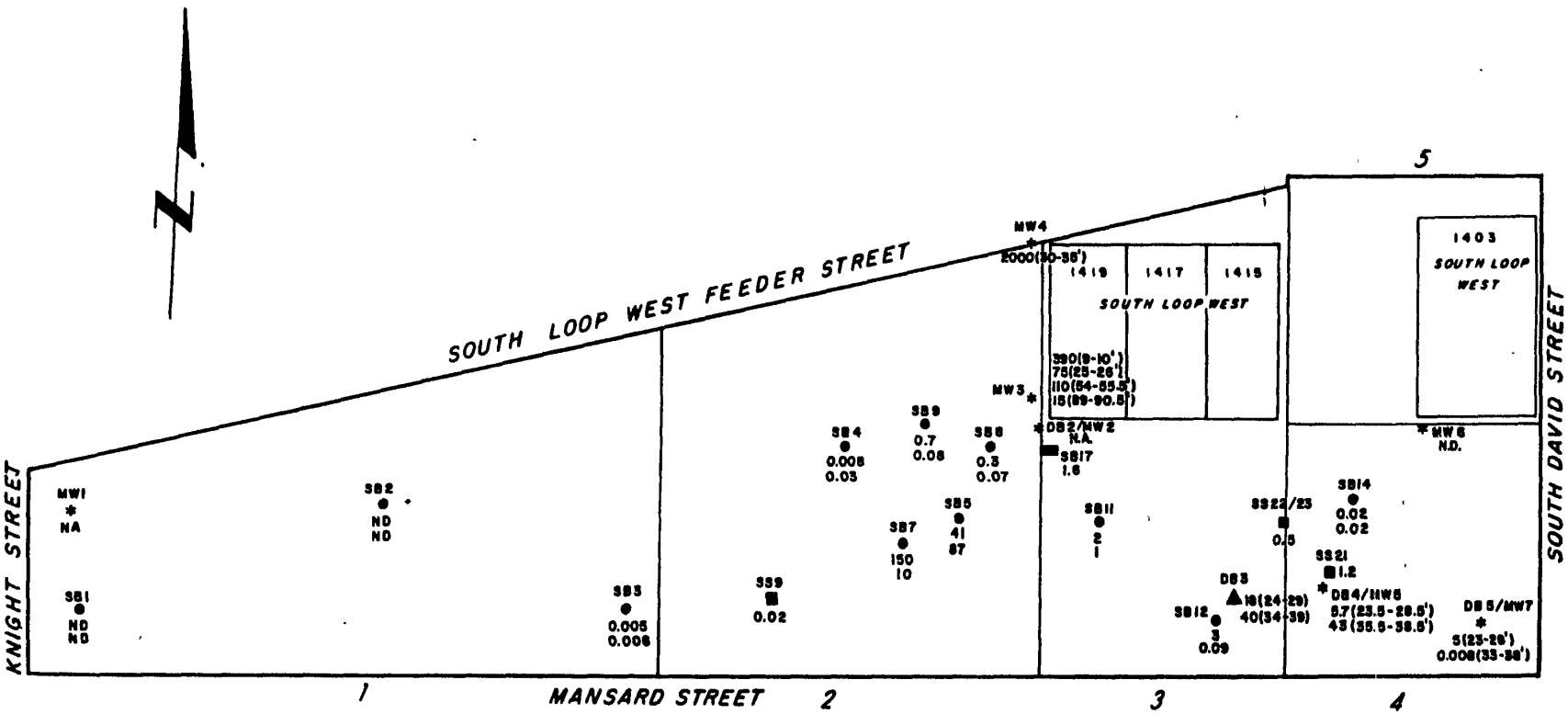
- Exposure pathways for PCBs and TCE include direct contact, ingestion of surface water and groundwater, and air inhalation.

- Data gaps and insufficiencies include: unknown depth of TCE contamination, inadequate delineation and magnitude of TCE contamination in groundwater, and establishment of background soil and water quality.

It was concluded from the Phase I investigation that PCBs greater than the 25 ppm action limit set by the EPA were restricted to the uppermost two feet of soil. In the surface and shallow subsurface soils, TCE was found in concentrations less than 161 ppm, the criterion set by the EPA for Phase I surface soil cleanup. However, the TCE concentrations in deeper soils and groundwater could not be conclusively defined.

001503

001503



LEGEND

DB3	DEEP BOREHOLE NUMBER	ND	NONE DETECTED
▲	BOREHOLE LOCATION	SS9	SURFACE SOIL NUMBER
18(24-29')	TCE CONCENTRATION (PPM); WITH DEPH IN PARENTHESIS	■	SAMPLE LOCATION
MW6	MONITOR WELL NUMBER	0.02	TCE CONCENTRATION (PPM)
*	MONITOR WELL LOCATION		
NA	NOT ANALYZED		
SB11	SHALLOW BOREHOLE NUMBER		
●	BOREHOLE LOCATION		

FIGURE 1-3

SUMMARY OF TCE VALUES IN SOIL SAMPLES - PHASE I

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001504

RADIAN CORPORATION

1.4 OBJECTIVES OF THE RI PHASE II

The objectives of the RI program can be summarized as follows:

- Determination of nature and extent of TCE contamination of soils underlying the uppermost (30 feet to 35 feet deep) water-bearing zone at the site;
- Completion of monitor wells in the intermediate (84 feet to 86 feet deep) water-bearing zone;
- Sampling of the intermediate water-bearing zone and analyzing for TCE;
- Definition of TCE plume and degree of contamination in the intermediate water-bearing zone; and
- Definition of the outer limits and concentration levels of the TCE plume in the uppermost water-bearing zone by use of water sampling penetrometers and existing groundwater monitor wells.

The remaining sections of this RI Phase II report describe the site investigation program, the results of analyses of samples collected, and characterization of the site based on analytical results and the evaluation of existing data.

001505

001505

RADIAN CORPORATION

SECTION 2
FIELD PROGRAM

The phase II field work consisted of drilling and installing three monitor wells (MW). All three wells were completed in the intermediate water-bearing zone and were logged using a gamma ray logging instrument. One of the wells from Phase I was plugged and abandoned. This chapter describes the location, drilling, soil sampling, well installation, well development, and logging procedures used in Phase II of the RI. A discussion of the chemical data and results are presented in a later section.

001506

2.1 MONITOR WELL INSTALLATION PROCEDURES

The locations of the three 101 foot depth monitor wells in the intermediate water-bearing zone were selected to characterize that zone. It was desirable to locate the wells far enough apart to determine a hydraulic gradient and groundwater flow direction. Locations were also picked in the vicinity of previous industrial activity, such as near an old drum storage area where TCE was suspected to have been discharged.

Three monitor wells, MW-8, MW-9 and MW-10, were drilled and completed in the intermediate water-bearing zone. MW-8 was drilled to a total depth of 101 feet, MW-9 to 101 feet, and MW-10 to 100.5 feet.

2.1.1 Construction of the Intermediate Depth (101 foot) Wells

The general procedures for construction of the intermediate depth (101 foot) monitor wells are illustrated by the following discussion of MW-8:

- A 12-inch borehole was advanced to a depth of 10 feet, using a hollow-stem auger, then reamed with a 14-inch bit.
- A 12-inch PVC surface casing was installed from surface to 10 feet and grouted in place to prevent surface contamination from migrating down the borehole. The grout was allowed to set for 24 hours before drilling proceeded.

001506

- Grout was then checked and more was added if settling had occurred.
- For MW-8, a continuous flight auger was used to advance the borehole through the uppermost water-bearing zone to a depth of 45 feet; the hole was cased off with 8" PVC.
- A six-inch hollow-stem auger was used to drill below the casing.
- At the sampling depths, the center plug was pulled out of the hole, a Shelby tube or split spoon sampler was advanced downhole, pushed 2 feet and then pulled out of the hole with the sample.
- Samples were extruded and trimmed. A cross-sectional slice was taken out of the middle of the core, placed in a glass container and covered with aluminum foil.
- An Organic Vapor Meter (OVM) analyzer was inserted through the foil after a period of approximately 2 minutes, and the peak reading was noted.
- A second piece of foil was then placed over the glass container. The container was tightly lidded and held for Organic Vapor Analyzer (OVA) analysis. Readings are recorded in Appendix A.
- Samples were stored on-site in iced storage containers until taken to the laboratory for OVA analysis.
- A cross-sectional slice was taken out of the core and placed in an appropriate glass container, tightly lidded, labeled and stored on ice until sent to the laboratory for TCE analysis.
- A geologic description was taken of the core. Borehole logs are recorded in Appendix B-1.
- The center plug was replaced at the bottom of the hole and drilling resumed to the next interval where the procedure was repeated.
- The six-inch borehole was advanced to a total depth of 101 feet.
- Well components as specified and diagrammed in the Well Completion Forms (Appendix B-2) were steam-cleaned before installation. Well construction details are listed in Appendix B-3 and, the screen and sand pack design is given in Appendix B-4.
- Casing and screen were lowered through the borehole. Selection of screen is detailed in Appendix B-4.
- The borehole annulus of MW-8 was packed with clean No. 4 sand poured from total depth of 101 to 84 feet.

001507

001507

- Bentonite was tremied downhole to make a six foot seal.
- The annulus was grouted to the surface with cement/bentonite grout mix.
- The protective housing was cemented into place. A locking cover and padlock were placed on the protective housing.

Geologic conditions encountered during drilling resulted in some variations in construction procedures for MW-9 and MW-10:

- Hollow stem augering and sampling proceeded as outlined earlier, until heaving sands in the uppermost water-producing zone made it impossible to set surface casing to a depth of fifty feet, so the decision was made to utilize wet rotary drilling.
- A rotary drilling rig was brought in, and the mud pit and pump were set up to circulate mud in the hole for MW-9.
- An eight-inch PVC surface casing was installed from the surface to a depth of 41.5 feet for MW-9.
- The casing annulus was grouted from bottom to top. The grout was allowed to set for 24 hours and checked again for settling.
- In MW-10, a second rotary drilling rig was brought in, and the mud pit and pump were set up to circulate mud in hole.
- An eight-inch PVC surface casing was installed from the surface to a depth of 77 feet in MW-10.
- The casing annulus was grouted from bottom to top. Grout was allowed to set for 24 hours and checked again for settling.
- At the sampling depths, the bit was pulled out of the hole, a Shelby tube or split spoon was advanced down the hole, pushed 2 feet and pulled out of the hole with the sample.
- Samples were extruded and treated as outlined for OVM and OVA sample screening earlier.
- A core sample was collected for TCE analysis as outlined earlier.
- A geologic description was noted of the core. Descriptions are recorded in Appendix B-1.

001508

001508

- A six-inch hollow-stem auger was used to drill below the casing and advance the borehole to a total depth of 101 feet (MW-9) and 100.5 feet (MW-10).
- Well components as specified and diagrammed in the Well Completion Forms (Appendix B-2) were steam-cleaned before installation. Well construction details are listed in Appendix B-3.
- Casing and screen were lowered through the borehole and sand pack, bentonite seal, and grout were placed as earlier described for MW-8.
- An at-grade completion with locking lid was used at MW-9.
- A protective housing, locking cover and padlock were installed at MW-10.

All cuttings and fluids generated during the drilling of the three wells were placed in 55-gallon drums, which were sealed and labeled.

2.1.2 Analytical Parameters and Procedures

The drilling and monitor well construction program as described previously yielded a total of 49 soil samples. All samples were screened by head space analyzer and the thirty samples with the highest readings (plus field blanks) were selected for laboratory analysis. The procedure was:

- Three shallow soil samples were analyzed for PCBs;
- Forty-nine samples were screened for volatile organics with an OVM (manufactured by Thermo Electron Co.);
- The same forty-nine samples were screened for volatile organics with a Foxboro Century OVA 128 GC;
- Thirty samples were chosen for complete volatile organics analyses in the laboratory; and
- Three samples were chosen from the intermediate-depth water producing sand for grain-size analysis.

As part of the Quality Assurance/Quality Control (QA/QC) program, a total of three equipment blanks were analyzed for TCE. A discussion of the results is presented in a separate QA/QC report.

001509

001509

Appendix C summarizes the analytical methods and procedures and the sample preservation and handling requirements. A discussion of chemical data, results and comparison with data collected in Phase I is presented later in this report.

Appendix D summarizes geotechnical data from three soil samples.

2.1.3 Well Development Procedures

All intermediate wells were developed using the following procedures:

- Depth to water level from top of casing was measured using a "popper" tape.
- Volume of casing was calculated and multiplied by 3. This was the amount of water to be removed from the aquifer from each well.
- Air lift techniques were used to develop each well; dedicated lengths of hose carried the produced water from the wellbore to a 55-gallon drum.
- Temperature, pH, salinity and electrical conductivity of the produced water were measured until readings stabilized and conductivity measurements were within 25% of the two previous measurements (Appendix B-2).

2.2 ELECTRIC LOGGING

The purpose of electric logging is to characterize the stratigraphic column in a fluid-filled cased hole. The three newly installed (Phase II) wells completed in the intermediate water-bearing sand were logged with gamma ray to cover gaps in lithology resulting from the intermittent nature of core sampling. A truck-mounted logging device was centered over the well casing and the sonde was lowered to the bottom of the hole. As the sonde was pulled up the casing, a continuous log was recorded. These logs are shown in Appendix F.

001510

001510

2.3 PLUGGING AND ABANDONING MONITOR WELL 3

MW-3 was installed to a depth of 99 feet during Phase I field activities, and a screen was installed across a water-bearing zone at 84-94 foot depth. The water-bearing zone consists of unconsolidated, fine-grained sand, silt and clay. Well completion specifications are listed in Appendix D-2 of the RI (Phase I) report.

Static water level has varied considerably in this well and is attributed to the "silting in" of the screened portion of the well. Grain-size analyses document that the formation contains about 40% fine-sized sand and 60% fine silt and clay-sized material that would continue to "silt in" the wellbore. Therefore, it was decided to plug and abandon MW-3 as part of Phase II work and replace it with MW-10.

The following procedures were used to plug and abandon MW-3:

- Removed protective surface housing from around well casing;
- Placed a protective collar around the well to catch water forced up from the well as it was grouted;
- Inserted an approximately 110 foot length of tremie pipe to the bottom of the well and grouted the well from bottom to top with cement/bentonite grout;
- Cut off stainless steel casing at ground level; and
- Placed dirt and grass seed over the area.

2.4 POTENTIOMETRIC SURFACE DETERMINATION

Four sets of water level measurements were performed on the six shallow depth wells while two sets of measurements were collected in the intermediate depth wells. Water level measurements define the potentiometric surface and help define the direction and hydraulic gradient of groundwater flow at the site.

001511

001511

Water level elevations were computed as follows:

- Depth to water from the top of the casing was determined using a "popper" tape, which makes a sharp sound as the popper hits the water surface.
- This depth was then subtracted from the surveyed elevation of each casing top to obtain water level elevations in each well.
- Tape was rinsed with de-ionized water, acetone, and rinsed again with de-ionized water in between each measurement. Rinse water and acetone were drummed for appropriate disposal.

2.5 WATER SAMPLING

Six monitor wells were completed in the uppermost (shallow) water-bearing zone during Phase I work: MW-1, MW-2, MW-4, MW-5, MW-6, and MW-7. Three monitor wells (MW-8, MW-9, and MW-10) were completed in the intermediate water-bearing zone during Phase II work. Two rounds of water sampling and analyses from all nine wells were completed for Phase II field activities. The first round was completed on February 24, 1988. The second round of sampling was completed March 25, 1988. Both rounds of water samples were collected prior to the running of slug tests. Field (equipment) blanks were collected during field work for QA/QC purposes.

The following procedures were used to obtain and analyze water samples from monitor wells:

- Depth to water level was measured as described previously.
- Height of the column of water was computed and volume of water within the casing calculated.
- A stainless steel bailer was used to remove three casing volumes. The contents of the bailer were poured into a bucket, measured and then emptied into a 55-gallon drum.
- Temperature, pH, salinity, and electrical conductivity of the produced water were measured until readings stabilized and conductivity measurements were within 10% of the two previous measurements.

001512

001512

- After three casing volumes of water were evacuated, the bailer was filled with well water again and brought to the surface.

- As the bailer was emptied, a glass 40 mL septum cap vial was held in the water stream and filled so there were no bubbles in the vial. The vials were labeled, a chain-of-custody form was filled out and the samples were stored in a cooler.

- The bailer was taken apart, washed, rinsed, sprayed with acetone and rinsed in de-ionized water between sampling each well. Rope was used to lower the bailer into the well and new rope was used for each well.

- Well water and decontamination water was contained for later disposal at a treatment, storage or disposal facility in compliance with the EPA's off-site disposal policy.
- Field (equipment) blanks were collected by pouring de-ionized water through bailers cleaned by the previously detailed methods.

- Sampling handling and shipping procedures were followed as described in the ITS Sampling Plan and in the QA/QC Plan. Chain-of-custody procedures were followed from field to laboratory.

All eighteen water samples (2 rounds of all six shallow wells and three intermediate-depth wells) were analyzed for TCE. Appendix C lists the analytical methods, preservation, shipping and handling procedures for the groundwater samples.

2.6 HYDRAULIC CONDUCTIVITY

Falling head slug tests were conducted in each of the six shallow monitor wells during Phase I field work. Similar tests were conducted in each of the three intermediate-depth monitor wells installed during Phase II field activities to assess hydraulic conductivity (K) and transmissivity (T). Tests were run following well completion, well development, and sampling activities.

The Bouwer and Rice (1976) method of determining hydraulic conductivity in unconfined aquifers was used, even though the intermediate aquifer is in a confined state. A comparison of methods with Cooper, et al (1967) in confined aquifers shows that the two methods result in similar conclusions, as stated by Bouwer and Rice (1976). Appendix G-1 details the hydraulic conductivity calculations and results.

001513

001513

The following procedures were used:

- Static water level was measured with an electronic water-level sensing device;
- A water-tight cylinder of known volume (4.225 cubic feet) was lowered into the water until completely submerged, thus displacing water upward in the well casing;
- Water level was then immediately measured with an electric tape and recorded in a field log book; and
- Similar measurements were collected until the water level measurements returned to former static level or normalized at a level near static water level.

2.7 CONE-PENETROMETER USE

The cone-penetrometer was used to investigate site-stratigraphy to a depth of 40 feet and to sample water from the uppermost water-bearing zone. A total of twenty cone-penetrometer soundings were taken, and locations of the soundings are illustrated in Figure 2-1. These locations were selected based on estimated plume movement and various access restrictions to property surrounding the ITS site.

The following procedures were used to obtain cone-soundings:

- Using a truck-mounted rig, a cone-penetrometer was advanced to a maximum depth of 40 feet.
- A cone-sounding was run simultaneously with insertion of the cone-penetrometer. Appendix E includes the Campanella and Robertson Classification Chart (a plot of friction versus tip resistance ratios) used in soil categorization.
- The cone-penetrometer was advanced until the sounding indicated that the uppermost water-bearing sand had been completely penetrated and that the cone had advanced into the underlying clay several feet, to a maximum of 40 feet.
- The cone-penetrometer was then removed from the hole.
- A tremie pipe was then inserted to the bottom of the hole and the hole grouted from bottom to top.

001514

001514

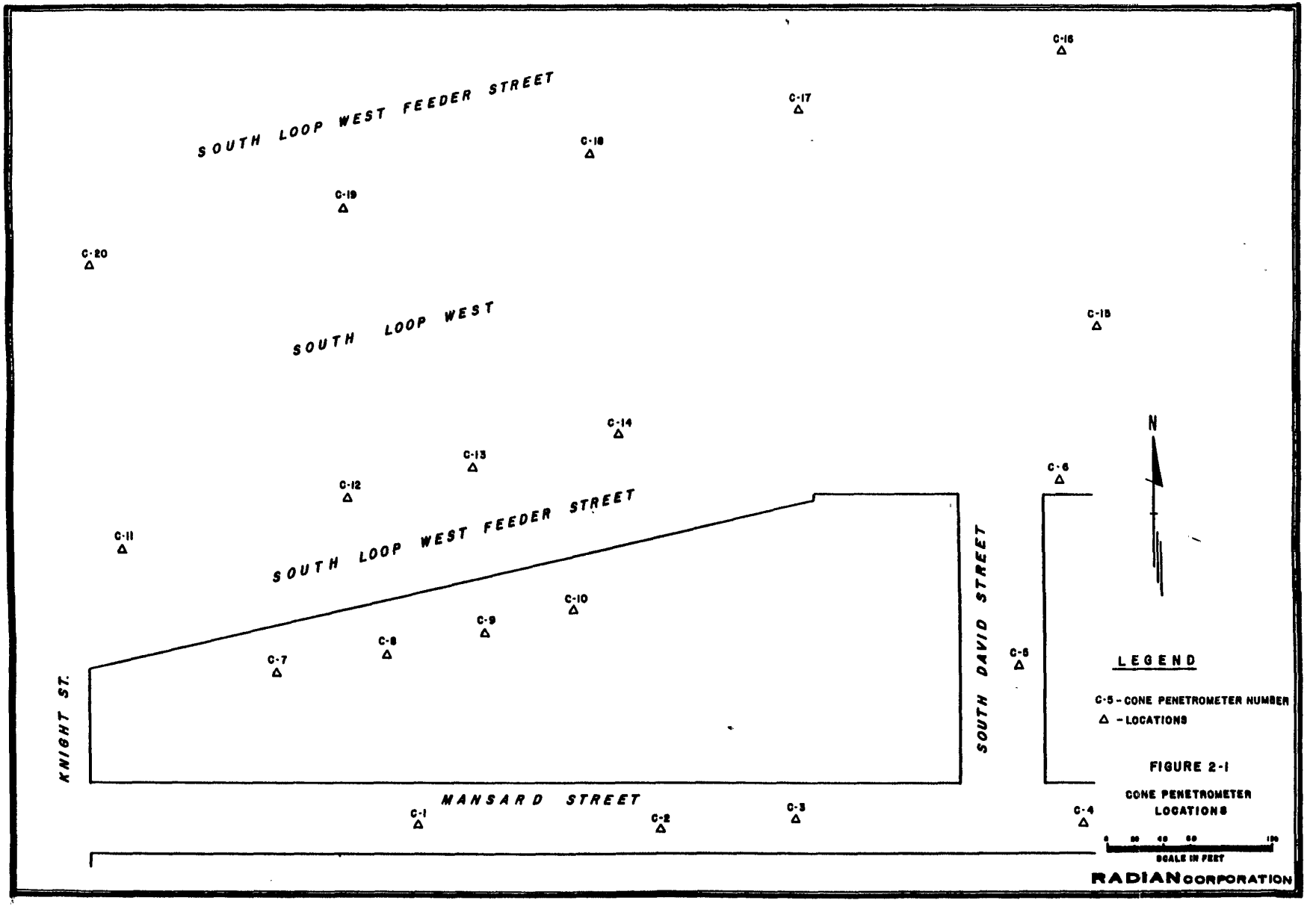


FIGURE 2-1

CONE PENETROMETER LOCATIONS

001515

- The grout was allowed to set for 24 hours to allow for settling and more grout was added if necessary.
- Penetration locations were staked, labeled and surveyed.

Procedures for water sampling utilizing the cone-penetrometer were as follows:

- A well-screen tip protected by a steel sleeve was substituted for the tip of the cone-penetrometer.
- The well-screen tip was advanced until it reached the selected depth.
- The sampling sleeve was pulled up to expose the screen.
- A teflon bailer was used to collect a water sample.
- Conductivity, salinity, temperature and pH were measured on this sample.
- The bailer was then used again to collect a water sample by pouring it into a 50 mL glass vial with a septum top.
- Excess water was contained for disposal at a treatment, storage or disposal facility in compliance with EPA's off-site disposal policy.
- The water-sampler was then removed from the hole, and the screen tip and cone rods were steam-cleaned in-between holes.
- The bailer was steam-cleaned, detergent washed and rinsed.
- Field (equipment) blanks were collected by pouring distilled water through the bailer previously cleaned according to the above procedures.
- A tremie pipe was then inserted to the bottom of the hole and the hole grouted from bottom to top.
- The grout was allowed to set for a period of 24 hours to allow for settling. Boreholes were checked for settling and more grout added if necessary.
- Sample handling and shipping procedures were followed as described in the ITS Sampling Plan and in the QA/QC Plan. Chain-of-custody procedures were followed from field to laboratory.

001516

001516

The cone-penetration was terminated provided one of the following conditions were met:

1. The water sampling device was set at the bottom of the uppermost water-bearing interval and water was collected from the interval.

2. In the event that water was not immediately produced, the hole was allowed to sit for several hours until enough water was produced for sampling and measuring purposes.

3. If still no water was produced, then either another penetration was placed nearby, but terminated at a slightly different stratigraphic interval; or

4. The water screen was pulled up (within the same hole) to a slightly higher stratigraphic interval.

5. If the water sampling device was unable to be advanced to the desired depth due to a zone of calcareous nodules and/or caliche within the uppermost water-bearing zone, the sleeve was opened at the "top" of the calcareous nodule zone and within the uppermost water-bearing zone.

All twenty water samples taken with the penetrometer were analyzed for TCE. Appendix C summarizes the analytical methods, preservation, shipping and handling procedures for the groundwater samples.

001517

001517

RADIAN CORPORATION

SECTION 3
SITE GEOLOGY

The regional setting is reported in the Phase I Remedial Investigation report (Radian, 1988). In summary, the ITS site is underlain by interdistributary clays. These interdistributary clays are composed of overbank deposits called crevasse splays or floodbasin deposits. A typical event occurs during high floods when floodwater and sediment overtops the stream banks, either as a flash flood or through a water-cut channel called a crevasse. There are several cycles of sedimentation present in the shallow subsurface at the ITS site. Phase II activities provided more geologic data which is used herein to describe the shallow subsurface geology at the site.

3.1 DATA SOURCES

During Phase I activities, nine monitor wells were completed at depths ranging from 38 to 44 feet, and one monitor well was drilled to a depth of 99 feet (later plugged and abandoned). The logs for these wells can be found in the Phase I Remedial Investigation (Radian, 1988). In Phase II work, three more wells were installed to a depth of 101 feet. Gamma logs were run on these three cased holes (Appendix F).

A cone-penetrometer was pushed to a maximum depth of 40 feet at twenty locations on and surrounding the site. Soundings were recorded at each location, and these provide an additional source of information concerning the site stratigraphy. Figure 3-1 shows penetrometer locations and the cross-sections referenced in this section.

001518

001518

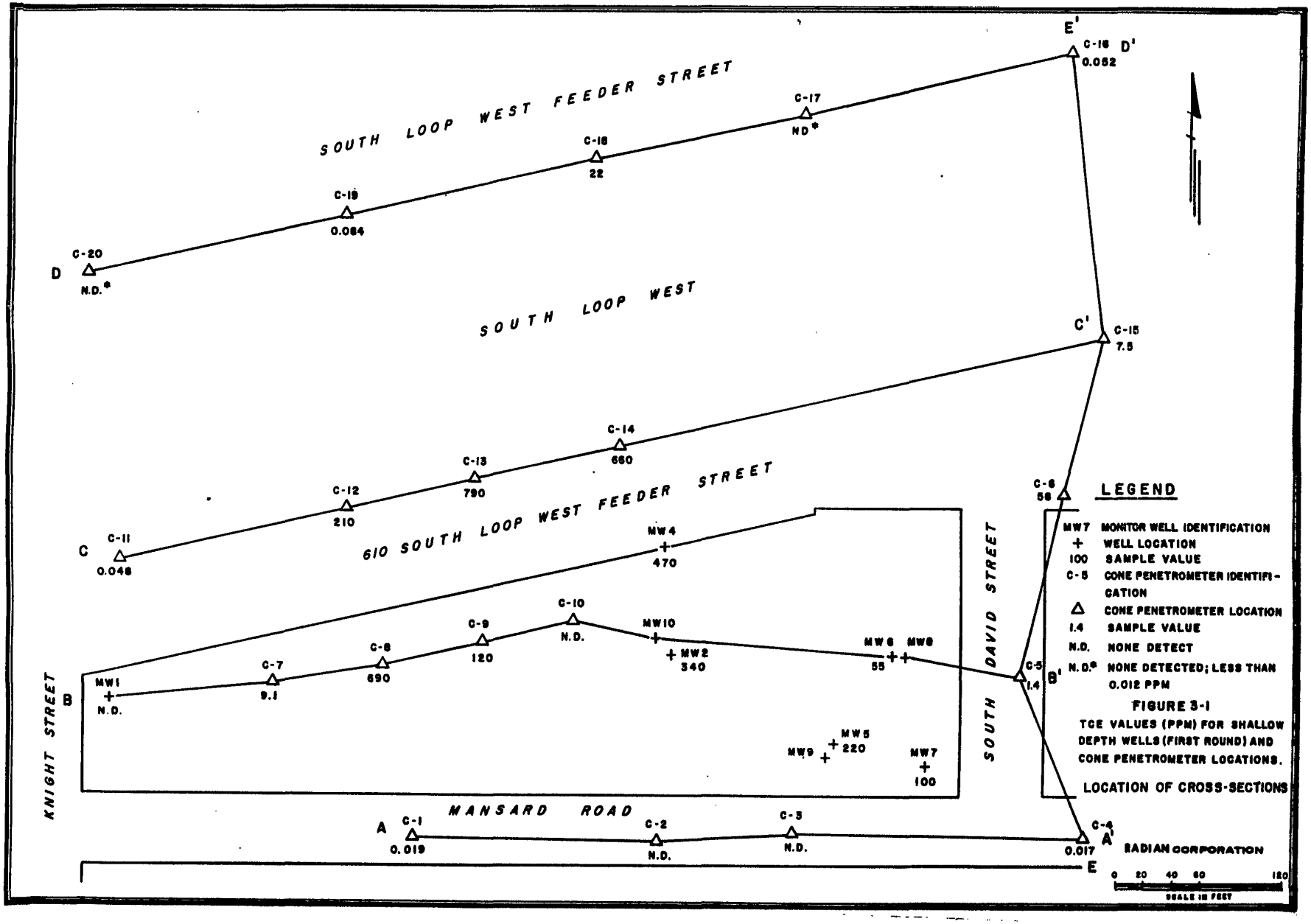


FIGURE 3-1
TCE VALUES (PPM) FOR SHALLOW DEPTH WELLS (FIRST ROUND) AND CONE PENETROMETER LOCATIONS.

001519

3.2 DEPOSITIONAL SETTING

The uppermost stratigraphic unit consists predominantly of clay, extending from the surface down to a depth of 15 feet, as indicated on east-west cross-sections A-A' (Figure 3-2), B-B' (Figure 3-3), C-C' (Figure 3-4), D-D' (Figure 3-5) and north-south cross-sections E-E' (Figure 3-6) and F-F' (Figure 3-7). Clays alternating with beds of silty clays and sandy silts extend from a depth of 15 feet to 30 feet. The clays and silty clays vary in color from brownish-gray to gray in the uppermost few feet. With depth, the clay changes to red mottled with green, grey, tan and/or brown. Iron-oxide and calcareous nodules are scattered throughout the uppermost clay and the alternating silty clays and silty sands. Core descriptions are recorded in Appendix B-1.

These types and changes in lithology are consistent with depositional models of overbank deposits, such as crevasse splays, each fining-upward sequence (silty sand to silty clay to clay) representing an event. The relative thinness and rapid alternation of the beds may be due to flooding events carrying low amounts of sediment or these deposits may be at the distal end, far from the source (Reineck and Singh, 1980).

The top of the uppermost water-bearing sand occurs at approximately 30 to 33 feet depth and averages 5 feet in thickness. This water-bearing zone was defined as the uppermost water-bearing unit because it is the thickest and only continuous unit observed across the site. This unit can be followed in a stratigraphic sense on cross-sections immediately surrounding the ITS site. It is underlain by clay or alternating lenses of silty clay and clay. The variation in the thickness of this unit across the site allows the identification of the proximal end, at the east end of the site, where this water-bearing unit is nearly seven feet thick. An unidentified buried channel may be a nearby source. The distal end is towards the west, where this zone thins to about 1.5 feet.

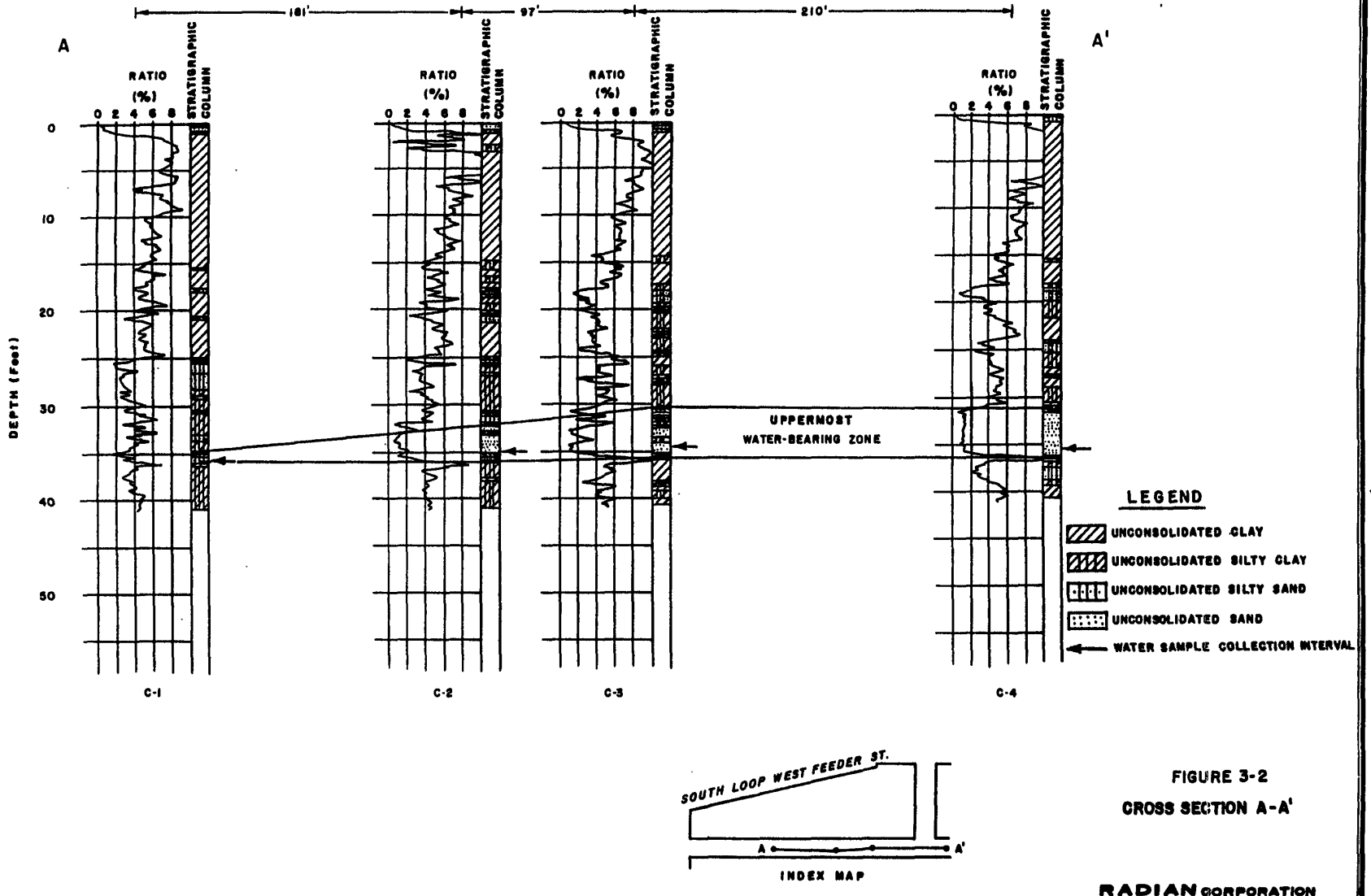


FIGURE 3-2
CROSS SECTION A-A'

RADIAN CORPORATION

001521

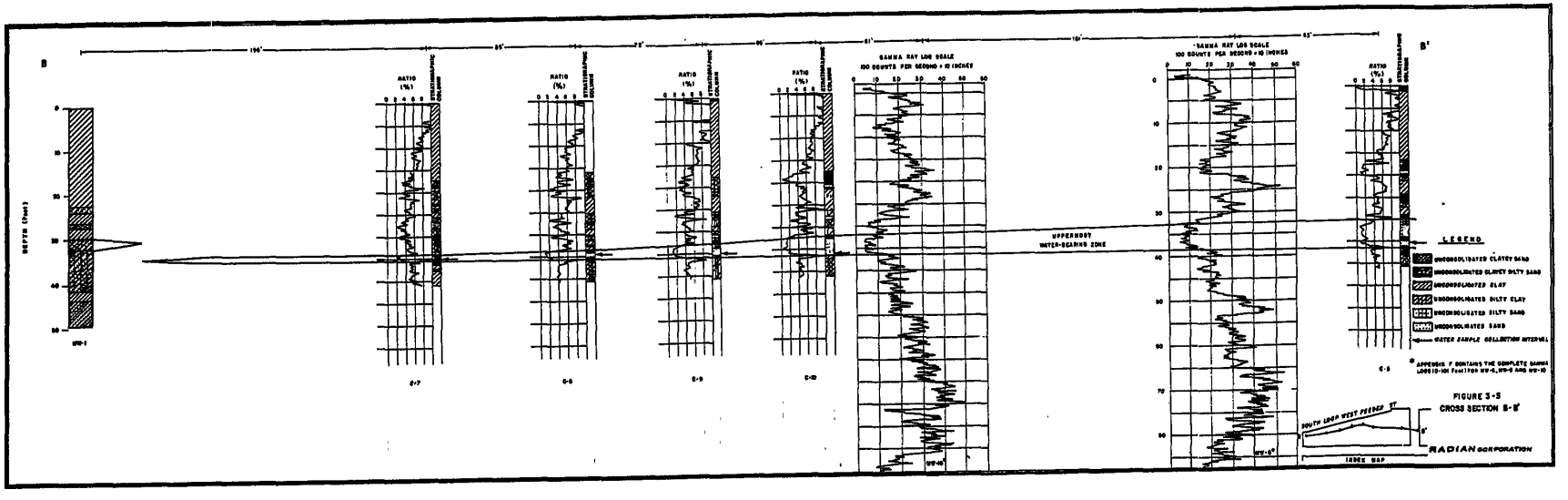


FIGURE 3-5
CROSS SECTION B-B'

001522

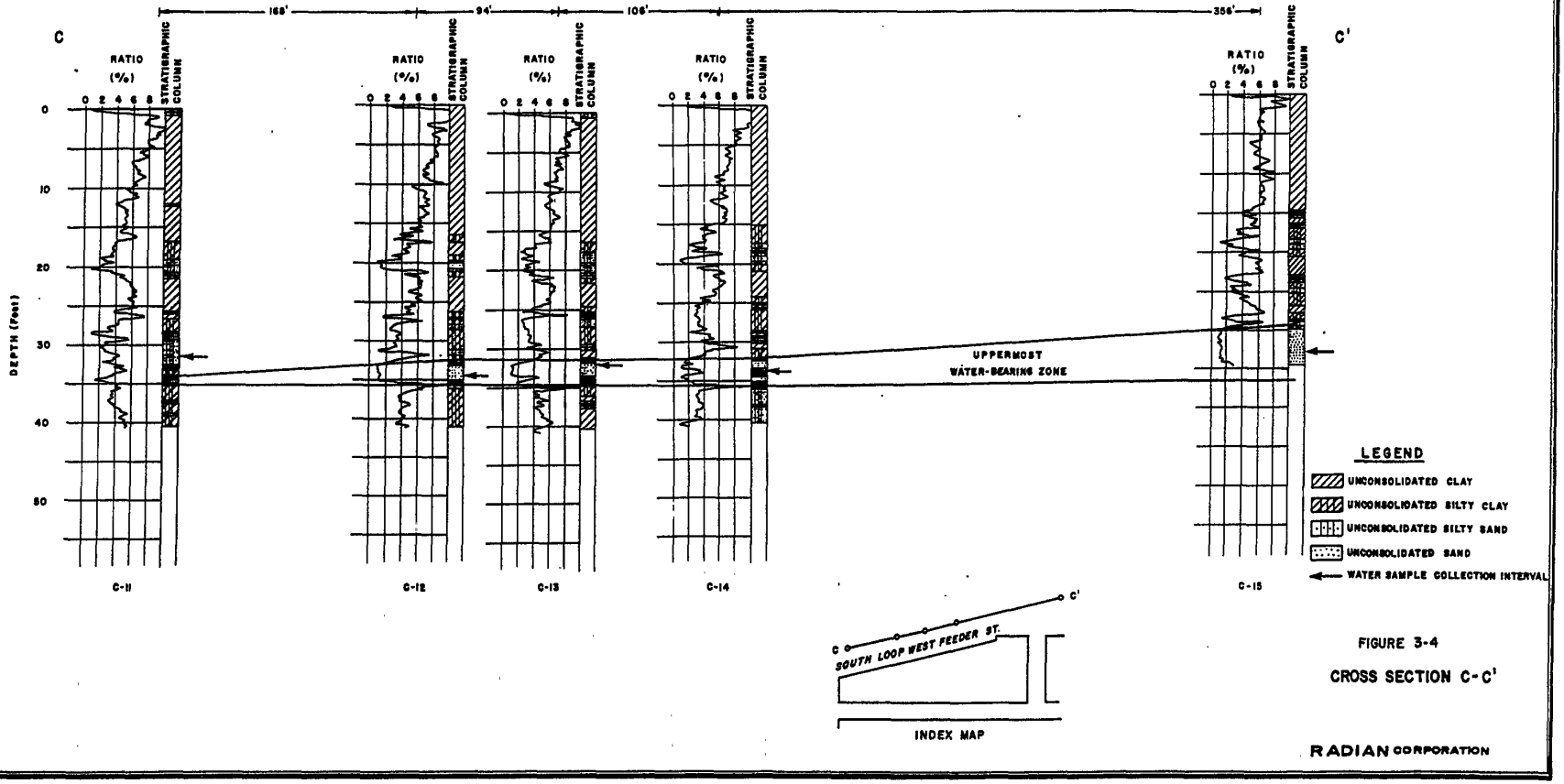


FIGURE 3-4

CROSS SECTION C-C'

001523

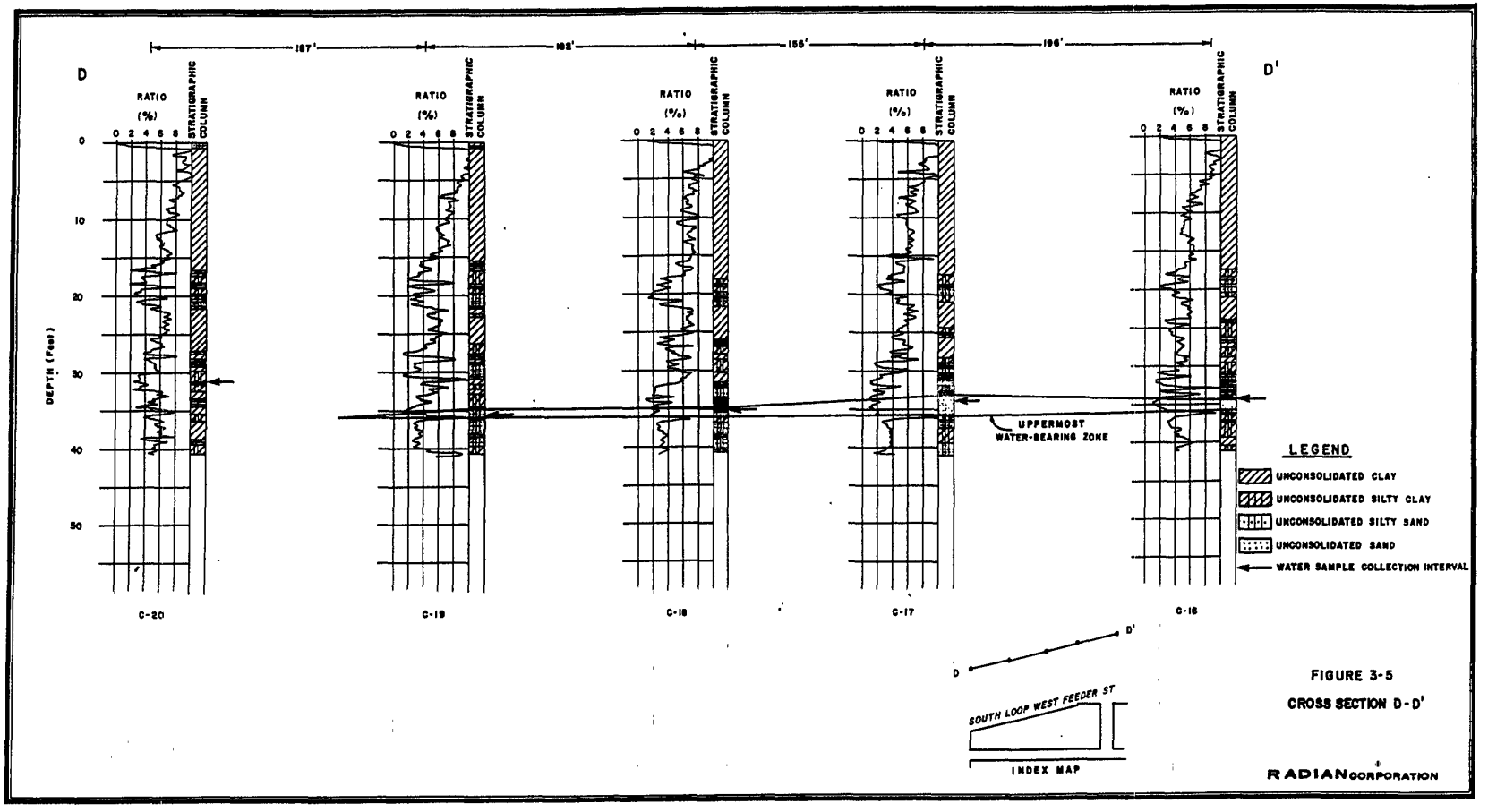


FIGURE 3-5

CROSS SECTION D-D'

001524

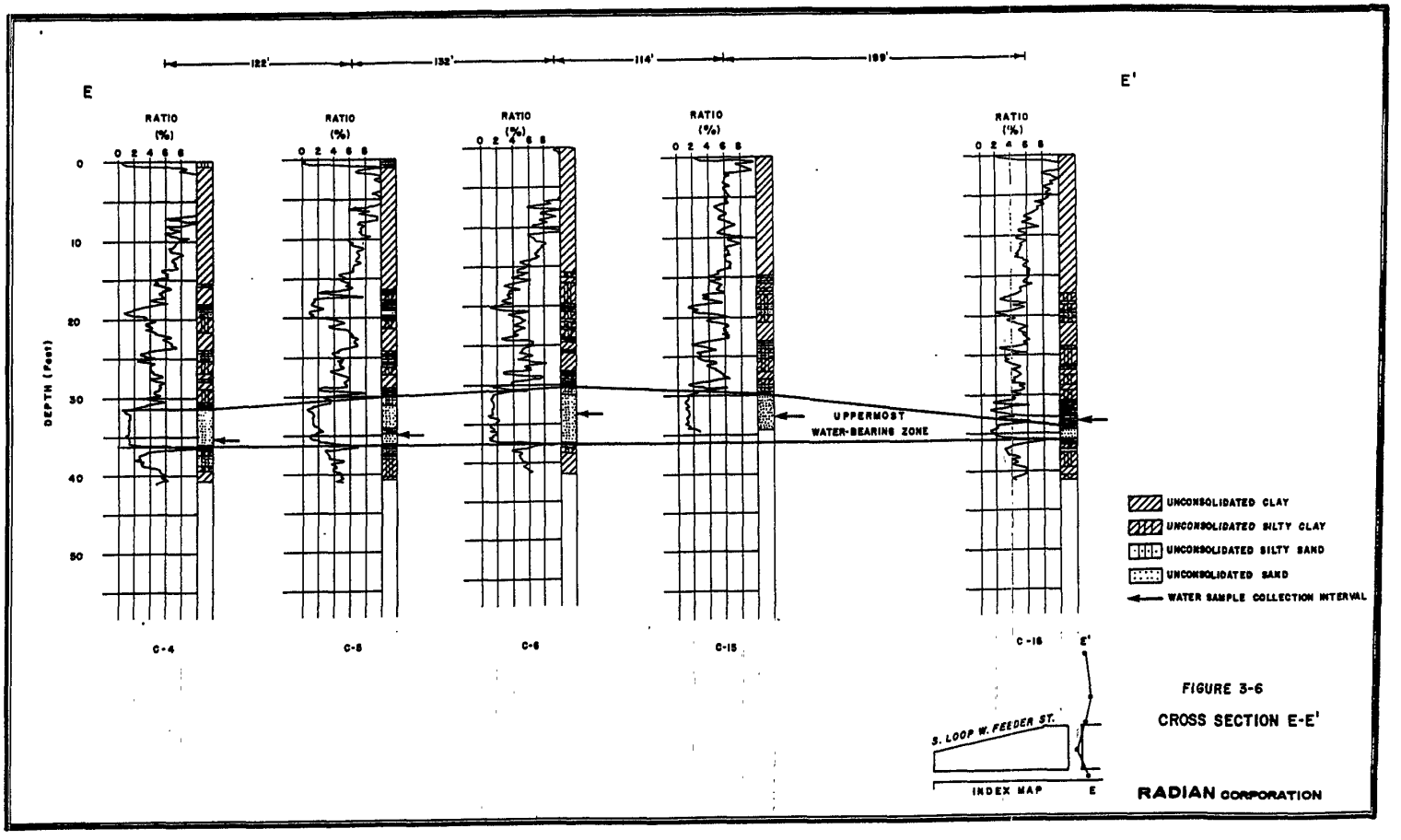


FIGURE 3-6

CROSS SECTION E-E'

001525

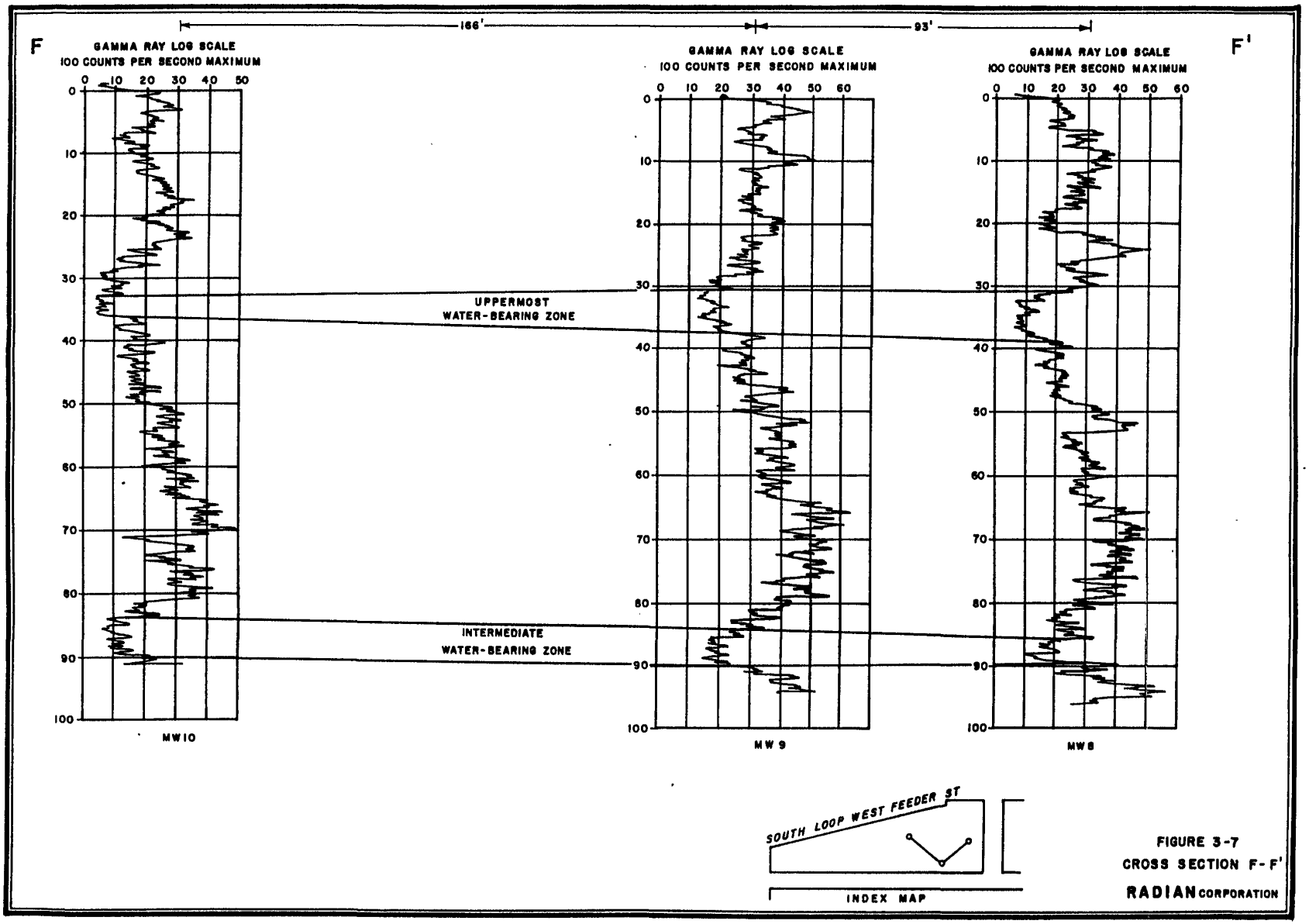


FIGURE 3-7
CROSS SECTION F-F'
RADIAN CORPORATION

001526

Calcareous nodules are scattered throughout the horizon from the surface to the uppermost water-bearing zone. A densely packed zone of calcareous nodules was observed within the uppermost water-bearing zone. The zone is recognized by increased resistance when drilling and in both the friction sleeve and tip resistance measurements during cone-penetrometer advancement. Resistance can be so great that it prevents further advancement of the penetrometer, such as at C-15 (Appendix E).

A densely packed zone is rarely observed at the top of the water-bearing zone, but is more common at the bottom of the water-bearing sand. It is also more common towards the east end of the site. It is possible that the zone is so tightly lithified that a "perched" or isolated water table could exist above it. This may explain the lack of TCE contamination noted in C-10 when there are locations surrounding C-10 that have TCE-contaminated water. Cone penetrometer locations containing a densely lithified zone include: C-2, C-3, C-5, C-6, C-10, C-12, C-14, C-15, and C-16 (Appendix E).

Certain of the cone-penetrometer soundings on the off-site cross-sections show silty sands subjacent to the uppermost water-bearing unit. In cross-section A-A' to the south of the site, C-4 contains silty sand separated from the main water-bearing zone by thin lenses of silty clay. This subjacent sand does not appear in other soundings or logs in cross-sections along the south or east side of the site.

To the north of the site, cross-section C-C' shows an approximately 5 foot thick silty sand underlying the uppermost water-bearing zone at the C-14 location. This location is of interest because it has a high concentration of TCE, 790 ppm. A nearby sounding, C-13, does not contain any silty sand but does contain clay and silty clay underlying the water-bearing zone. This subjacent sand may be hydraulically connected with the overlying "uppermost water-bearing zone", enabling the TCE-contaminated water to migrate deeper into the subsurface. Thin stringers of silty clay away from this sand may act to carry the TCE-contaminated water laterally.

001527

001527

The cross-section D-D' located further north of the ITS site than cross-section C-C' shows several locations where a silty sand underlies the uppermost water-bearing zone. The C-17, C-18 and C-19 locations all show up to 5 feet of silty sand underlying the "uppermost water-bearing zone" and separated from it by thin lenses (less than one foot thick) of silty clay. This silty sand is probably connected to that observed at the C-14 location (cross-section C-C').

All information together indicates that the presence of a silty sand, up to 7.5 feet thick, lies immediately under the "uppermost water-bearing unit" to the north of the ITS site. This underlying silty sand may direct the flow of groundwater to the deeper subsurface horizons. No information is available below a depth of 40 feet off-site, the limit of cone-penetrometer insertion.

Figure 3-7 (cross-section F-F') is composed of gamma logs and illustrates the relative position of the intermediate water-bearing zone compared to the uppermost water-bearing zone. The intermediate water-bearing zone is slightly thicker (6.5 feet) at MW-10 compared to the more easterly MW-8, where it is 5 feet thick. The gamma logs are also presented in Appendix F.

The logs are interpreted in conjunction with available core sample data to indicate that clay underlies the water-bearing unit; the clay (generally red, mottled with green or gray) alternates with silty clay (interpreted as overbank deposits) to a depth of about 84 feet. At this depth, the intermediate water-bearing sand then extends for about six feet in depth and is underlain by more clay. The intermediate water-bearing sand may also be a depositional product of a crevasse-splay.

001528

001528

RADIAN CORPORATION

SECTION 4

CHEMICAL DATA RESULTS AND INTERPRETATION

This section presents the results of the laboratory analyses of PCBs in shallow soil samples and TCE in soil samples and groundwater. These data are compared to the Phase I data. The QA/QC procedures used by the laboratory are documented in a separate report titled "Quality Assurance and Quality Control Report - Phase II, Industrial Transformer Superfund Site".

4.1 POLYCHLORINATED BIPHENYLS (PCBs)

PCB values for the 0 to 2 foot composite samples collected from each of the three monitor wells drilled during Phase II field activities are summarized in Table 4-1.

Samples from MW-8 and MW-10 contain less than the detection limit of 0.025 ppm of the three Arochlors of interest, PCB-1248, PCB-1254 and PCB-1260. The sample from MW-9 contains less than 0.36 ppm of the three Arochlors of interest.

As noted in Remedial Investigation Report of Phase I (Radian, 1988) field activities, PCB concentrations are random and localized. Most of the occurrences and the highest degree of contamination found in Phase I activities occur in Areas 3 and 4 and the eastern part of Area 2. The very low concentrations of PCBs found in the soils of the Phase II wells illustrate the sporadic nature of the original spills. Comparison with data from Phase I (see Figure 4-1) illustrates the nearby occurrence of relatively high values, such as 220 ppm in surface soil sample No. 39, 57 ppm in surface soil sample No. 40 and 350 ppm in the uppermost foot of Deep Boring 3 (DB-3).

001529

001529

RADIAN CORPORATION

TABLE 4-1

POLYCHLORINATED BIPHENYLS (PCBs) DATA

Intermediate Depth Monitor Well

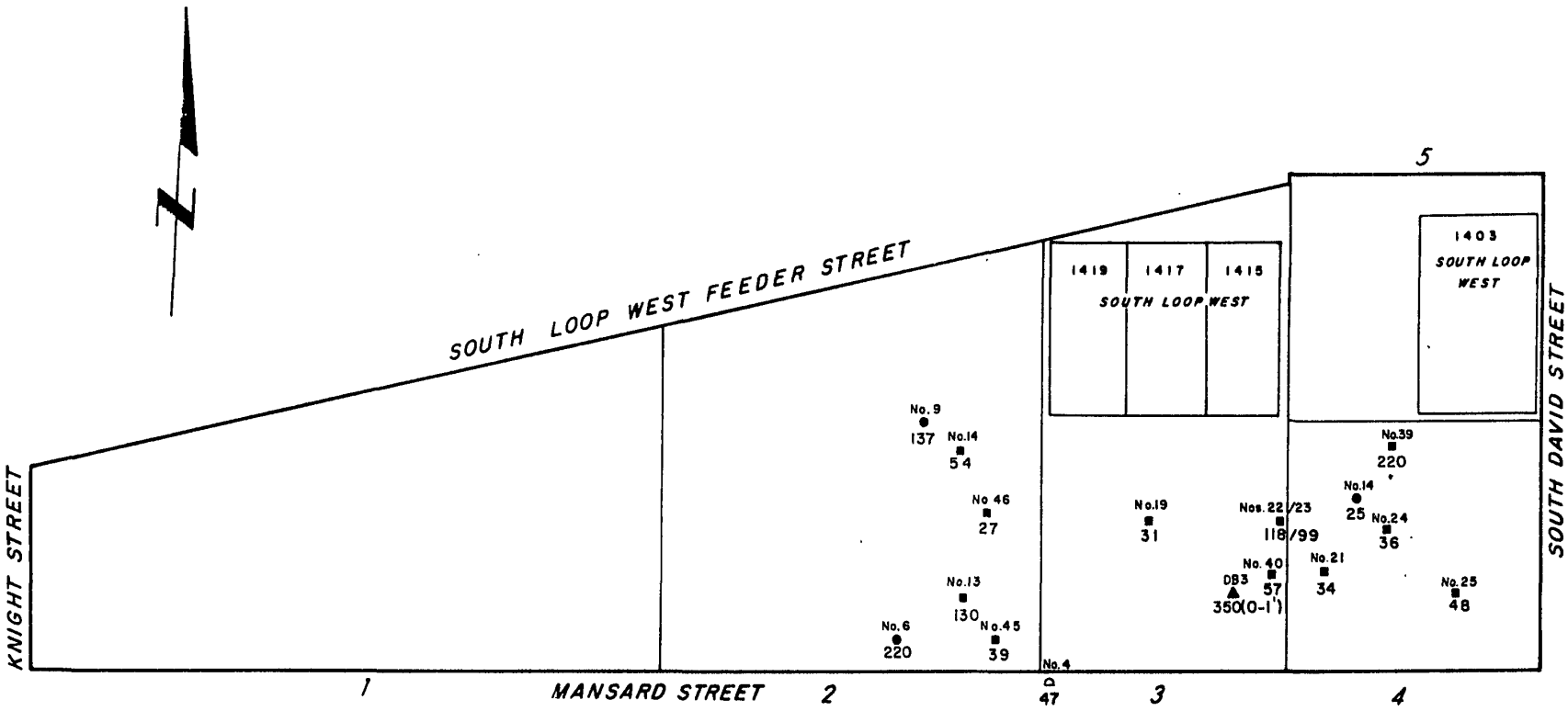
Soil Samples

Sample Identification	Depth (feet)	Horizon	Value (ppm)
MW8-ST1	0-2	Upper Clay	<0.025
MW9-ST1	0-2	Upper clay	0.36
MW10-ST1	0-2	Upper Clay	<0.025
MW8-FB1			<0.025

Key

MW - Monitor Well
ST - Shelby Tube
FB - Field Blank

001530



LEGEND

No.9 SAMPLE NUMBER

■ SURFACE SOIL LOCATION

● SHALLOW BOREHOLE LOCATION (0-2' DEPTH)

▲ DEEP BOREHOLE LOCATION (DEPTH IN PARENTHESIS)

⌂ SEDIMENT LOCATION

31 SAMPLE VALUE

FOR THE PURPOSES OF PRESENTATION, ALL VALUES HAVE BEEN ROUNDED OFF.

FIGURE 4-1
SUMMARY DIAGRAM OF SOIL SAMPLES >25 PPM PCB'S (INCLUDING SURFACE, SHALLOW AND DEEP SUBSURFACE SAMPLES)

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

001531

4.2 TRICHLOROETHENE (TCE) IN SOILS

This section presents the results of TCE analyses on soil samples taken during drilling of the three intermediate monitoring wells (MW-8, MW-9, and MW-10) installed in Phase II. These data are also compared to data collected in Phase I.

4.2.1 Phase II Data

A number of the samples indicated the presence of volatile organics, according to OVA results (see Appendix A). Those with the highest responses were selected for TCE analysis in the laboratory. TCE data for monitor well soil samples are listed in Table 4-2 and illustrated in Figure 4-2. Also shown on Table 4-2 are the results of three field blank samples. The blank sample concentrations ranged from 0.011 to 0.035 ppm. Therefore, TCE concentrations of less than 0.04 ppm are considered not detected.

Only two soil samples were selected for TCE analyses from MW-8 because of either a low response or no response on the OVA/GC. In MW-8, one soil sample from the uppermost water-bearing zone and one from just below that zone were analyzed for TCE. The sample from 34-36 feet in the upper water-bearing zone contained 1.5 ppm TCE, while no TCE was detected in the sample from the 39 to 41 foot depth just below the zone.

MW-9 contained TCE present in amounts greater than 0.04 ppm at 6 locations scattered from 23 to 101 feet depth. The highest of these values are discussed here. The clay sample from 23 to 25 feet contained 6.9 ppm, and the sample from 30 to 33 feet, which is from the uppermost water-bearing sand, contained 31 ppm. This is the highest value reported from this well. The clay interval from 49 to 50 feet contained 3.2 ppm. In the intermediate water-bearing sand the interval of 89 to 90 feet contained 0.3 ppm. The underlying clay from 99 to 101 feet contained 0.11 ppm.

001532

RADIAN CORPORATION

TABLE 4-2
TRICHLOROETHENE (TCE) DATA

Intermediate Depth Monitor Well
Soil Samples

Sample Identification	Depth (feet)	Horizon	TCE Value (ppm)
MW8-ST2	4-6	Upper Clay	NA
MW8-ST3	8-10	Upper Clay	NA
MW8-ST4	13-15	Upper Clay	NA
MW8-ST5	18-20	Upper Clay	NA
MW8-ST6	24-26	Upper Clay	NA
MW8-ST7	29-31	Upper Clay	NA
MW8-ST8	34-36	Uppermost Water-Bearing Sand	1.5
MW8-ST9	39-41	Intermediate Clay	ND
MW8-ST10	44-46	Intermediate Clay	NA
MW8-ST11	49-51	Intermediate Clay	NA
MW8-SS12	59-61	Intermediate Clay	NA
MW8-ST13	69-71	Intermediate Clay	NA
MW8-ST14	79-81	Intermediate Clay	NA
MW8-ST15	89-91	Intermediate Water-Bearing Sand	NA
MW8-ST16	99-101	Lower Clay	NA
MW9-ST2	3-5	Upper Clay	NA
MW9-ST3	8-10	Upper Clay	NA
MW9-ST4	13-15	Upper Clay	NA
MW9-ST5	18-20	Upper Clay	NA
MW9-ST6	23-25	Upper Clay	6.9
MW9-ST7	28-30	Upper Clay	ND*
MW9-ST8	33-35	Uppermost Water-Bearing Sand	31
MW9-SS9	38-40	Intermediate Clay	ND*
MW9-ST10	43-45	Intermediate Clay	0.063
MW9-ST11	49-50	Intermediate Clay	3.2
MW9-CB12	56-59	Intermediate Clay	0.95
MW9-ST13	69-71	Intermediate Clay	ND*
MW9-ST14	79-81	Intermediate Clay	ND*
MW9-ST15	84-85	Intermediate Water-Bearing Sand	ND*
MW9-ST16	89-90	Intermediate Water-Bearing Sand	0.3
MW9-ST17	94-95.5	Lower Clay	ND*
MW9-ST18	99-101	Lower Clay	0.11

Key
NA - Not Analyzed
ND - None Detected
ND* - Not Detected; Less than 0.04 ppm

001533

001533

RADIAN CORPORATION

TABLE 4-2
TRICHLOROETHENE (TCE) DATA (Continued)

Intermediate Depth Monitor Well
Soil Samples

Sample Identification	Depth (feet)	Horizon	TCE Value (ppm)
MW10-ST2	3-5	Upper Clay	250
MW10-ST3	8-10	Upper Clay	36
MW10-ST4	13-15	Upper Clay	36
MW10-ST5	18-20	Upper Clay	600
MW10-ST6	23-25	Upper Clay	400
MW10-ST7	28-30	Upper Clay	66
MW10-ST8	33-35	Uppermost Water-Bearing Sand	27
MW10-ST9	38-40	Intermediate Clay	12
MW10-ST10	43-45	Intermediate Clay	21
MW10-ST11	48-50	Intermediate Clay	26
MW10-ST12	58-60	Intermediate Clay	16
MW10-ST13	68-70	Intermediate Clay	ND*
MW10-ST14	78-80	Intermediate Clay	ND*
MW10-SB15	84-85.5	Intermediate Water-Bearing Sand	ND*
MW10-SS16	89-91	Lower Clay	0.1
MW10-SS17	94-95.5	Lower Clay	NA
MW10-SS18	99-100.5	Lower Clay	NA
MW8-FB2	--		0.035
MW10-FB6	--		0.011
MW9-FB5	--		0.011

Key

NA - Not Analyzed
ND - None Detected
ND* - Not Detected; Less than 0.04 ppm

001534

001534

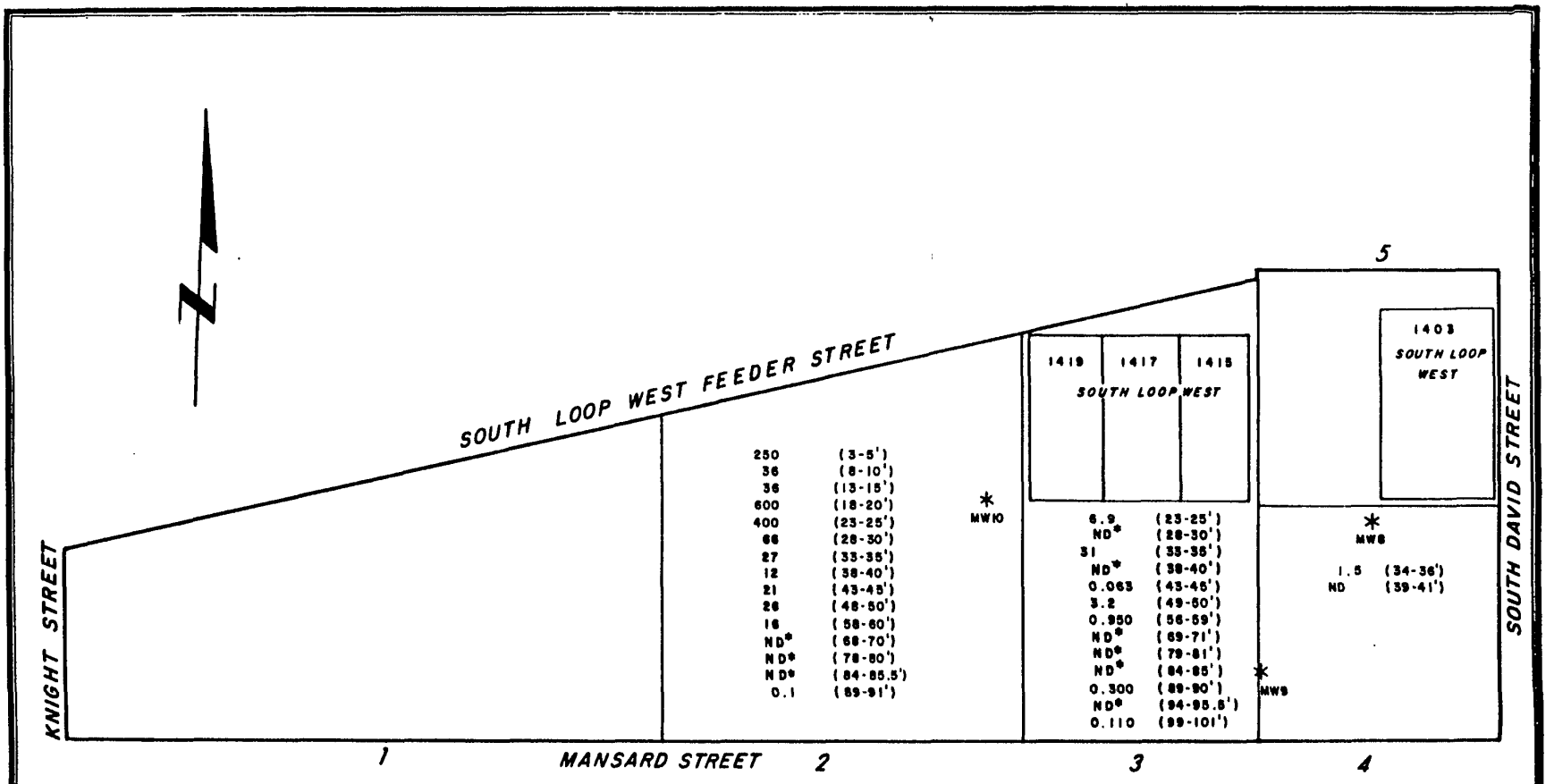


FIGURE 4-2

TCE VALUES FOR MONITOR WELL SOIL SAMPLES (PPM) PHASE II

LEGEND

MW8	MONITOR WELL NUMBER
*	MONITOR WELL LOCATION
69(23-25')	SAMPLE VALUE; WITH DEPTH IN PARENTHESIS
ND	NOT DETECTED
ND*	NOT DETECTED; LESS THAN 0.04 PPM

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001535

MW-10 soil samples contained the greatest concentrations of TCE of the three Phase II wells. The sample from 3 to 5 feet clay contained 250 ppm, while intervals 8 to 10 and 13 to 15 feet (both clay) reported 36 ppm. The sample from 18 to 20 feet (silty clay to clayey silt) contained 600 ppm and the interval between 23 to 25 feet (clay) reported 400 ppm. The next interval 33 to 35 feet, the uppermost water-bearing zone and a clayey sand, contained 27 ppm TCE. Values range from 12 to 26 ppm through a depth of 58 to 60 feet. A value of 0.1 ppm TCE is observed at 89 to 91 feet in the clay underlying the intermediate water-bearing sand.

These high concentrations may be because MW-10 is located near (approximately ten feet) an old water well that has since been plugged and abandoned. It is hypothesized that this old water well may have acted as a conduit for TCE-contaminated fluids to move into the subsurface. Total depth of the old well is not known, although various estimates place it between 20 and 60 feet.

001536

4.2.2 Comparison with Phase I Data

A total of eleven soil samples were analyzed for TCE during Phase I field activities. Table 4-3 lists the results, and Figure 4-3 illustrates the locations and distributions of samples from Phase I.

DB-5/MW-7 (Area 4) contained the least significant amounts of TCE, 5 ppm at a depth of 23 to 28 feet (clay, with increasing amounts of sand with depth) in the uppermost water-bearing sand at 34 to 39 feet. The most significant amounts of TCE were found in MW-3:

- At 9 to 10 feet (clay zone above uppermost water-bearing zone), 390 ppm TCE was observed;
- At 25 to 26 feet (also a clay zone above uppermost water-bearing unit), 75 ppm was seen;
- At 54 to 55.5 feet (clay), 110 ppm was observed; and
- At 89 to 90.5 feet (intermediate water-bearing zone), 15 ppm was observed.

001536

RADIAN CORPORATION

TABLE 4-3
TRICHLOROETHENE (TCE) DATA - Phase I

Surface Soil Samples

Sample Identification	Value (ppm)
SS-9	0.018
SS-17	1.6
SS-21	1.2
SS-22	0.55

Shallow Boring Soil Samples

Sample Identification	Depth (feet)	Value (ppm)
B3;ST-1*	0-2	0.0051
B3;ST-2	2-4	0.0062
B4;ST-1	0-2	0.0076
B4;ST-2	2-4	0.032
B5;ST-1	0-2	41
B5;ST-2	2-4	87
B7;ST-1	0-2	150
B7;ST-2	2-4	10
B8;ST-1	0-2	0.27
B8;ST-2	2-4	0.074
B9;ST-1	0-2	0.7
B9;ST-2	2-4	0.085
B11;ST-1	0-2	1.7
B11;ST-2	2-4	1
B12;ST-1	0-2	3
B12;ST-2	2-4	0.088
B14;ST-1	0-2	0.022
B14;ST-2	2-4	0.025

* This designation "B" refers to a shallow boring which is divided into an upper section, 0-2 foot depth, sampled by Shelby tube (ST) and labeled ST-1. A second sample is from the 2-4 depth and collected using a Shelby tube (ST) and labeled ST-2.

001537

001537

RADIAN CORPORATION

TABLE 4-3
TRICHLOROETHENE (TCE) DATA - Phase I
(Continued)

Deep Boring Soil Samples

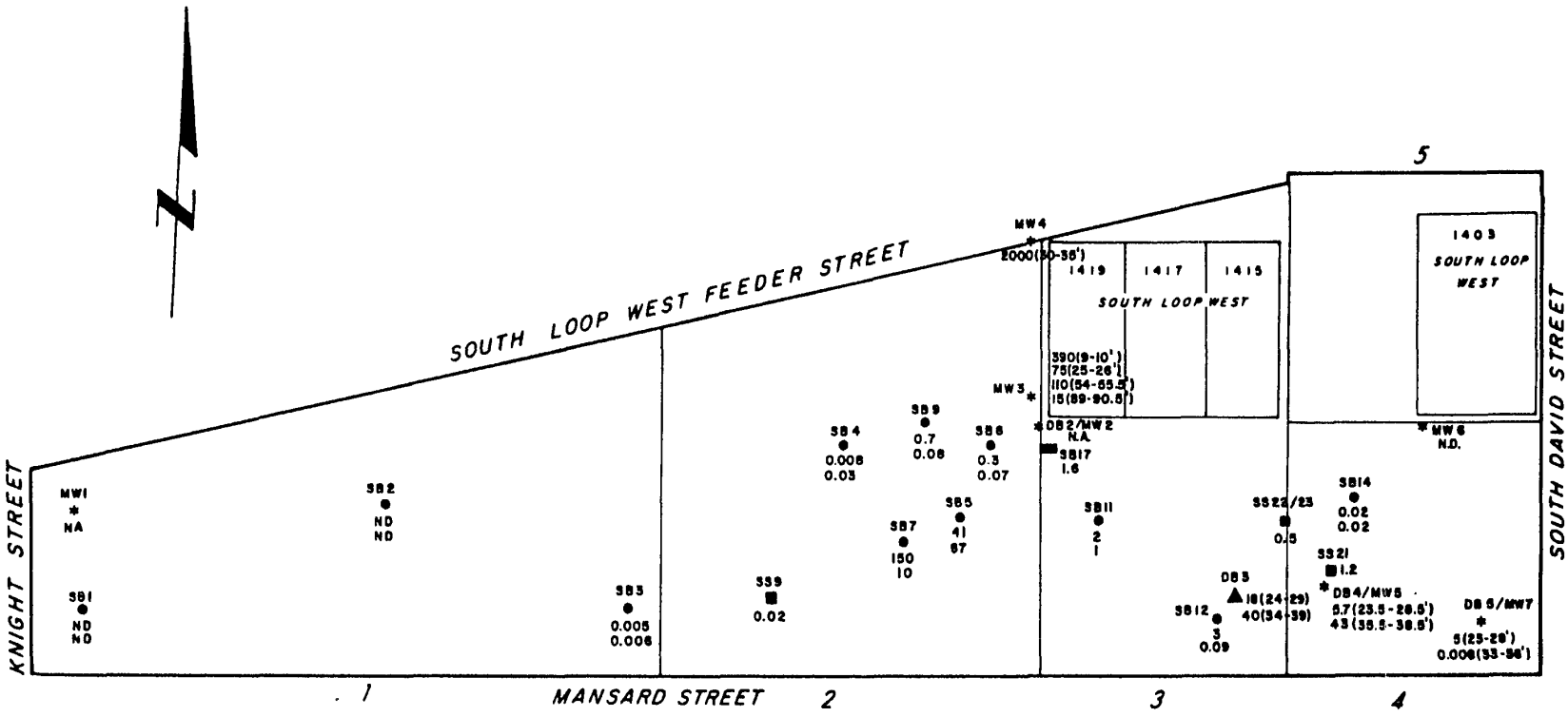
Sample Identification	Depth (feet)	Horizon	Value (ppm)
DB-3;CM-4	24-29	Upper Clay	18
DB-3;CM-6	34-39	Uppermost Aquifer	40
DB-4;CM-4	23.5-28.5	Upper Clay	5.7
DB-4;CM-6	33.5-38.5	Uppermost Aquifer	43
DB-5;CM-4	23-28	Upper Clay	5.1
DB-5;CM-6	33-38	Uppermost Aquifer	0.0077
Deep Boring 5 converted to Monitor Well 7			
MW-3;S-3	9-10	Upper Clay	390
MW-3;S-4	25-26	Upper Clay	75
MW-3;SB-1	54-55.5	Intermediate Clay	110
MW-3;SB-3	89-90.5	Intermediate Aquifer	15
MW-4;S-4	30-35	Uppermost Aquifer	2000

Key

DB - Deep Borehole
MW - Monitor Well
CM - Core Barrel Samples
S - Auger Cutting Samples
SB - Split Barrel Samples
SS - Split Spoon Samples

001538

001538



LEGEND

DB3	DEEP BOREHOLE NUMBER	ND	NONE DETECTED
▲	BOREHOLE LOCATION	SS9	SURFACE SOIL NUMBER
18(24-29')	TCE CONCENTRATION (PPM); WITH DEPH IN PARENTHESIS	■	SAMPLE LOCATION
MW6	MONITOR WELL NUMBER	0.02	TCE CONCENTRATION (PPM)
*	MONITOR WELL LOCATION		
NA	NOT ANALYZED		
SB11	SHALLOW BOREHOLE NUMBER		
●	BOREHOLE LOCATION		

FIGURE 4-3

SUMMARY OF TCE VALUES IN SOIL SAMPLES - PHASE I

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001539

These relatively high amounts of TCE coincide with the relatively high amounts of TCE found in nearby (approximately 10 feet away) MW-10, such as 250 ppm at 3 to 5 feet depth, 36 ppm at 8 to 10 and 13 to 15 feet depth (all clay samples), increasing to 600 ppm and 400 ppm at depths of 18 to 20 feet (clayey silt) and 23 to 25 feet (clay), respectively. Values range from 12 to 66 ppm TCE over the depths of 28 to 60 feet. Lower amounts of TCE were detected at scattered depths down to 91 feet (which includes the intermediate depth water-bearing sand).

The area surrounding and including MW-3 (now plugged and abandoned as described in Section 2.3) and MW-10 showed the highest TCE concentrations in the soils on-site. This may be due to the presence of an old water well (now plugged and abandoned) in the vicinity of these two wells that acted as a conduit for TCE to enter these deeper soil horizons. Drum storage and contents discharge may also have been concentrated in this area.

Results from Phase II show that the deep soil horizons within MW-8 are not contaminated with TCE, while the uppermost water-bearing sand shows the presence of TCE. This indicates lateral transport of TCE in addition to downward migration from ground level. This well is some distance away from known work and storage areas related to previous site activities.

MW-9 is in the vicinity of DB-3 and DB-4 and shows similar patterns of TCE concentration to the other deep borings. Samples were not analyzed for TCE in the upper 20 feet of the soil column because OVA/GC readings indicated low organic contamination levels. At a depth of 23 to 25 feet, 6.9 ppm TCE was reported coinciding with 5.7 ppm at 23.5 to 28.5 feet in DB-4 and with 5.1 ppm at 23 to 28 feet in DB-5.

In the uppermost water-bearing zone, at a depth of 33.5 to 38.5 feet, there were 43 ppm TCE in DB-4 and 0.0077 ppm TCE in DB-5/MW-7 were found.

Amounts of TCE detected within the uppermost water-bearing sands of the three deep borings or monitor wells DB-3, DB-4/MW-5 and MW-9 were likewise

001540

001540

very similar. In DB-3, 40 ppm TCE were reported, DB-4 contained 40 ppm and MW-9 contained 31 ppm.

This pattern of contamination suggests that migration of TCE downward through the soil has resulted in TCE at depth and that TCE has also migrated laterally through silty, more permeable clays above the water-bearing sand, through the sand itself and has continued to migrate below the water-bearing sand.

Overall, TCE distribution appears highest around the area of MW-3 (now plugged and abandoned) and MW-10, where soils to a depth of 60 feet and scattered deeper horizons contained TCE. No contamination was found in the clays underlying the intermediate water-bearing zone within MW-10 and no clays were analyzed from this depth in MW-3.

TCE was detected in lesser amounts in MW-8 and MW-9 and in deeper subsurface soils. The absence of TCE at shallow depths in these two wells indicates that lateral aqueous transport is responsible for TCE contamination of groundwater at these locations rather than downward migration from the soil surface.

In all three newly installed wells, TCE results are very similar in magnitude to values reported in nearby deep borings and monitor wells completed in Phase I field activity.

4.3 TRICHLOROETHENE (TCE) IN THE SHALLOW WATER-BEARING ZONE

The purpose of the monitor well and cone-penetrometer water sampling program was to identify the nature, extent and magnitude of TCE contamination in the shallow (uppermost) water-bearing zone. Phase II investigations included two rounds of sampling at each of the six monitor wells completed in the uppermost water-bearing zone and one round of sampling at cone-penetrometer locations from the same water-bearing zone. It also included two rounds of sampling at each of the three newly installed monitor wells completed in the intermediate water-bearing zone.

001541

4.3.1 Phase II Data

Table 4-4 summarizes monitoring well TCE data from the uppermost water-bearing zone, including equipment blanks. Concentrations for the first round of sampling are shown on Figure 4-4 and the second round of sampling in Figure 4-5.

The overall ranking of the wells in terms of TCE concentration shows that the highest concentrations were found at the MW-4 location (470 ppm and 550 ppm), respectively, for Rounds 1 and 2, then MW-2 (340 ppm/410 ppm) and, next lowest, MW-5 (220 ppm/160 ppm).

MW-6 and MW-7 had the lowest TCE concentrations, with MW-7 containing 100 ppm in the first round and MW-6 reporting 56 ppm. In the second round of sampling however, MW-6 contained 56 ppm, followed by MW-7 with 54 ppm. No TCE was detected in either round of sampling at the MW-1 location.

Table 4-5 summarizes TCE data for samples taken by cone-penetrometer from the uppermost water-bearing zone, including equipment blanks. Concentrations and sample locations are plotted on Figure 4-6. The highest equipment blank concentration is 0.012 ppm; therefore, no concentrations equal to or less than 0.012 ppm are considered detected.

TCE samples taken from concentrations along the south side of the site are very low (Figure 4-6). Location C-1 showed 0.019 ppm TCE, while C-2 and C-3 samples contained no detectable amounts of TCE. The location C-4 sample contains 0.017 ppm TCE. Cross-section A-A' (Figure 3-3) shows that the water-bearing sand at this depth thins in the southwesterly direction to a thickness of about one foot. It becomes a thicker (about 5 feet) and a cleaner (i.e., fewer fines) sand in the easterly direction. The low concentrations indicate the plume is not moving in this direction in the shallow aquifer.

Somewhat higher amounts of TCE are found along the east side of the site (C-5/1.4 ppm, C-6/58 ppm, C-15/7.5 ppm, C-16/0.052 ppm). Cross-section E-E' (Figure 3-7) show this water-bearing zone becoming thicker along the east

001542

RADIAN CORPORATION

TABLE 4-4
TRICHLOROETHENE (TCE) DATA

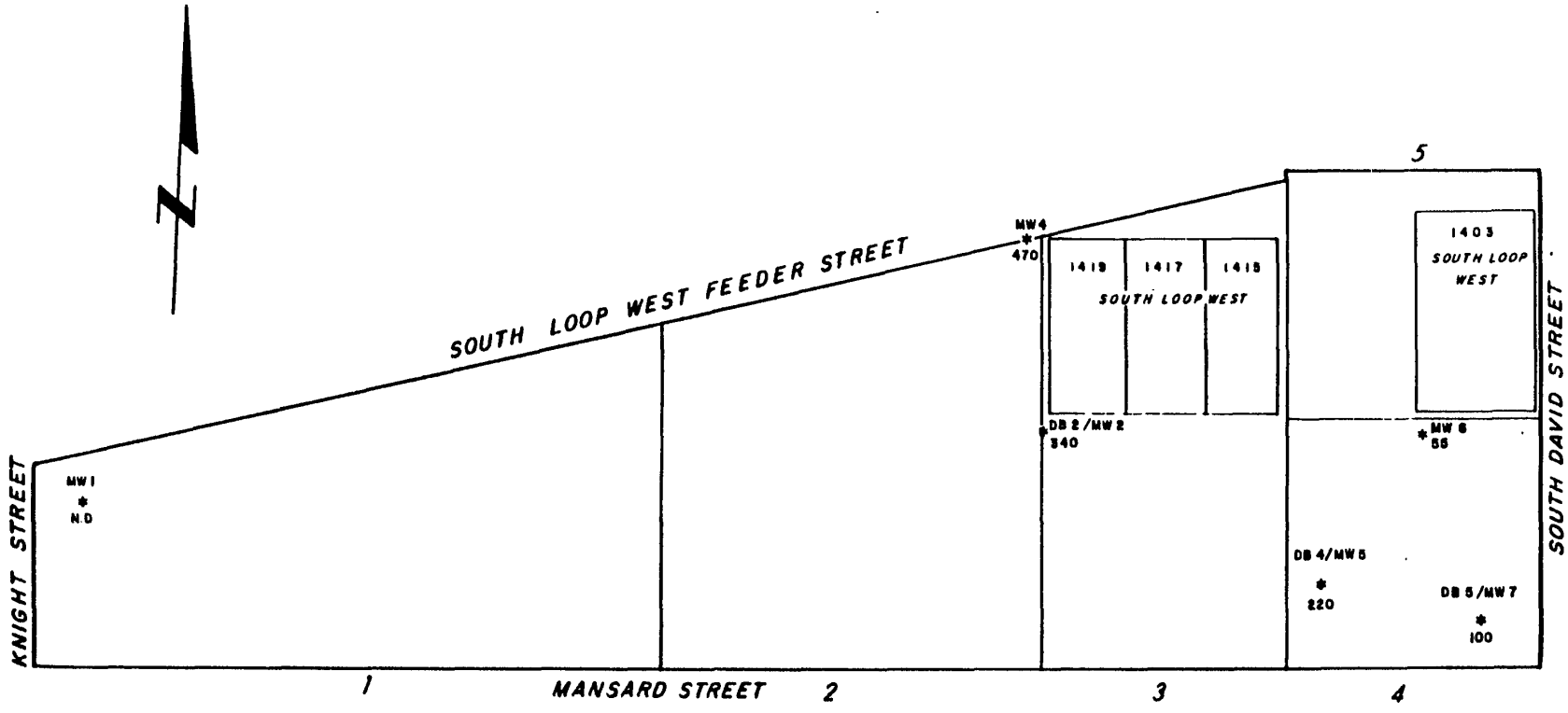
Monitor Well Water Samples
Uppermost Water-Bearing Zone
Phase II

Sample Identification	Round 1 Results (ppm)	Sample Identification	Round 2 Results (ppm)
MW1-C*	ND	MW1-D**	ND
MW2-C	340	MW2-D	410
MW4-C	470	MW4-D	550
		MW4-D Duplicate	510
MW5-C	220	MW5-D	160
MW6-C	55	MW6-D	56
MW7-C	100	MW7-D	54
EB-1	0.0013	EB-7	ND
EB-2	0.0021	EB-8	ND

ND - Not Detected
EB - Equipment Blank
* - The label "-C" refers to the first round of sampling in the second phase of the Remedial Investigation.
** - The label "-D" refers to the second round of sampling in the second phase of the Remedial Investigation.

001543

001543



LEGEND

DB 4/MW 5 – DEEP BORING/MONITOR WELL NUMBER
✱ – WELL LOCATION
220 – SAMPLE VALUE
N.D. – NONE DETECTED

FIGURE 4-4

TCE VALUES FOR SHALLOW DEPTH MONITOR WELL WATER SAMPLES (PPM).
(FIRST ROUND) PHASE II

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

001544

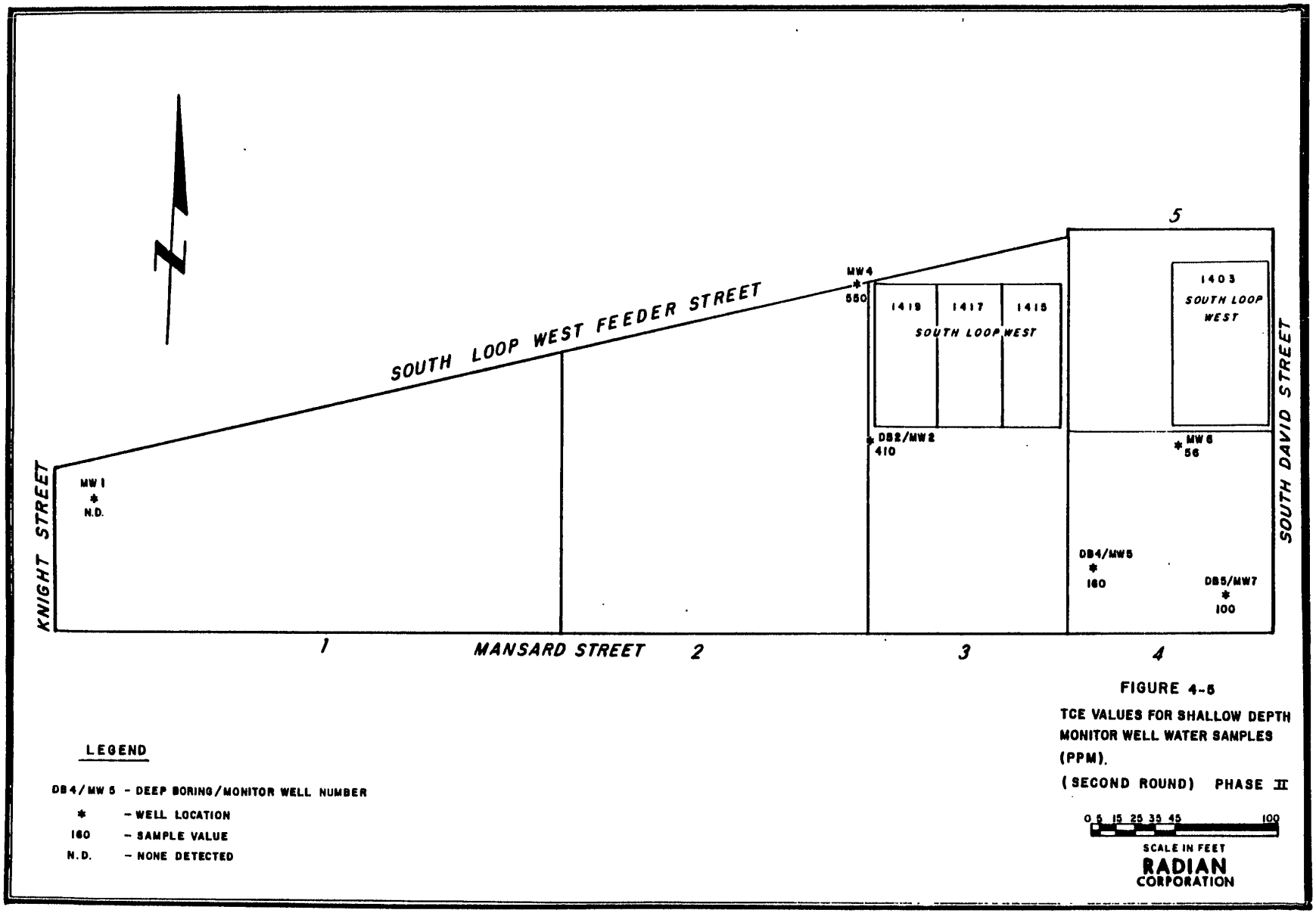


FIGURE 4-5

TCE VALUES FOR SHALLOW DEPTH MONITOR WELL WATER SAMPLES (PPM).

(SECOND ROUND) PHASE II

001545

RADIAN CORPORATION

TABLE 4-5
TRICHLOROETHENE (TCE) DATA

Cone-Penetrometer Water Samples
Uppermost Water-Bearing Zone

Sample Identification	Sample Collection Depth (feet)	Results (ppm)
C-1	35.3-36	0.019
C-2	34.3-35	ND
C-3	34.3-35	ND
C-4	36.2-36.7	0.017
C-5	35.3-36	1.4
C-6	34.3-35	58
C-7	34.8-35.5	9.1
C-8	34.8-35.5	690
C-9	35.3-36	120
C-10	33-33.7	ND
C-11	31.3-32	0.048
C-12	34.3-35	210
C-13	32.5-33.2	790
C-14	34-34.7	660
C-15	34-34.7	7.5
C-16	33.5-34.2	0.052
C-17	33-34	ND*
C-18	34.5-35.2	22
C-19	35-35.7	0.084
C-20	32-31	ND*
EB-3	Equipment Blank	0.012
EB-4	Equipment Blank	0.0086
EB-5	Equipment Blank	0.0006
EB-6	Equipment Blank	0.0006

ND - Not Detected
ND* - Not Detected; less than 0.012 ppm.

001546

001546

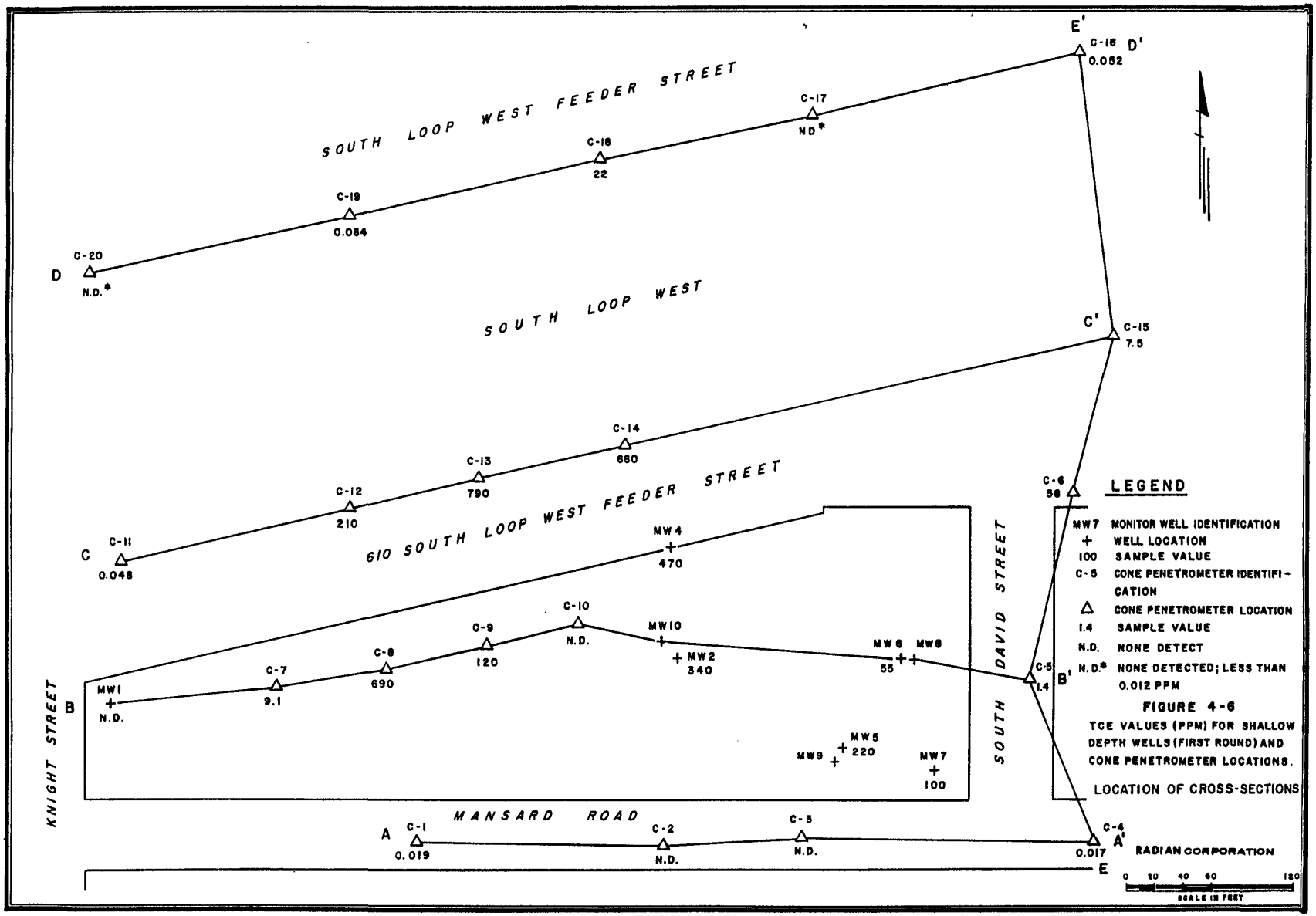


FIGURE 4-6
TCE VALUES (PPM) FOR SHALLOW DEPTH WELLS (FIRST ROUND) AND CONE PENETROMETER LOCATIONS.

001547

side, ranging from about 5 feet at C-4, to the thickest, 7.5 feet at C-6 and thinning to about 2 feet at C-16. TCE values towards the east tend to increase with proximity to the site and decrease with increasing distance away from the site. This is not the plume's primary direction of movement.

Along the near north side of the site, TCE values indicate that north is definitely the plume's primary direction of movement in the shallow aquifer (Figure 3-5). Values are highest at C-13 (790 ppm), which is to the northwest of the high values reported at MW-4 (470 ppm/550 ppm) and MW-2 (340 ppm/410 ppm). At nearby locations, values are 660 ppm (C-14) and 210 ppm (C-12). At the far west end of the site, there is 0.048 ppm TCE at location C-11, which, together with no TCE detected at MW-1, indicates that the western extent of the plume has been defined. Cross-section C-C' (Figure 4-2) illustrates how the water-bearing zone of interest has thinned to about one foot in thickness at the far western location of C-11 and thickens to the east, to at least 5 feet at C-15.

On the north side of I-610 South Loop (Section D-D') TCE values delineate the plume to the north. Sample C-18 contained 22 ppm TCE. Nearby locations along this cross-section show TCE values dropping off, so that C-19 (192 feet west of C-18) contained 0.084 ppm and C-20 (another 187 feet west of C-19) contained 0.0015 ppm TCE (highest relative blank sample was 0.012 ppm). To the east, C-17 (155 feet east of the high at C-18) contained 0.012 ppm TCE (equal to highest blank), and even further to the east (196 feet), C-16 contained 0.052 ppm TCE. Along this cross-section it is clear there is an attenuation of the plume with increasing distance away from the site and away from the center of the plume.

Cross-section D-D' (Figure 3-6) shows the uppermost water-bearing sand thinning in the northerly direction. This sand is about 2 feet thick at C-17. Stratigraphically the sand pinches out to the west thinning to about one foot at C-18 and C-19 locations. At location C-20, there is only clay and silty clay. (A thin, silty clay at about 31 feet depth was chosen for water sampling).

001548

001548

On-site, a line of water samples was collected in order to better define the edge of the plume at the west end of the site. Location C-10, which lies less than 100 feet to the west of MW-2 and MW-4 (containing high values of TCE), did not contain detectable amounts of TCE. This anomaly may be due to a "perched" water zone above a lithified zone of calcareous nodules; thus, the water sample was possibly composed of TCE-free water, perched or isolated from the plume of contamination. Further west, location C-9 contained 120 ppm TCE. The next location, C-8, contained a high concentration of 690 ppm TCE. The plume severely attenuates further to the west, with TCE values decreasing to 9.1 ppm (C-7) and no TCE detected at MW-1. The variation in the pattern of decreasing concentrations to the west observed at C-10 and C-8 is apparently due to the geologic heterogeneity of the site.

001549

4.3.2 Comparison with Phase I Data

Table 4-6 summarizes the Phase I TCE data, and Figure 4-7 illustrates the distributions of TCE from the two rounds of sampling the uppermost water-bearing zone during Phase I.

The overall ranking of wells (in terms of TCE concentration) remained the same in both rounds. MW-2 had the highest values of TCE (430 ppm and 500 ppm for Rounds 1 and 2, respectively), followed by MW-4 (250 ppm/400 ppm), then MW-5 (190 ppm/300 ppm). Next are MW-7 (46 ppm/72 ppm), MW-6 (25 ppm/26 ppm), and lastly MW-1 (0.003 ppm/0.007 ppm). All six wells reported somewhat higher values in the second round of sampling compared to the first round.

The highest TCE concentrations have been observed off-site to the north and northwest of MW-2 and MW-4. The data from Phase I data show TCE concentrations highest at MW-2, moving north-northwest in the direction of groundwater flow toward MW-4. In Phase II, MW-4 had replaced MW-2 as the well with the highest TCE concentration, confirming the north-northwesterly movement in the shallow aquifer. The highest values of both phases were observed off-site at cone-penetrometer locations C-13 and C-14, both to the north-northwest of the site.

001549

RADIAN CORPORATION

TABLE 4-6
TRICHLOROETHENE (TCE) DATA

Monitor Well Water Samples
Phase I

Sample * Identification	Depth	Round 1 Results(ppm)	Sample Identification	Round 2 Results(ppm)
MW-1	Uppermost Aquifer	0.0035	MW-1A	0.0007
MW-2	Uppermost Aquifer	420	MW-2A	500
MW-4	Uppermost Aquifer	250	MW-4A	400
MW-5	Uppermost Aquifer	190	MW-5A	300
MW-6	Uppermost Aquifer	25	MW-6A	26
MW-7	Uppermost Aquifer	46	MW-7A	72

* A total of 2 rounds of water samples were collected for TCE analysis from the wells; each round of samples is labeled uniquely, i.e., "MW-1" sample identification refers to the first round of sampling; "MW-2A" sample identification refers to the second round of sampling.

001550

001550

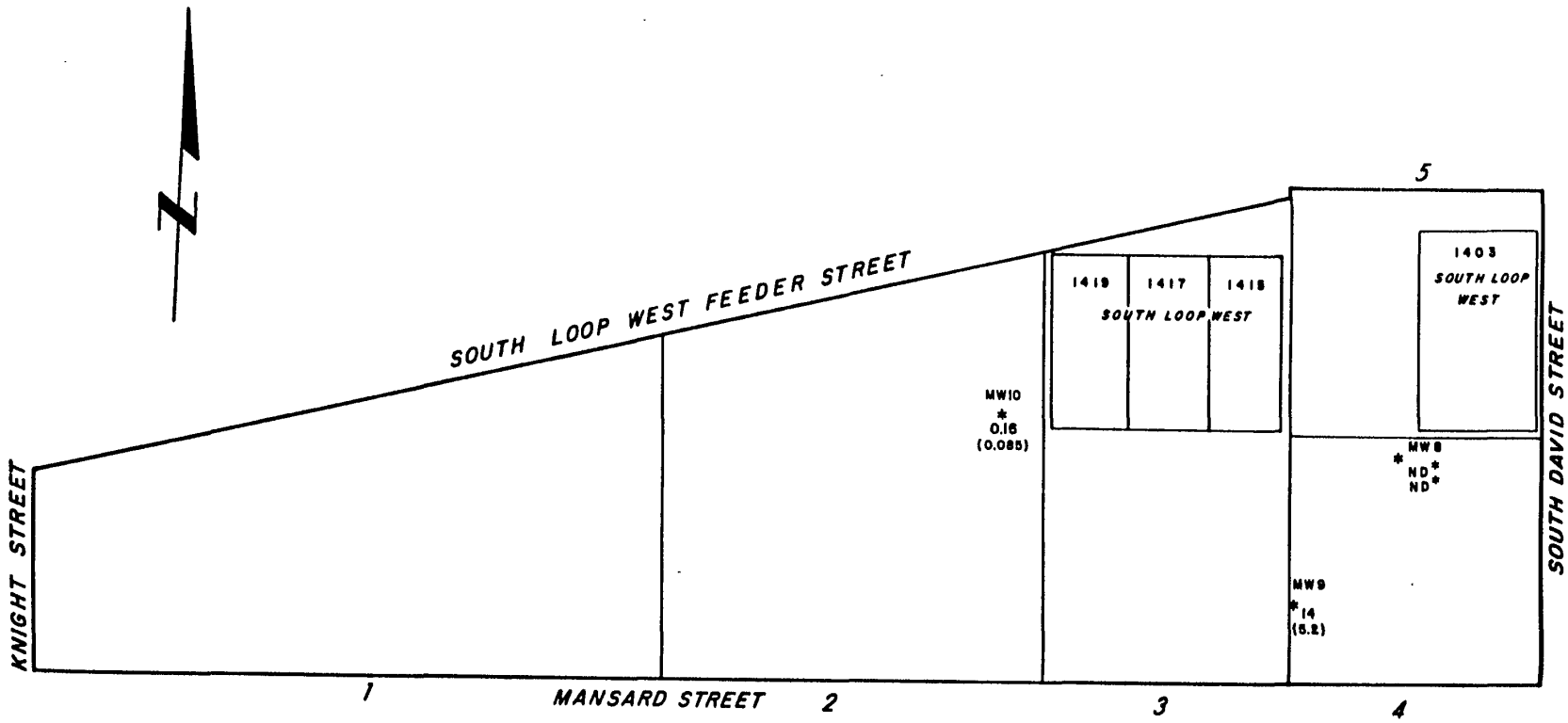


FIGURE 4-7

TCE VALUES FOR INTERMEDIATE DEPTH (101 Foot) MONITOR WELL WATER SAMPLES (PPM). (FIRST AND SECOND ROUNDS)

LEGEND

MW10	– MONITOR WELL NUMBER
*	– MONITOR WELL LOCATION
0.160	– SAMPLE VALUE 1st ROUND
(0.085)	– SAMPLE VALUE 2nd ROUND
ND*	– NOT DETECTED; LESS THAN 0.0021 PPM

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001551

4.4 TRICHLOROETHENE (TCE) IN THE INTERMEDIATE WATER-BEARING ZONE

Table 4-7 summarizes TCE data from the intermediate water-bearing zone. Concentrations for the first and second rounds of sampling are shown on Figure 4-8.

MW-9 had the highest values of TCE in both rounds 1 and 2, 14 ppm and 5.2 ppm, respectively. MW-10 contained 0.160 ppm and 0.085 ppm in rounds 1 and 2, respectively. Last was MW-8, containing less than the equipment blank concentrations in both rounds. All values decreased slightly in the second round of water sampling.

TCE concentrations indicate contamination at MW-9, but migration limits are undetermined at this time. Soil sample data from this well shows TCE is present from at least 23 feet depth downward to about 60 feet and at scattered horizons below that depth (Figure 4-2).

MW-8 water appears to be clean, which is consistent with the soil analyses. TCE appears to have a very limited distribution in the soil samples from MW-8, appearing only at a depth of 34 to 36 feet and coincident with the uppermost water-bearing zone.

MW-10 currently has low concentrations of TCE (0.160 and 0.085 ppm). However, because of high TCE values (36 to 600 ppm) in the soil overlying the intermediate water-bearing zone in MW-10 (Figure 4-2), possibly higher values due to infiltration could be expected in the groundwater from the intermediate zone at this location in the future.

The groundwater flow direction in the intermediate water-bearing unit appears to be variable, one set of data indicating a south-southeast direction and two other sets of data indicating a westerly gradient.

001552

001552

RADIAN CORPORATION

TABLE 4-7
TRICHLOROETHENE (TCE) DATA

Monitor Well Water Samples
Intermediate Water-Bearing Zone

Sample Identification	Round 1 Results (ppm)	Sample Identification	Round 2 Results (ppm)
MW-8	ND*	MW-8D	ND*
MW-8-1 (Duplicate)	ND*		
MW-9	14	MW-9D	5.2
MW-10	0.160	MW-10D	0.085
EB-1	0.0013	EB-7	ND
EB-2	0.0021	EB-8	ND

ND - Not Detected
ND* - Not Detected; Less than 0.0021 ppm.

001553

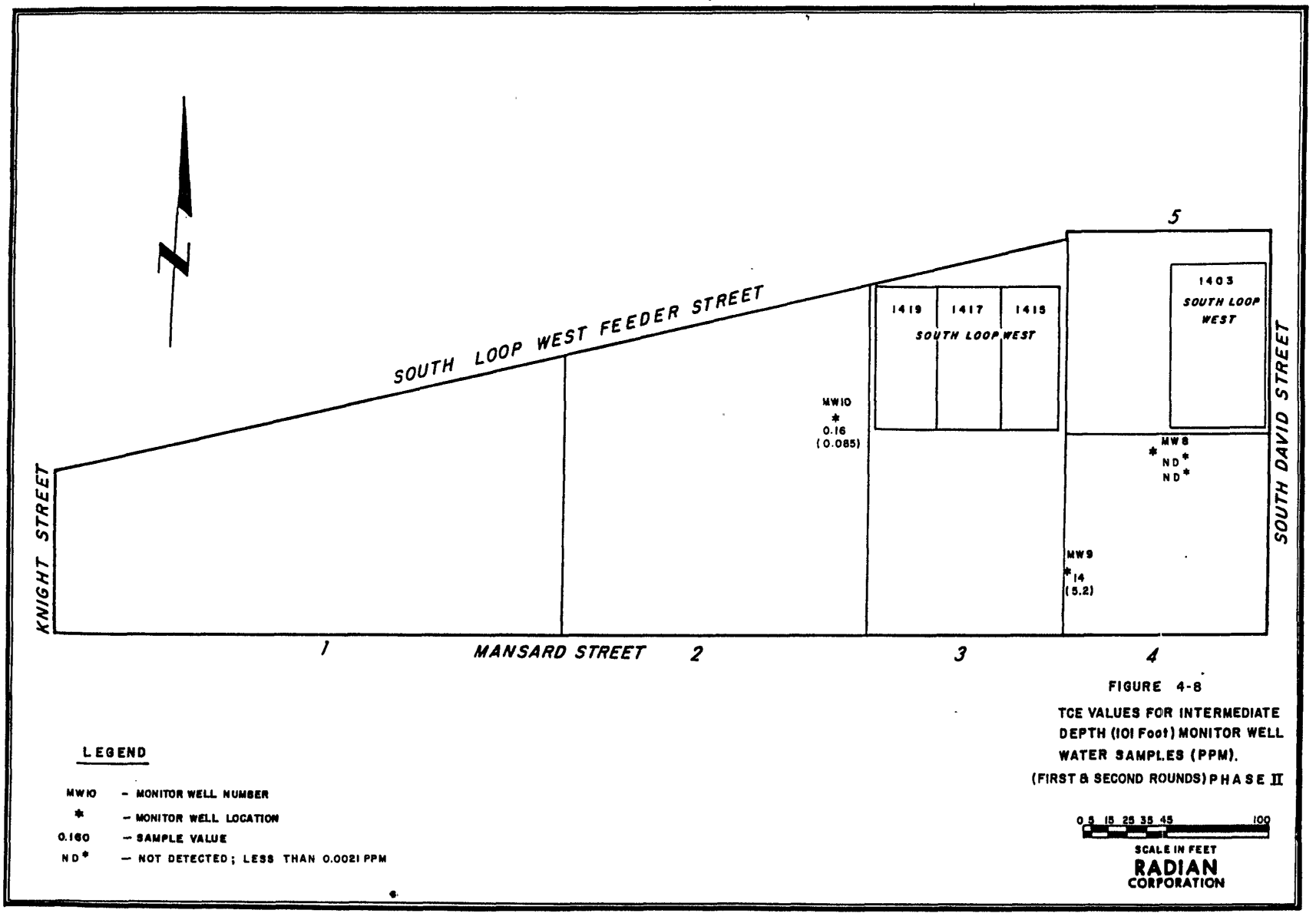


FIGURE 4-8

TCE VALUES FOR INTERMEDIATE DEPTH (101 Foot) MONITOR WELL WATER SAMPLES (PPM).

(FIRST & SECOND ROUNDS) PHASE II

001554

4.5 GENERAL AQUIFER PARAMETERS

Table 4-8 lists the Total Dissolved Solids (TDS), Carbonaceous Oxygen Demand (COD) and metals found in water samples from the uppermost and intermediate water-bearing zones.

Water from both water-bearing zones exceeds the recommended drinking water standards (500 mg/L) for TDS by two to four times.

A metals analysis for a sample from the uppermost water-bearing zone shows relatively small amounts of metals. These are within or are very close to recommended drinking water standards. An analysis of all constituents listed for the drinking water standards was not done. This data implies that water from these water-bearing zones could be treated and suitable for human consumption.

001555

001555

RADIAN CORPORATION

TABLE 4-8 GENERAL AQUIFER PARAMETERS

Well	Aquifer	Parameter*	Result**
MW-1	Upper	TDS	3670 mg/L
MW-4	Upper	TDS	2320 mg/L
MW-7	Upper	TDS	2590 mg/L
MW-8	Intermediate	TDS	1040 mg/L
MW-9	Intermediate	TDS	1650 mg/L
MW-4	Upper	COD	110 mg/L
MW-4	Upper	Silver	N.D.
		Aluminum	1.7 mg/L
		Arsenic	N.D.
		Boron	0.9 mg/L ***
		Barium	0.065 mg/L
		Beryllium	N.D.
		Calcium	180 mg/L
		Cadmium	N.D.
		Cobalt	N.D.
		Chromium	0.037 mg/L***
		Copper	N.D.
		Iron	0.83 mg/L
		Potassium	N.D.
		Magnesium	100
		Manganese	0.12 mg/L
		Molybdenum	N.D.
		Sodium	440 mg/L
		Nickel	0.03 mg/L***
		Lead	N.D.
		Antimony	N.D.
		Selenium	N.D.
		Silicon	13 mg/L
		Thallium	N.D.
		Vanadium	N.D.
		Zinc	0.40 mg/L

* TDS - Total Dissolved Solids
COD - Carbonaceous Oxygen Demand

** N.D. - Not Detected

*** Less than 5 times the detection limit.

001556

001556

RADIAN CORPORATION

SECTION 5
HYDROGEOLOGIC TESTING

In order to characterize the intermediate water-bearing zone and determine direction of groundwater flow in the shallow and intermediate zones, slug tests were performed and water levels were measured.

5.1 SLUG TESTS

Hydraulic conductivity (K) data for the intermediate water-bearing zone ranges from 0.32 to 0.87 feet/day (see Table 5-1 and Figure 5-1). Field procedures used to determine these values are detailed in Section 2.6. Calculations are presented in Appendix G-1. The highest hydraulic conductivity, 0.87 feet/day, was measured at MW-10. The next lower value, 0.78 feet/day, was found at MW-9. Finally, a value of 0.31 feet/day was measured at MW-8.

These values are representative only of the area immediately surrounding the borehole; therefore, these values should be used in a qualitative sense. These values vary because of differences in aquifer properties, such as porosity, grain size, grain shape, sorting and packing. However, these variations are typical of poorly sorted silty sands.

Also, a ten-foot length of screen was used to screen off the water-bearing zone and clays and silty clays bounding the zone on either side. These other lithologies have lower hydraulic conductivities than the predominantly sandy water-bearing zone. The total effect is to lower the overall average of the well.

Transmissivity, an arithmetic product of hydraulic conductivity and aquifer thickness, represents the quantity of water which passes through a unit width of the aquifer under a unit hydraulic gradient. Transmissivity values are listed in Table 5-1. Because transmissivity is a function of hydraulic conductivity, it follows the same pattern (Figure 5-1) as hydraulic conductivity.

001557

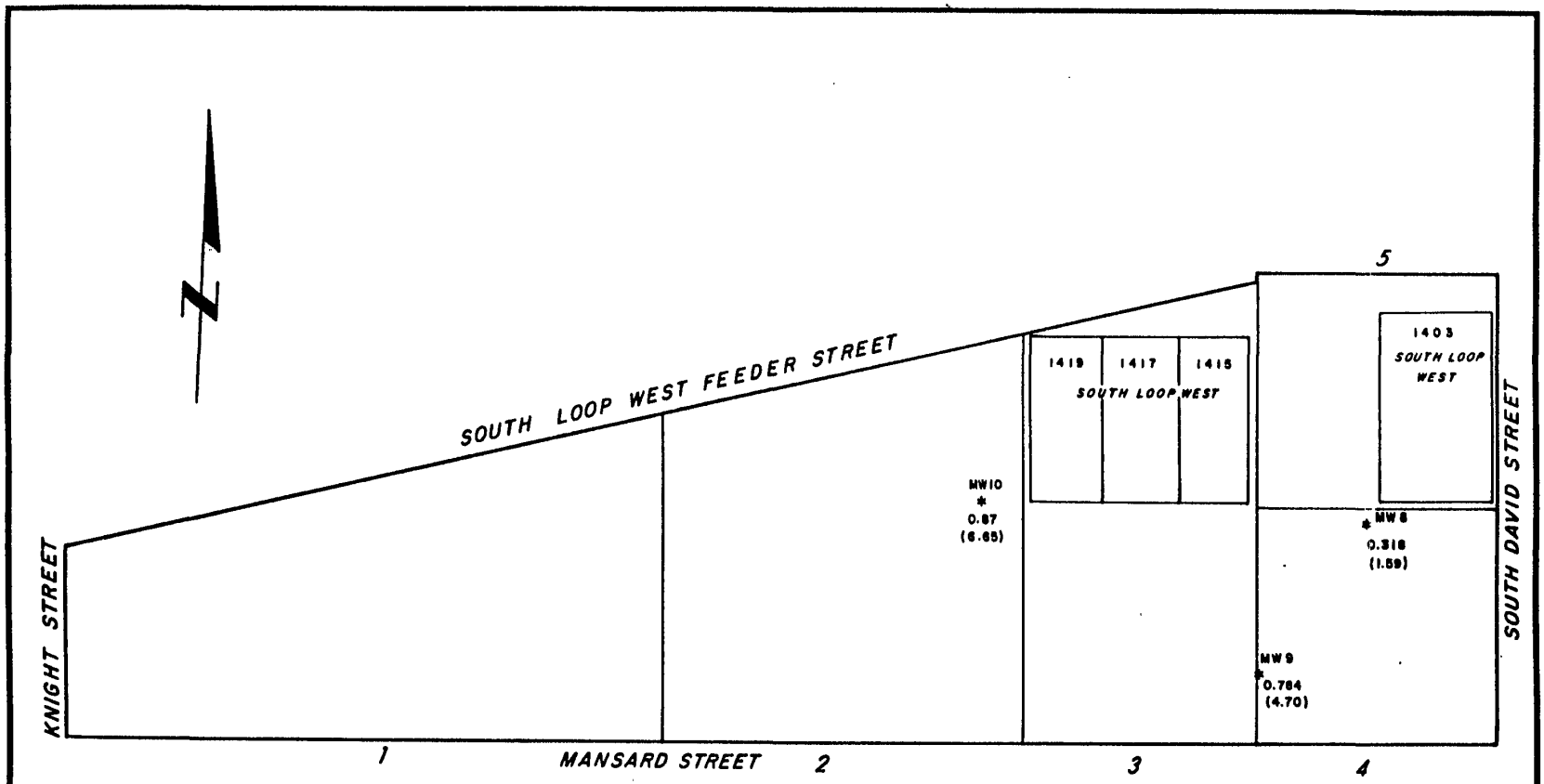
RADIAN CORPORATION

TABLE 5-1
HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY DATA

Intermediate Water-Bearing Zone

Well Identification	Hydraulic Conductivity (K)	Thickness (feet)	Transmissivity
MW-8	0.318 ft/day	5	1.59 ft^2/day
MW-9	0.784 ft/day	6	4.70 ft^2/day
MW-10	0.87 ft/day	6.5	5.65 ft^2/day

001558



LEGEND

MW8 – MONITOR WELL NUMBER

* – MONITOR WELL LOCATION

0.318 – HYDRAULIC CONDUCTIVITY (Feet Per Day)

(1.59) TRANSMISSIVITY (Feet^2 Per Day)

FIGURE 5-1

HYDRAULIC CONDUCTIVITY

TRANSMISSIVITY

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001559

RADIAN CORPORATION

5.2 STATIC WATER LEVEL MEASUREMENTS AND HYDRAULIC GRADIENTS

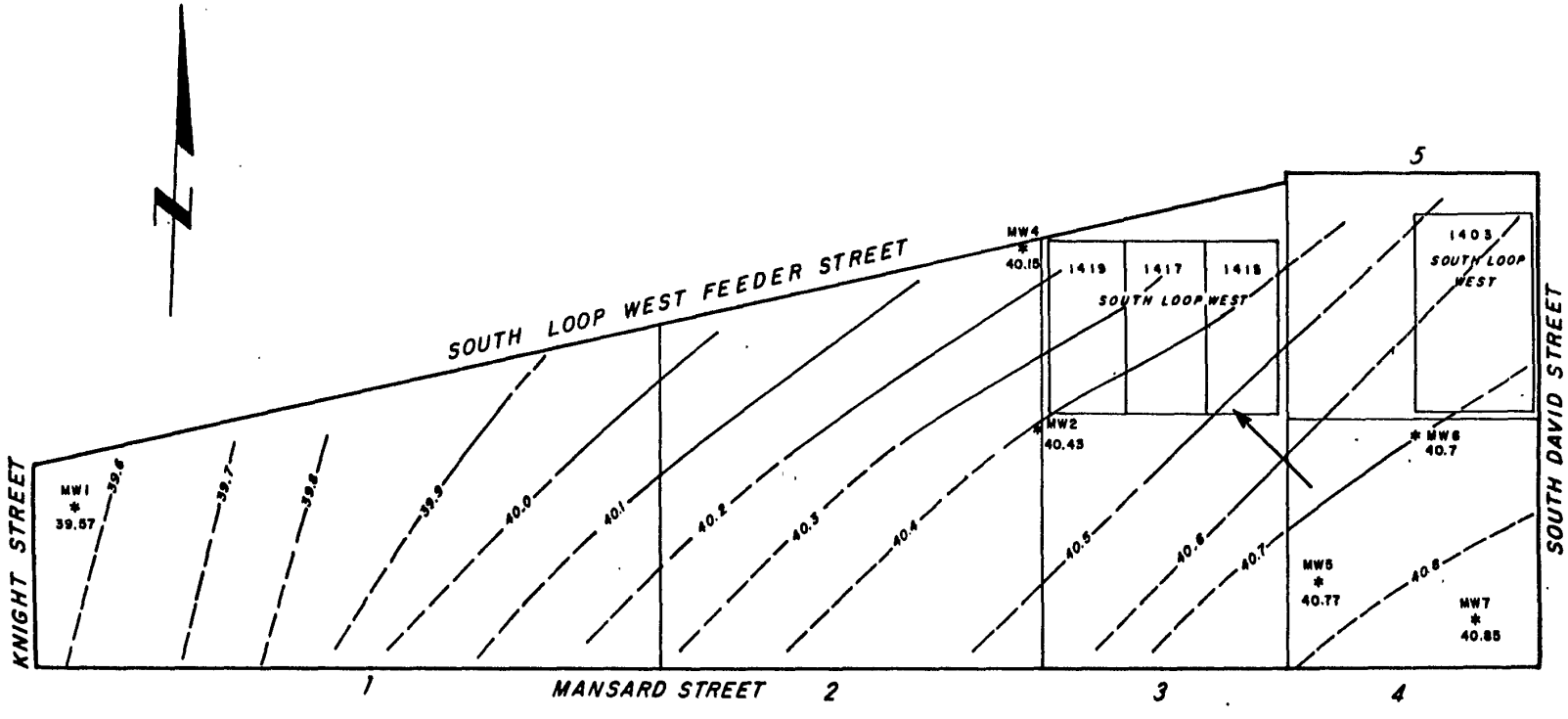
Summarized in Appendix G-2 is information used to claculate the hydraulic gradient from water levels. The water levels for the shallow water-bearing zone are presented in Figures 5-2, 5-3, 5-4 and 5-5. The intermediate water-bearing zone water levels are presented in Figures 5-6 and 5-7. Each figure represents one set of measurements.

The groundwater elevations and flow directions have remained relatively constant over the measuring period. The predominant flow for the uppermost water-bearing zone is to the north-northwest. The hydraulic gradient averages 0.0037 feet/feet (Appendix G-3).

The groundwater elevations and flow directions have varied over the measuring period in the intermediate water-bearing zone. Flow directions have been measured to the southeast and to the west. The hydraulic gradient averages 0.0083 ft/ft, based on three sets of measurements (Appendix G-3).

A westerly gradient appears to be anomalous with the prevailing regional trend of flow towards the Gulf of Mexico.

001560



LEGEND

DB4/MW5	– DEEP BORINGS/MONITOR WELL NUMBER
*	– WELL LOCATION
40.77	– OBSERVED WATER LEVEL ABOVE M.S.L.
⟵	– GROUNDWATER FLOW DIRECTION
—39.7—	– EXTRAPOLATED WATER LEVEL CONTOURS

FIGURE 5-2

SHALLOW-DEPTH MONITOR WELLS - ELEVATION OF GROUNDWATER ABOVE MEAN SEA LEVEL (Feet)

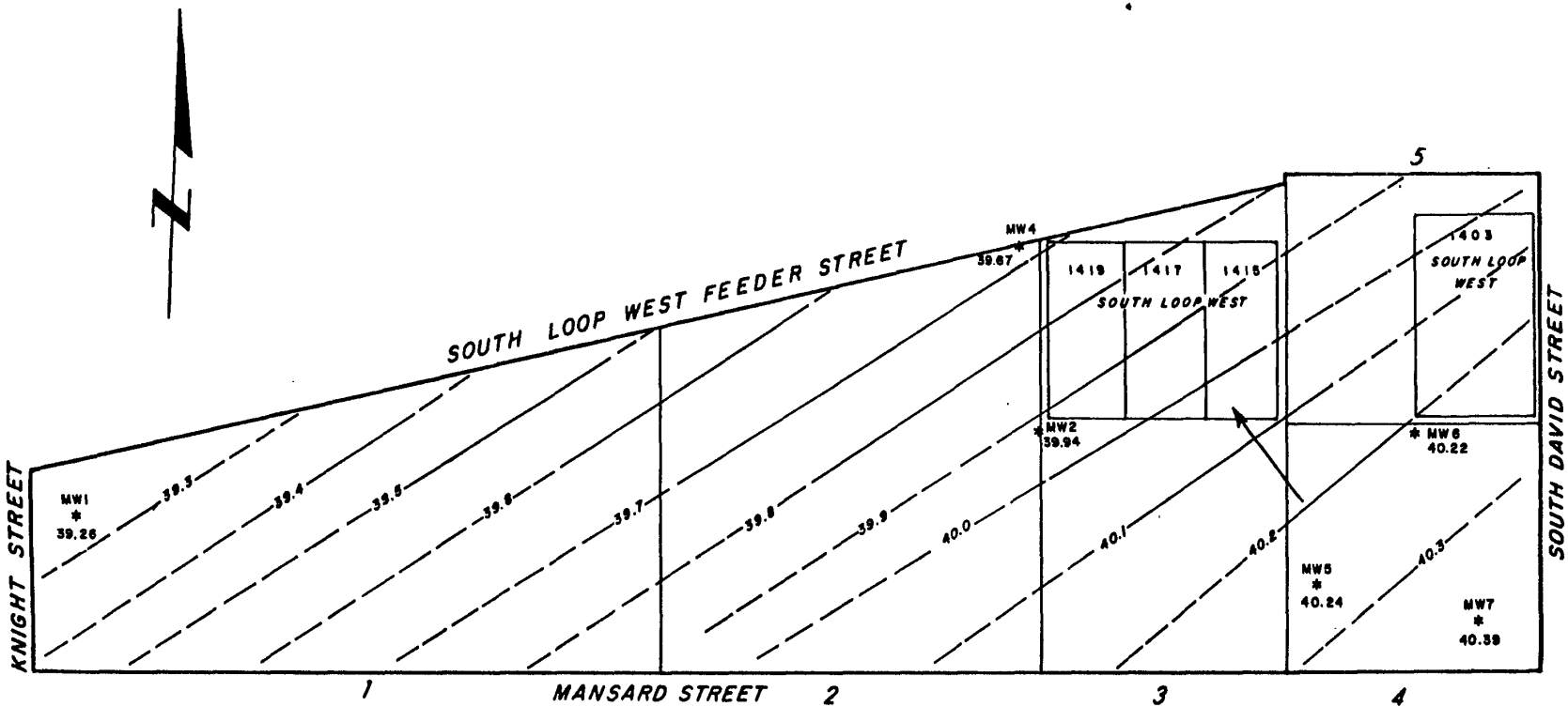
1-27-88

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

001561



LEGEND

DB4/MW5	– DEEP BORINGS/MONITOR WELL NUMBER
*	– WELL LOCATION
40.24	– OBSERVED WATER LEVEL ABOVE M.S.L.
←	– GROUNDWATER FLOW DIRECTION
– – – –	– EXTRAPOLATED WATER LEVEL CONTOURS

FIGURE 5-3

SHALLOW-DEPTH MONITOR WELLS
ELEVATION OF GROUNDWATER ABOVE
MEAN SEA LEVEL (Feet)
2-22-88

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

001562

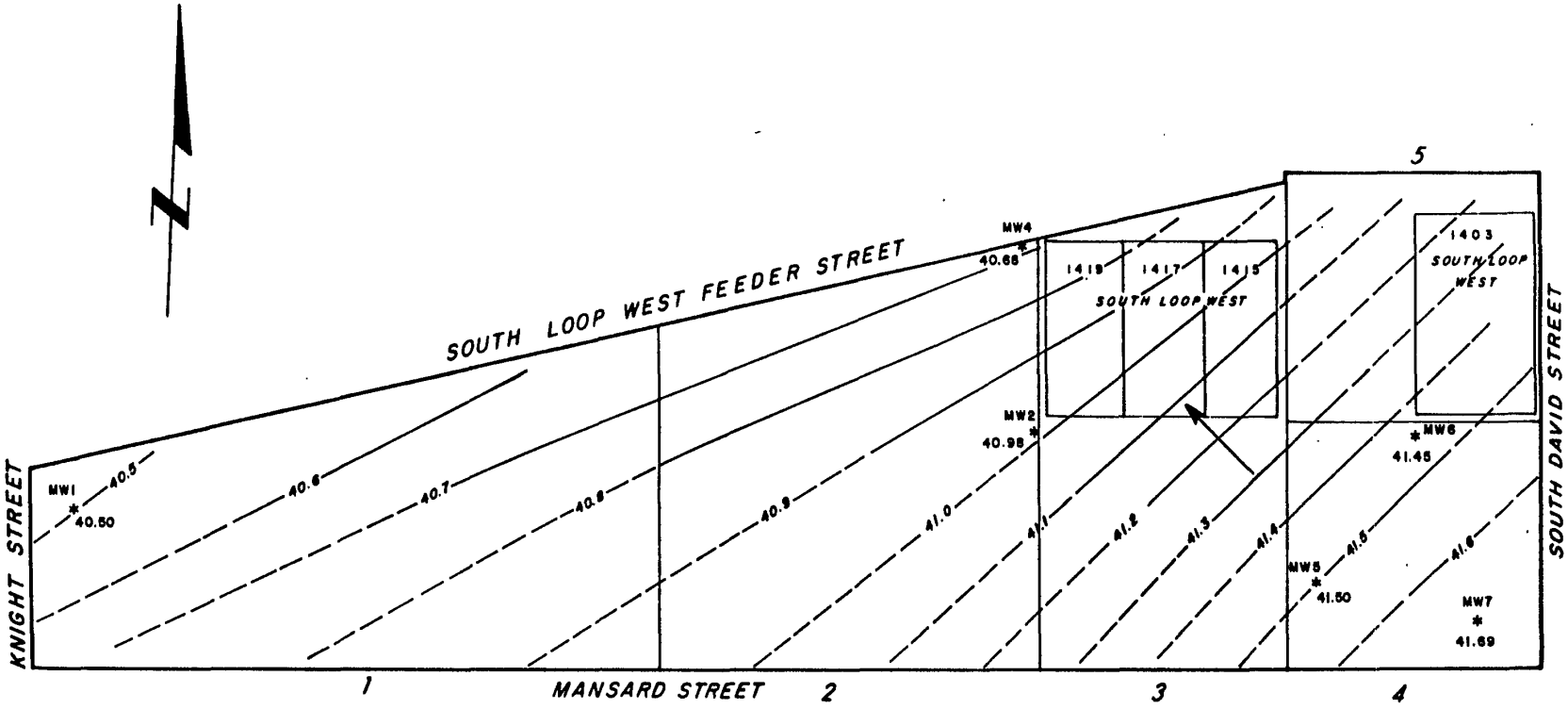


FIGURE 5-4

SHALLOW-DEPTH MONITOR WELLS
ELEVATION OF GROUNDWATER ABOVE
MEAN SEA LEVEL (Feet)
3-22-88

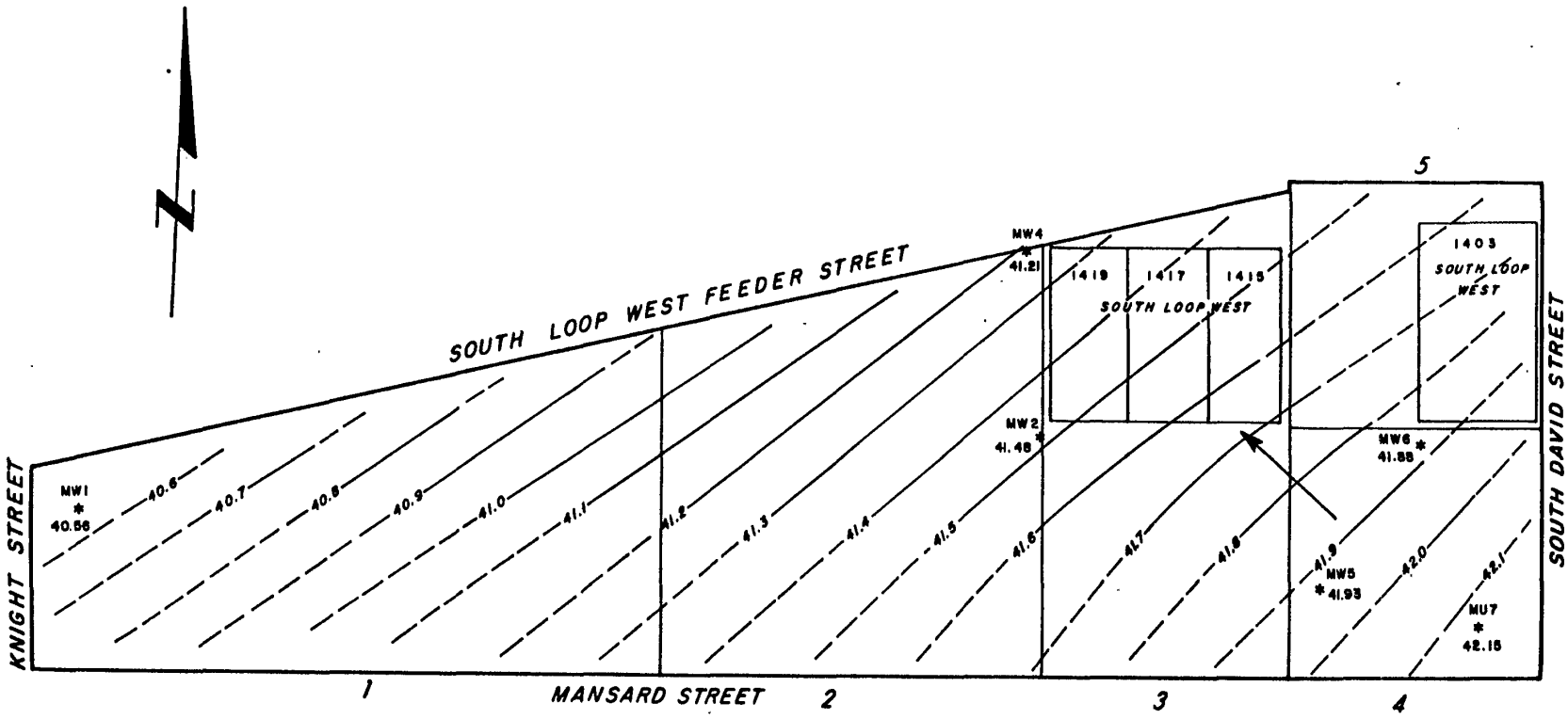
0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

LEGEND

DB4/MW5 – DEEP BORINGS/MONITOR WELL NUMBER.
* – WELL LOCATION
41.50 – OBSERVED WATER LEVEL ABOVE M.S.L.
← – GROUNDWATER FLOW DIRECTION
– – – – – – EXTRAPOLATED WATER LEVEL CONTOURS

001563



LEGEND

DB4/MW5	– DEEP BORINGS/MONITOR WELL NUMBER
*	– WELL LOCATION
41.93	– OBSERVED WATER LEVEL ABOVE M.S.L.
←	– GROUNDWATER FLOW DIRECTION
– – – –	– EXTRAPOLATED WATER LEVEL CONTOURS

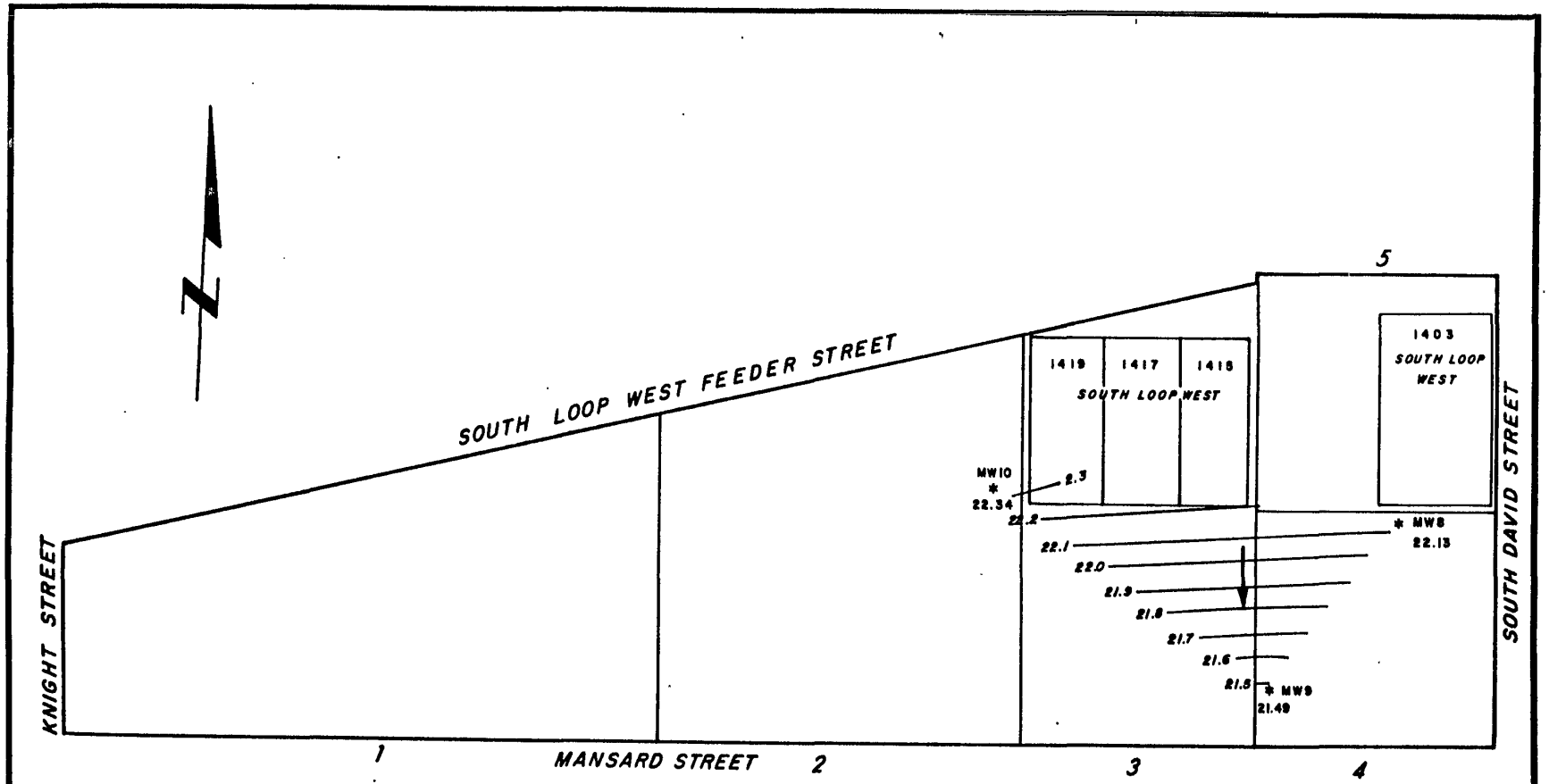
FIGURE 5-5

SHALLOW-DEPTH MONITOR WELLS
ELEVATION OF GROUNDWATER ABOVE
MEAN SEA LEVEL (Feet)
4-8-86

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

001564



LEGEND

MW8 - MONITOR WELL NUMBER
* - WELL LOCATION
22.13 - OBSERVED WATER LEVEL ABOVE M.S.L.
← - DIRECTION OF GROUNDWATER FLOW
21.5 — - STATIC WATER CONTOUR LINES

FIGURE 5-6

INTERMEDIATE-DEPTH MONITOR WELLS - ELEVATION OF GROUND WATER ABOVE MEAN SEA LEVEL (Feet)

4-7-86

0 5 15 25 35 45 100

SCALE IN FEET

RADIAN CORPORATION

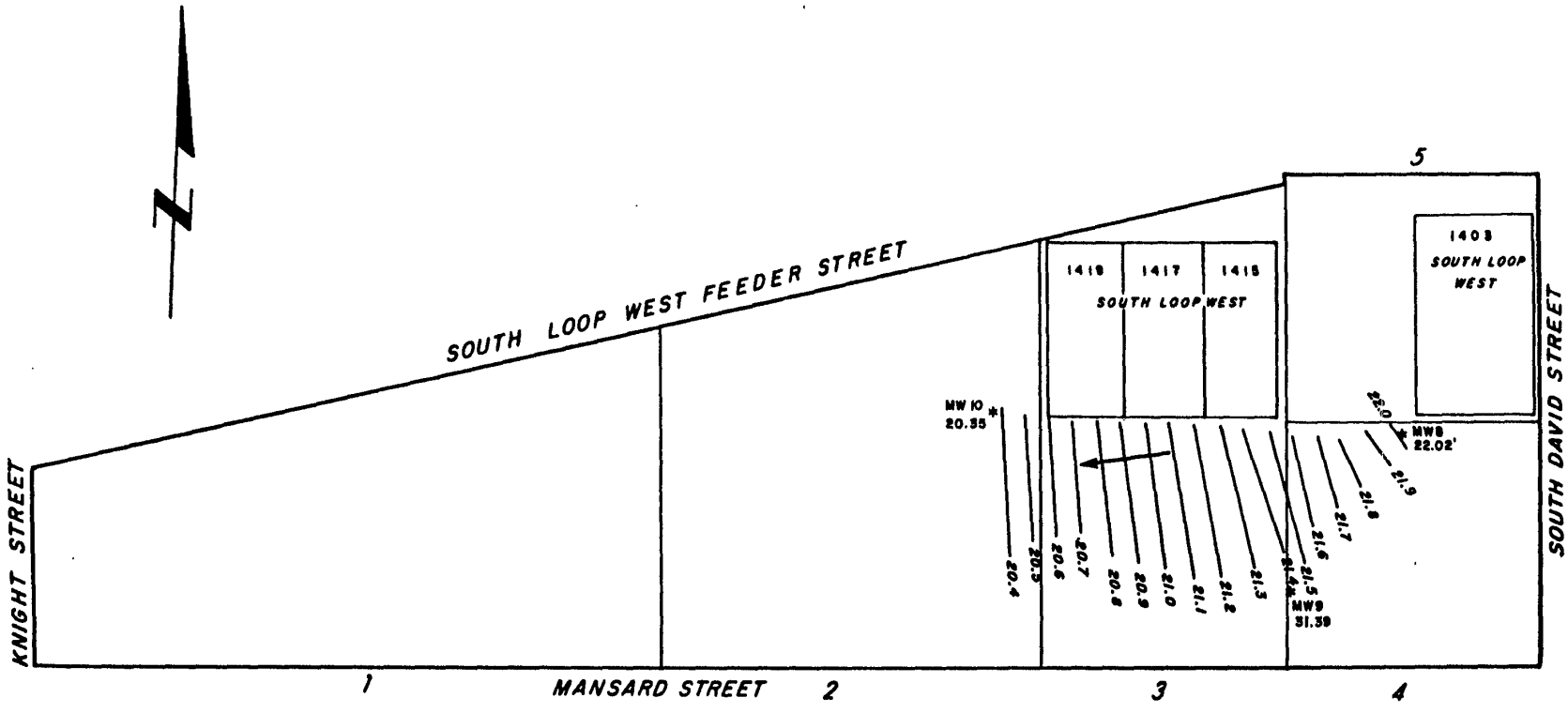


FIGURE 5-7

INTERMEDIATE DEPTH MONITOR WELLS-
ELEVATION OF GROUNDWATER ABOVE
MEAN SEA LEVEL (Feet).
4-25-88

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

LEGEND

MW8	MONITOR WELL NUMBER
*	WELL LOCATION
22.02	OBSERVED WATER ABOVE M.S.L
←	DIRECTION OF GROUNDWATER FLOW
21.2	STATIC WATER CONTOUR LINES

001566

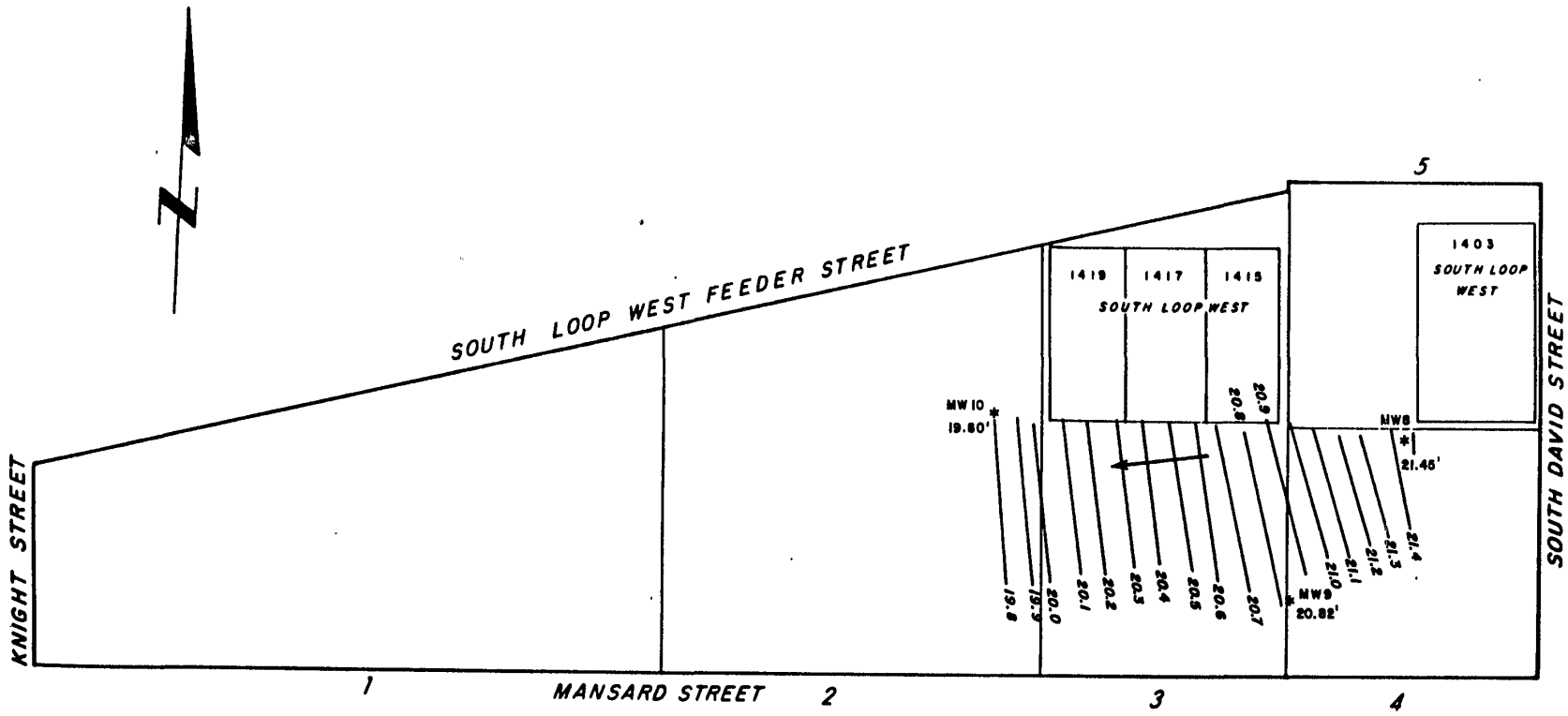


FIGURE 5-8

INTERMEDIATE DEPTH MONITOR WELLS-
ELEVATION OF GROUNDWATER ABOVE
MEAN SEA LEVEL (Feet).
7-8-88

0 5 15 25 35 45 100
SCALE IN FEET

RADIAN CORPORATION

LEGEND

MW8 MONITOR WELL NUMBER
* WELL LOCATION
20.82' OBSERVED WATER ABOVE M.S.L
DIRECTION OF GROUND WATER FLOW
21.1 STATIC WATER CONTOUR LINES

001567

5.3 ESTIMATE OF YIELD

An estimated yield of 350 to 400 gallons per day was calculated for the uppermost water-bearing zone, using development and building records. Examining similar records for the intermediate water-bearing zone, this zone may yield an estimated 500-550 gallons per day.

Because both water-bearing sands are composed of nearly half sand-sized material and half fine sediment (silts and clays), water developed and bailed tends to be "dirty" with suspended sediment. Because of the fines, water produced from the uppermost sand is a yellowish-tan color, while water produced from the intermediate sand tends to be a deep red color.

001568

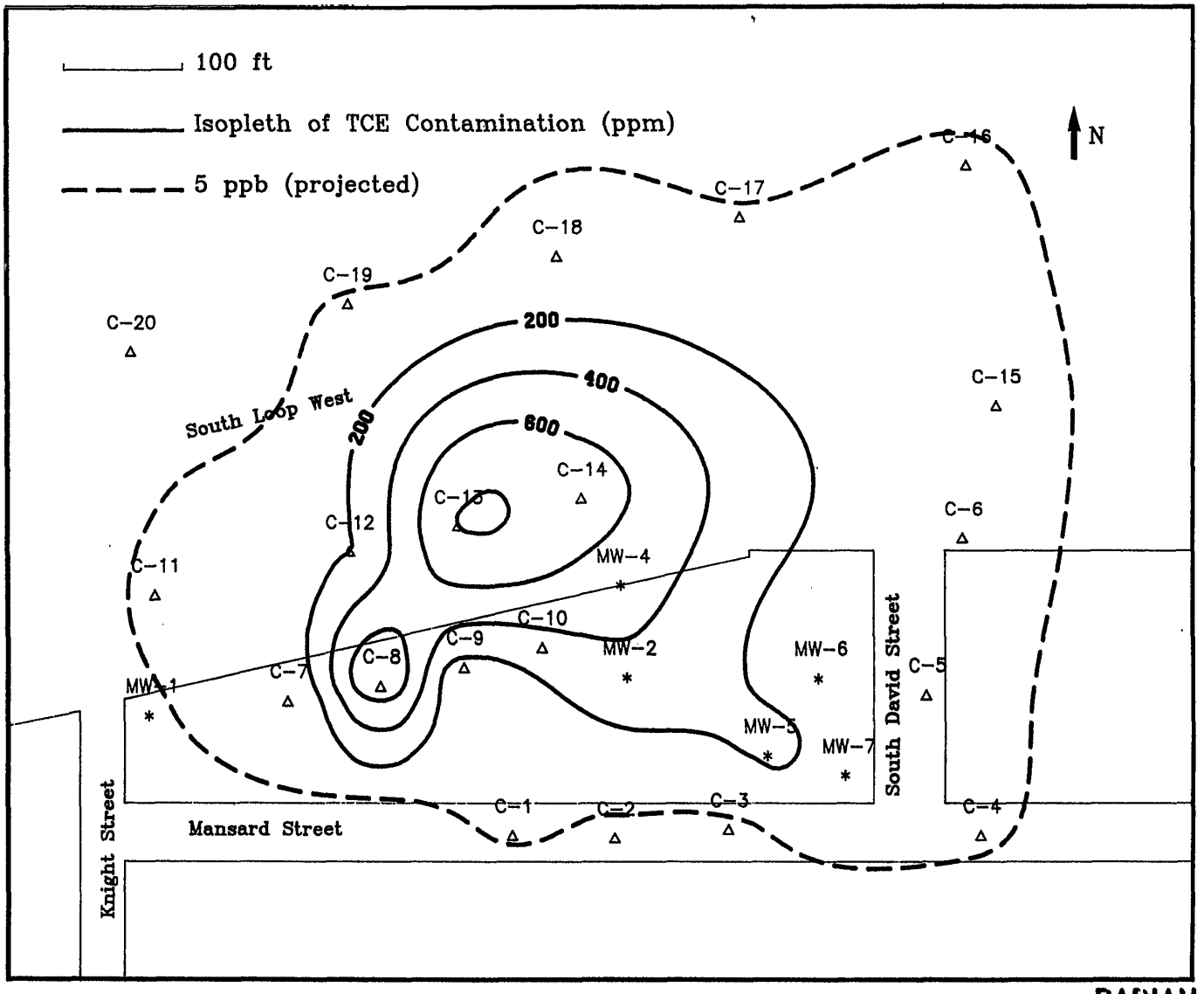
5.4 LOCATION OF PLUME IN UPPERMOST WATER-BEARING ZONE

Figure 5-9 illustrates TCE concentrations in the uppermost water-bearing unit. The plume location was estimated using Radian's software program. This program draws a more strict mathmatical interpolation than practiable using non-computerized approaches. To draw this map, the program uses a projection algorythmn to interpolate between values at sporadically placed locations.

To extrapolate the 5 ppb line on Figure 5-9, a logarithmic extrapolation using a projections algorythmn was generated. Major assumptions are that:

- There is no TCE concentrations where the uppermost aquifer pinches out.
- The program was not allowed to extrapolate more than 100 feet beyond the last data point.
- Cone-penetrometer sample C-10 had a TCE value of N.D. (Not Detected); because of C-10's location near known high values, this data point was considered anamalous and not included in the estimate of plume concentrations and location.

001568



RADIAN CORPORATION

Figure 5-9
TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit

001569

- Cone-penetrometer sample C-20 was not collected from the same stratigraphic horizon as other data points and was not included in the estimate of plume location.

Section 4.1 of the Feasibility Study presents the details of the modeling procedure, where a dispersivity factor was taken into account for rate of movement of the plume through time. To summarize the results, using a longitudinal dispersivity factor of 200 feet, the extent of the modeled plume in the direction of groundwater flow after ten years approximates the location of the plume itself.

The ten-year time span assumed in modeling roughly matches historical data (Section 1.2 and Appendices A-3 and A-4 of the Remedial Investigation, 1988). Beginning in 1978, a chemical supply house was located on-site for several years. Barrels labeled TCE were stored on-site. Various accounts state that the drum contents were drained onto the ground in early 1981. This may be the source of the TCE presently observed in groundwater.

5.5 RATE OF MOVEMENT OF PLUME

Groundwater velocity calculations were performed on all shallow and intermediate-depth monitor wells (Table 5-2 and Appendix G-4). MW-2 had the highest calculated velocity, at 9.13 ft/yr. It also had the highest hydraulic conductivity, at 2.03 ft/day. The next highest value was at MW-6, at 7.2 ft/yr, then MW-7, at 6.52 ft/yr. Velocities were measured at 3.9 ft/yr at MW-4, 3.66 ft/yr at MW-5 and 2.83 ft/yr at MW-1.

In general, the higher velocities are dependent on higher hydraulic conductivities and methods used to conduct the slug tests. Hydraulic conductivities in turn reflect distribution of sediment size, that is, sand containing relatively few or many fines. The sand in the uppermost water-bearing zone contains more fines in an east to west direction across the site. This is reflected in higher hydraulic conductivities and higher velocities from east to west.

001570

001570

RADIAN CORPORATION

TABLE 5-2
GROUNDWATER VELOCITIES AT EACH
MONITOR WELL LOCATION

Well Identification	Zone	Velocity (ft/yr)
MW-1	Uppermost	2.83
MW-2	Uppermost	9.13
MW-4	Uppermost	3.9
MW-5	Uppermost	3.66
MW-6	Uppermost	7.2
MW-7	Uppermost	6.52
MW-8	Intermediate	3.1
MW-9	Intermediate	7.87
MW-10	Intermediate	8.78

001571

Within the intermediate water-bearing zone, MW-10 had the highest velocity at 8.78 ft/yr, followed by MW-9m at 7.87 ft/yr, then MW-8 at 3.1 ft/yr.

Section 4.1 of the Feasibility Study presents the details of the modeling procedure, where a dispersivity factor was taken into account for rate of movement of the plume through time. To summarize the results, using a longitudinal dispersivity factor of 200 feet, the extent of the modeled plume in the direction of groundwater flow after ten years approximates the location of the plume itself.

The ten year time span assumed in modeling roughly matches historical data (Section 1.2 and Appendices A-3 and A-4 of the Remedial Investigation, 1988). Beginning in 1978, a chemical supply house was located on-site for several years. Barrels labeled TCE were stored on-site. Various accounts state that the drum contents were drained onto the ground in early 1981. This may be the source of the TCE presently observed in groundwater.

5.6 PLUME VOLUME

An estimate of TCE-contaminated water within the uppermost water-bearing zone was made using the Radian CPS software. Once the area of the plume was established (see Section 5.4 and Figure 5-9), volume was calculated by the following:

- The 5ppb line (Figure 5-9) was discretized and the volume of the aquifer within that area was calculated;
- The program then integrated the thickness over the area discretized; and
- The resulting volume, known as aquifer volume, was then multiplied by porosity (0.30) to yield pore volume.

A volume of 3.2 million gallons of TCE-contaminated water was estimated by this method.

001572

001572

RADIAN CORPORATION

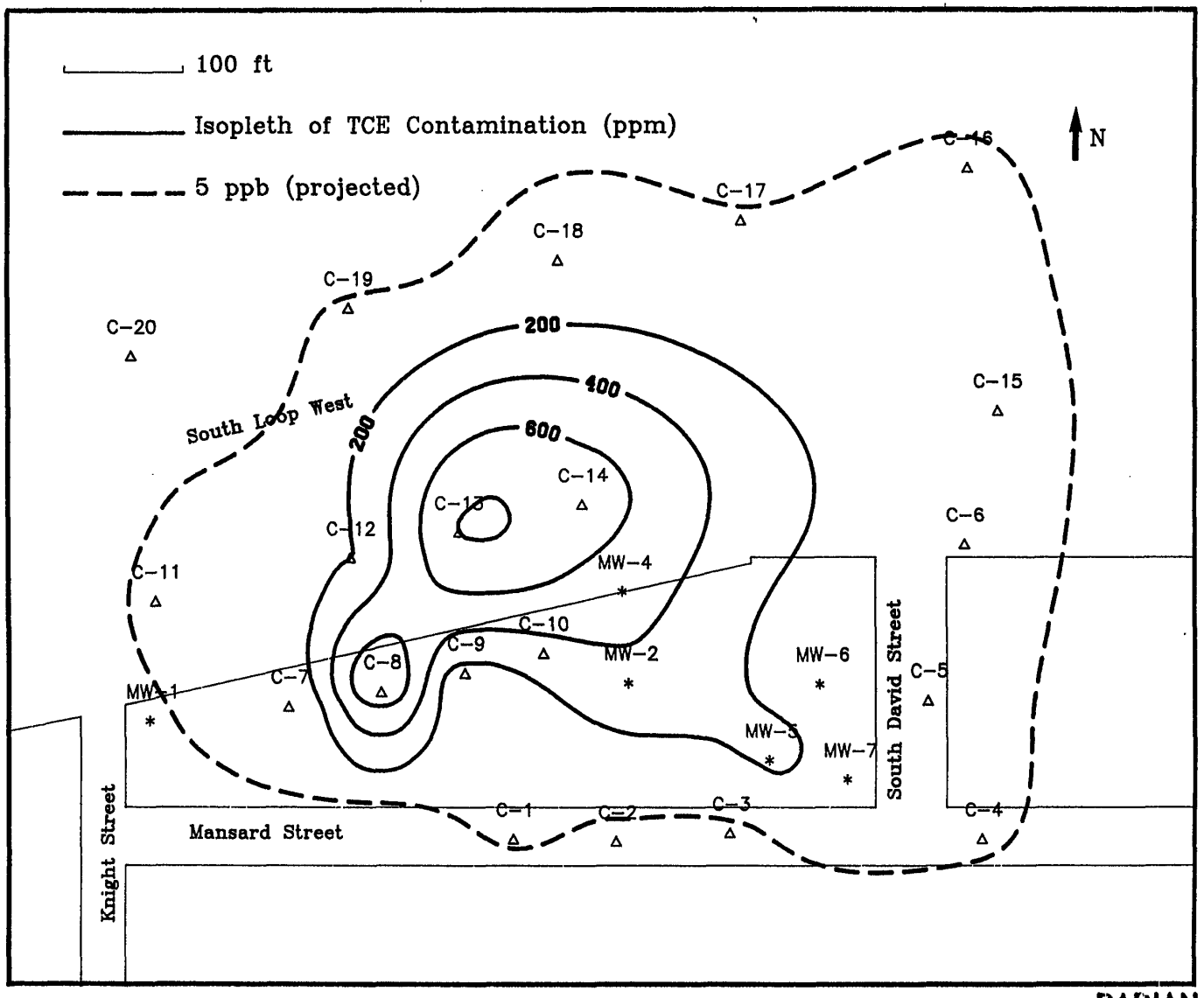
SECTION 6
CONCLUSIONS

Chemical analyses and hydrogeologic testing have yielded the following conclusions about subsurface contamination by TCE at the ITS site:

- TCE contamination is observed in the soils on-site from the surface to a depth of 60 feet and again at 89-91 feet.
- TCE contaminates both the uppermost and the intermediate water-bearing units. The highest concentrations (790 ppm) in the uppermost aquifer was observed off-site underneath the median strip between I-610 South Loop West and the southern feeder street.
- The estimated volume of TCE contaminated water (above 5 ppb) in this zone is 3.2 million gallons. Figure 6-1 illustrates the estimated plume of contamination and concentrations within it.
- Because of the variable gradient in the intermediate aquifer, it is not clear that the Phase II investigation discovered the upgradient and downgradient ends of the plume in that unit. Thus, a volume of contaminated groundwater could not be calculated for that aquifer.
- The extent of the TCE plume in the uppermost aquifer to the north of I-610 and to the east of the site has not yet been fully defined.
- The extent of the TCE plume in the intermediate aquifer cannot be determined based on available information.

001573

001573



RADIAN CORPORATION

Figure 6-1
TCE Concentrations (ppm) in the Uppermost Water-Bearing Unit

001574

RADIAN CORPORATION

REFERENCES

Bouwer, H. and R.C. Rice, 1976. A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research. Volume 12, p. 423-428.

Cooper, H.H., J.D. Bredehoeft, and I.S. Papadopulos. "Response of a Finite - Diameter Well to an Instantaneous Charge of Water". Water Resources Research. 3 (1): 263-269, 1967.

Radian Corporation, 1979. CPS-1 Users' Manual Training Documentation.

Radian Corporation, 1988. Site Investigation Report - Industrial Transformer Superfund Site.

Radian Corporation, 1988. Feasibility Study, Industrial Transformer Superfund Site.

Reineck, H.E. and I.B. Singh, 1980. Depositional Sedimentary Environments, 549 p, Berlin, Heidelberg, New York: Springer-Verlag.

RADIAN CORPORATION

APPENDIX A

ORGANIC VAPOR ANALYZER (OVA) AND TRICHLOROETHENE DATA

001576

RADIAN CORPORATION

APPENDIX A
ORGANIC VAPOR ANALYZER (OVA) AND TRICHLOROETHENE (TCE) DATA

Intermediate Depth Monitor Well
Soil Samples

Sample Identification	Depth (ft)	OVA Reading (ppm)	Lab Analyses	TCE Value (ppm)
MW8-ST2	4-6	0.5		NA
MW8-ST3	8-10	1		NA
MW8-ST4	13-15	0		NA
MW8-ST5	18-20	0		NA
MW8-ST6	24-26	0		NA
MW8-ST7	29-31	0		NA
MW8-ST8	34-36	18	YES	1.5
MW8-ST9	39-41	2.2	YES	ND
MW8-ST10	44-46	0		NA
MW8-ST11	49-51	0		NA
MW8-SS12	59-61	0		NA
MW8-ST13	69-71	0		NA
MW8-ST14	79-81	0		NA
MW8-ST15	89-91	0		NA
MW8-ST16	99-101	0		NA
MW9-ST2	3-5	9		NA
MW9-ST3	8-10	2.3		NA
MW9-ST4	13-15	1.1		NA
MW9-ST5	18-20	5.7		NA
MW9-ST6	23-25	380	YES	6.9
MW9-ST7	28-30	420	YES	0.027*
MW9-ST8	33-35	340	YES	31
MW9-SS9	38-40	10	YES	0.019*
MW9-ST10	43-45	38	YES	0.063
MW9-ST11	49-50	400	YES	3.2
MW9-CB12	56-59	40	YES	0.95
MW9-ST13	69-71	16	YES	0.009*
MW9-ST14	79-81	26	YES	0.015*
MW9-ST15	84-85	36	YES	0.025*
MW9-ST16	89-90	10	YES	0.3
MW9-ST17	94-95.5	7.2	YES	0.034*
MW9-ST18	99-101	7.3	YES	0.11

NA - Not Analyzed
ND - None Detected
* - Actual Value reported; note that field blank or equipment blank data has invalidated certain of these samples, as noted on Table 4-2 in the text.

RADIAN CORPORATION

APPENDIX A
ORGANIC VAPOR ANALYZER (OVA) AND TRICHLOROETHENE (TCE) DATA
(Continued)

Intermediate Depth Monitor Well
Soil Samples

Samples ID	Depth (ft)	OVA Reading (ppm)	Lab Analyses	TCE Values (ppm)
MW10-ST2	3-5	>1000	YES	250
MW10-ST3	8-10	>1000	YES	36
MW10-ST4	13-15	>1000	YES	36
MW10-ST5	18-20	>1000	YES	600
MW10-ST6	23-25	>1000	YES	400
MW10-ST7	28-30	>1000	YES	66
MW10-ST8	33-35	420	YES	27
MW10-ST9	38-40	>1000	YES	12
MW10-ST10	43-45	900	YEA	21
MW10-ST11	48-50	970	YES	26
MW10-ST12	58-60	250	YES	16
MW10-ST13	68-70	12	YES	0.0092*
MW10-ST14	78-80	24	YES	0.014*
MW10-SB15	84-85.5	9.2	YES	0.017*
MW10-SS16	89-91	10	YES	0.1
MW10-SS17	94-95.5	0		NA
MW10-SS18	99-100.5	0		NA
		Field Blanks		
MW8-FB2	--	--	YES	0.035
MW10-FB6	--	--	YES	0.011
MW9-FB5	--	--	YES	0.011
PCB samples are as follows:				
MW8-ST1	0-1	--	YES	
MW9-ST1	0-1	--	YES	
MW10-ST1	0-1	--	YES	
MW8-FB1	--	--	YES	

NA - Not Analyzed
ND - None Detected
* - Actual Value reported; note that field blank or equipment blank data has invalidated certain of these samples, as noted on Table 4-2 in the text.

RADIAN CORPORATION

APPENDIX B-1
BOREHOLE LOGS

001579

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Boring or Well No. MONITOR WELL 8
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55
SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-22-88 of drilling operation
Sampling Interval (Est.) 0-101 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
	X	ST-1	Grass roots, sm. pebbles, dark brown and grey clay	
5-	X	ST-2	Dark brown/grey clay, with calcareous nodules or pebbles	
10-	X	ST-3	Mottled yellow red/orange and black streaked clay; calcareous nodules @ 8-9 ft; red, yellow clay with calcareous nodules at 10-11'.	
15-	X	ST-4	Greenish-gray clay mottled with red/orange; a few, small, scattered calcareous nodules throughout length of core.	
20-	X	ST-5	Mottled red and greenish-gray clay at 18-19'; then silty clay, increasing amounts of silt towards bottom of core; a few, small scattered calcareous nodules.	
25-	X	ST-6	Red, mottled with green-gray clay; lower 4.5" of core is gray with fine sand, sharp contact with overlying clay.	
30-	X	ST-7	Uppermost 2" is red clay, then mottled green and gray clay, slightly silty.	
35-	X	ST-8	Reddish-orange very fine sand, gray, contains small amounts of clay.	
40-	X	ST-9	Uppermost 2" is very fine gray sand, sharp contact with underlying clay, sand is reddish-orange, clay is mostly greenish-gray; calcareous nodules; orange mottling.	

001580

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Boring or Well No. MONITOR WELL 8
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55
SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-22-88 of drilling operation
Sampling Interval (Est.) 0-101 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
45-	X	ST-10	Red and green mottled clay with abundant calcareous nodules; clay contains minor amounts of silt.	
50-	X	ST-11	Red and green-gray mottled clay.	
55-				
60-	X	SS-12	Red and gray mottled clay, some small silty pockets.	
65-				
70-	X	ST-13	Upper 8.5" of core is red clay mottled with gray; clay is very stiff and crumbly; lower portion of core is red and gray mottled clay with silt pockets, very crumbly.	
75-				
80-	X	ST-14	Red mottled clay with small amount of gray mottling and some silt pockets. Very dry and crumbly.	

001581

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Boring or Well No. MONITOR WELL 8
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55
SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-22-88 of drilling operation
Sampling Interval (Est.) 0-101 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
85-				
90-	X	ST-15	Upper 3" of core is silty, water-bearing unit, red, lower part of core is stiff, crumbly red clay with gray mottling. Few scattered iron oxide nodules. Uppermost 1-1 1/2" of core is red clayey fine sand, sharp contact with underlying red clay.	
95-				
100-	X		Stiff red clay with gray mottling. A few small silt pockets.	

001582

RADIAN CORPORATION

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Sheet 1 of 3

Boring or Well No. MONITOR WELL 9
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55/FAILING 1500 SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-26-88 of drilling operation
Sampling Interval (Est.) 0-101 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
	X	ST-1	Dark gray-black clay, roots.	
5-	X	ST-2	Upper 5" is dark gray, dark green clay, followed by dark gray clay with a few calcareous nodules.	
10-	X	ST-3	Mottled green/gray clay, iron oxide nodules scattered thru-out the core, as are calcareous nodules.	
15-	X	ST-4	Mottled green-gray and orange clay; abundant calcareous and iron oxide nodules.	
20-	X	ST-5	Mostly red clay mottled with small amounts of greenish-gray clay, calcareous nodules more abundant at 20'; slightly silty clay at 20'.	
25-	X	ST-6	Mostly red clay mottled with small amounts of greenish-gray clay; bottom 1" of core is very fine, light tan sand (50% clay/50% sand); sharp contact with above clay.	
30-	X	ST-7	Light tan very fine sand with 35% clay; abundant calcareous nodules; black organic matter; orange mottling scattered throughout.	
35-	X	ST-8	Light tan very fine sand with 25% clay; black organic matter increasing towards bottom.	
40-	X	SS-9	Light tan silty clay; few calcareous nodules; small amounts of orange mottling.	

001583

RADIAN CORPORATION

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Boring or Well No. MONITOR WELL 9
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55/FAILING 1500 SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-26-88 of drilling operation
Sampling Interval (Est.) 0-101 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
45-	X	ST-10	Grayish tan clay with extremely abundant calcareous nodules.	
50-	X	ST-11	Tan to gray silty clay with orange mottling; iron oxide nodules; calcareous nodules; crumbles easily; 50% very fine sandy silt and 50% clay; increasing amount of clay with depth changing to red-brown color, very stiff.	
55-				
60-	X	CB-12	Red silty clay mottled with gray-green clay; red clay reacts mildly to HCL; scattered calcareous nodules.	
65-				
70-	X	ST-13	Deep red clay with greenish-gray clay; silty lenses and pockets; dry, crumbly appearances.	
75-	X			

001584

RADIAN CORPORATION

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Sheet 3 of 3

Boring or Well No. MONITOR WELL 9
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55/FAILING 1500 SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-26-88 of drilling operation
Sampling Interval (Est.) 0-101 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
	X	ST-14	Deep red, stiff clay, mottled with greenish gray.	
85-	X	ST-15		
90-	X	ST-16	Deep red very fine sand with minor amounts of clay and silt.	
95-	X	ST-17	Deep red stiff clay mottled with minor amounts of greenish gray clay.	
100-	X	ST-18	Stiff, crumbly red clay.	

001585

RADIAN CORPORATION

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Boring or Well No. MONITOR WELL 10
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55
SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-28-88 of drilling operation
Sampling Interval (Est.) 0-100.5 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
45-		ST-10	Red clay with numerous calcareous nodules; greenish-gray silty clay (35% silt, 75% clay); calcareous nodules scattered.	
50-		ST-11	Moist reddish clay in upper 3" of core; sharp contact with dry, crumbly, deep red clay, mottled with greenish-gray clay; very few calcerous nodules; black iron oxide nodules.	
55-				
60-		ST-12	Predominantly red clay mottled with greenish-gray clay; clay very dry and stiff, deep red; slightly indurated areas react violently to HCl.	
65-				
70-		ST-13	Upper part of core is mottled green and red clay, zone of calcareous and iron oxide nodules; bottom part of core is deep red clay, stiff, crumbly texture.	
75-				
80-		ST-14	Stiff red clay.	

001586

RADIAN CORPORATION

RADIAN CORPORATION

LOG OF DRILLING OPERATIONS

Boring or Well No. MONITOR WELL 10
Location HOUSTON, TEXAS
Log Recorded by MARY M. McGILL
Type Drill Rig and Operator CME 55
SW LABORATORIES

Project INDUSTRIAL TRANSFORMER
Beginning 1-14-88 and end 1-28-88 of drilling operation
Sampling Interval (Est.) 0-100.5 ft

Depth	Sample Interval	ID No. of Sample Taken	Stratigraphy	Cumulative Depth
85-		SS-15	Deep red, very fine sand with clay and silt.	
90-		SS-16	Stiff, deep red clay.	
95-		SS-17	Deep red, stiff clay with few scatterd spots of greenish-gray clay.	
100-		SS-18	Deep red, stiff clay with few scattered spots of greenish-gray clay.	

001587

RADIAN CORPORATION

APPENDIX B-2

WELL COMPLETION FORMS

001588

RADIAN CORPORATION

RADIAN CORPORATION

WELL COMPLETION LOG: SHEET 1/2

Boring or Well No. Monitor Well 8 Project Industrial Transformer
Location Houston, Texas Log Recorded by Mary McGill

Construction started 1-14-88 completed 1-19-88
Development started 1-28-88 completed 1-29-88

Total depth drilled (ft) One hundred one (101) feet
Hole diameter Six (6) inches
Drilling method Hollow stem auger 0-101'
Problems encountered during drilling None

Water source for drilling and completion procedures City water

Number and type of samples collected Fifteen (15) Shelby tube samples in discrete two foot interval from 0-101' and one (1) split spoon from interval 59-61'
Sample interval (ft-ft) 5 foot intervals from 0-50'; 10 foot intervals from 50-100'
Storage method(s) appropriate size glass containers

Casing type PVC Diameter 12 inches, 8 inches
Casing type Stainless Steel Diameter Two inches
Depth of casing (ft) One hundred one (101) Feet
Screen type Wire wrapped stainless steel Diameter two (2) inches
Slot size .006 inches Screen interval (ft-ft) 86-96'
Type(s) of glue used to join casing All joints are flush threaded; no glues used

Type of gravel pack used Tex Blast No.4 Amount of sand pack used
Grain size distribution of sand pack Sieve #30/size 0.6mm/0-10% retained; #30/0.42 mm/40-70%. Quartz + chert #80/0.18 mm/95-100%; #100/0.16 mm/99.8%
Lithology of gravel pack
Source (company and quarry/pit)

Interval of sand pack (ft-ft) 84-101 feet
Interval of bentonite seal (ft-ft) 78-84 feet
Interval of grouting (ft-ft) 0-78 feet

Description of security measures Protective casing with locked cap

Padlock ID No. Masterlock 2068 Location of key(s) Radian -Houston

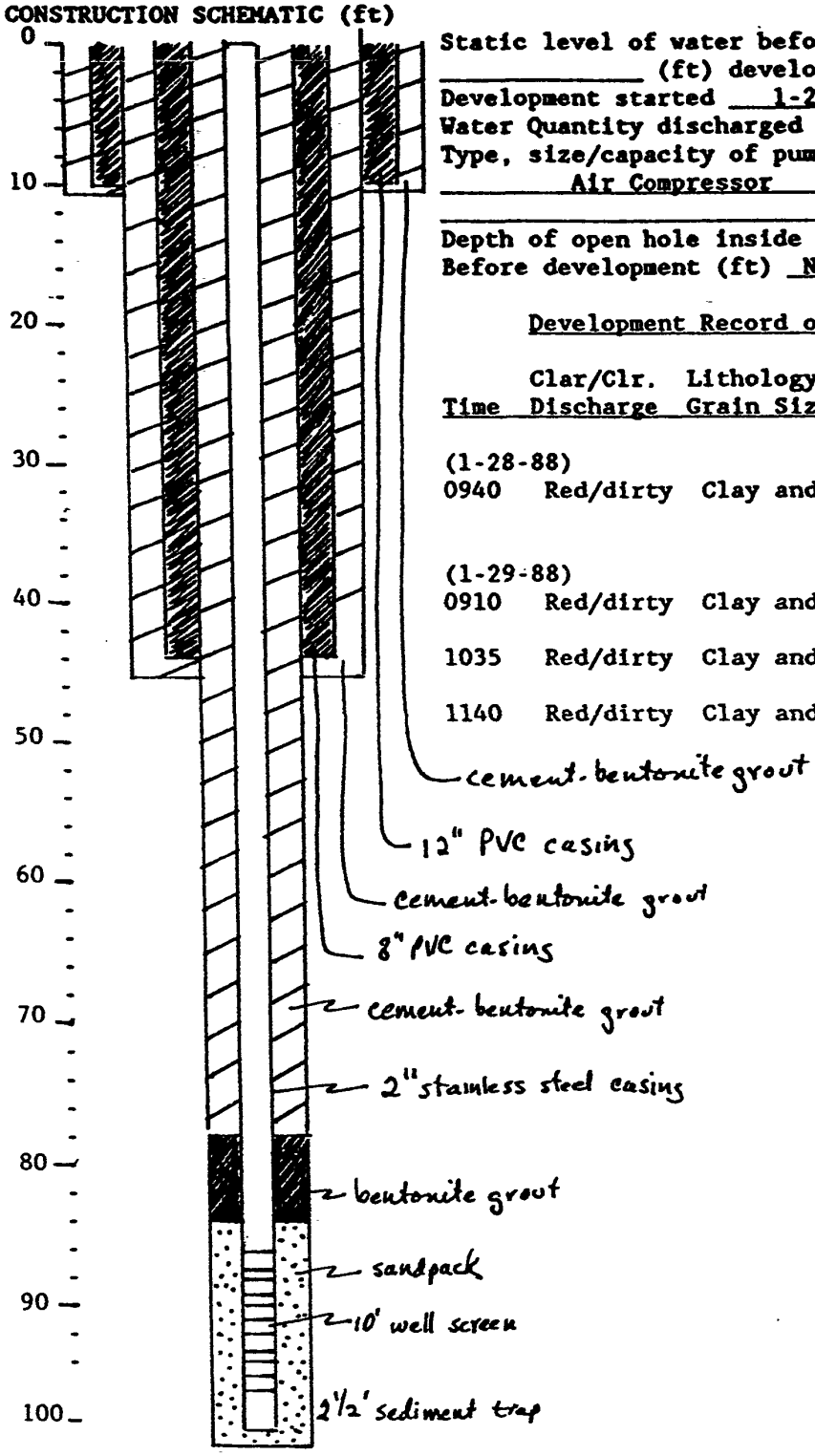
001589

RADIAN CORPORATION

WELL COMPLETION LOG: SHEET 2/2

Boring or Well No. Monitor Well 8 Project Industrial Transformer
Location Houston, Texas Log Recorded by Mary McGill

CONSTRUCTION SCHEMATIC (ft)



Static level of water before _____ (ft) and after _____ (ft) development _____
Development started 1-28-88 and ended 1-29-88
Water Quantity discharged during development _____ (ft^3)
Type, size/capacity of pump or bailer used for development
Air Compressor

Depth of open hole inside well 98.5 ft.
Before development (ft) NA After development (ft) NA

Development Record of Discharge and Sediment

Time	Clar/Clr. Discharge	Lithology/ Grain Size	pH	Conductivity	Temp.	Sal.
(1-28-88)						
0940	Red/dirty	Clay and fines		900		0.3
(1-29-88)						
0910	Red/dirty	Clay and fines	9.6	1350	18	1.5
1035	Red/dirty	Clay and fines	8.0	1300	19	1.0
1140	Red/dirty	Clay and fines	7.7	1700	22.5	0.9

001590

RADIAN CORPORATION

RADIAN CORPORATION

WELL COMPLETION LOG: SHEET 1/2

Boring or Well No. Monitor Well 9 Project Industrial Transformer
Location Houston, Texas Log Recorded by Mary McGill

Construction started 1-14-88 completed 2-1-88
Development started 1-27-88 completed 1-27-88

Total depth drilled (ft) One hundred one (101) feet
Hole diameter Six (6) inches
Drilling method Hollow stem auger 0-10' and 45-100'; rotary 10-45'
Problems encountered during drilling heaving sands at about 33'

Water source for drilling and completion procedures City water

Number and type of samples collected Seventeen (17) Shelby tube samples in discrete two foot intervals from 0-101' and one (1) core barrel sample from 56-59' interval
Sample interval (ft-ft) 5' intervals from 0-50' and 80-101'; 10' intervals from 50-80'
Storage method(s) appropriate sized glass containers

Casing type PVC Diameter 12 inches, 8 inches
Casing type Stainless Steel Diameter two inches
Depth of casing (ft) One hundred one (101) feet
Screen type wire wrapped stainless steel Diameter two (2) inches
Slot size 0.006 inches Screen interval (ft-ft) 84-94 ft
Type(s) of glue used to join casing All joints are flush joint threaded; no glues used

Type of sand pack used Tex Blast No.4 Amount of sand pack used 2.09 cu.ft.
Grain size distribution of sand pack Sieve #30/size 0.6 mm/0-10% retained; #30/0.42mm/40-70% Quartz+chert #80/0.18 mm/95-100%; #100/0.16 mm/99.8%.
Lithology of gravel pack
Source (company and quarry/pit)

Interval of gravel pack (ft-ft) 82-101 feet
Interval of bentonite seal (ft-ft) 76-82' feet
Interval of grouting (ft-ft) 0-76' feet

Description of security measures at grade completion protective casing

Padlock ID No. American Lock Co. 15036 Location of key(s) Radian-Houston

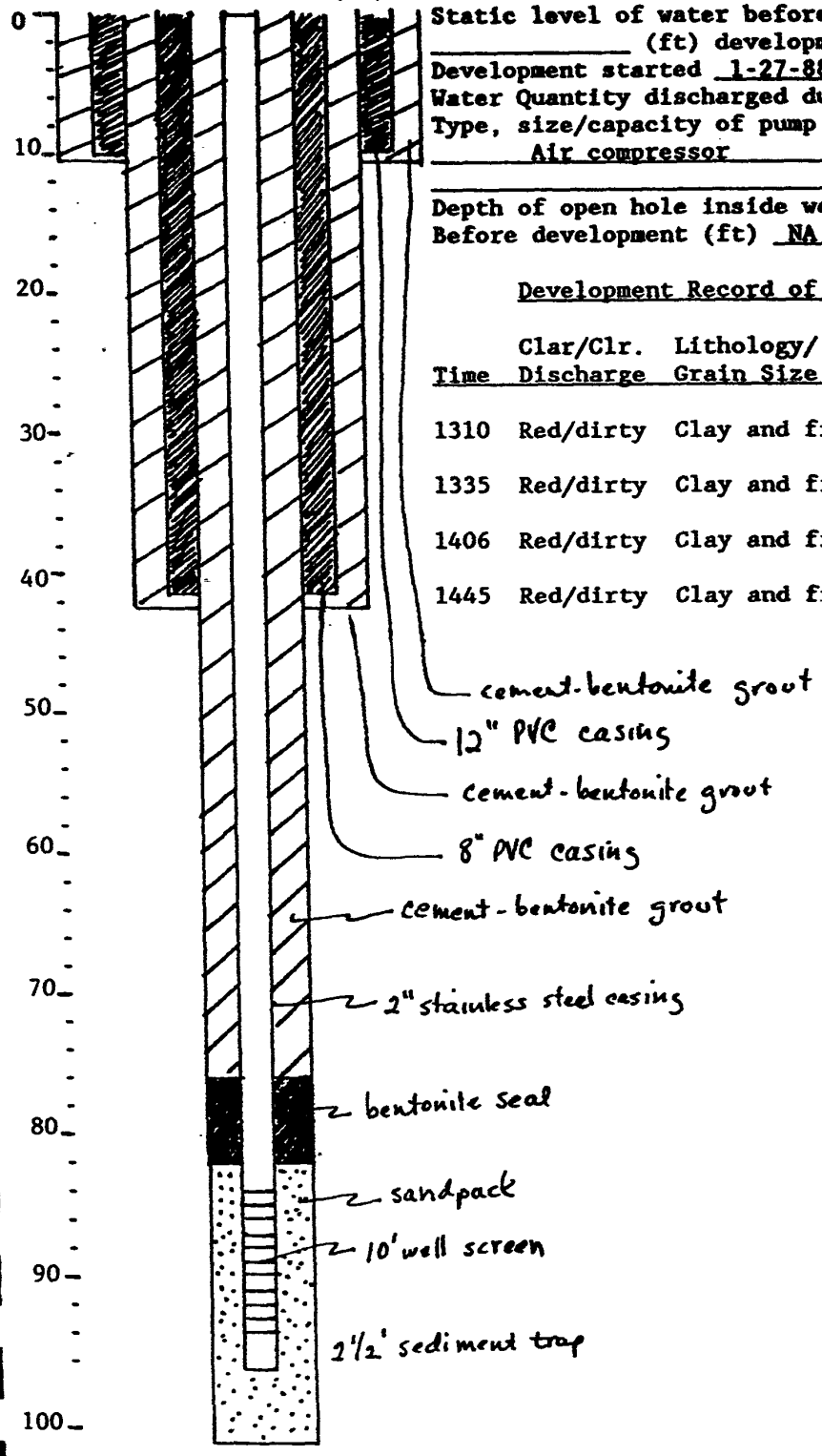
001591

RADIAN CORPORATION

WELL COMPLETION LOG: SHEET 2/2

Boring or Well No. Monitor Well 9 Project Industrial Transformer
Location Houston, Texas Log Recorded by Mary McGill

CONSTRUCTION SCHEMATIC (ft)



Static level of water before _____ (ft) and after _____ (ft) development _____
Development started 1-27-88 and ended 1-27-88
Water Quantity discharged during development _____ (ft^3)
Type, size/capacity of pump or bailer used for development
Air compressor

Depth of open hole inside well 101 feet
Before development (ft) NA After development (ft) NA

Development Record of Discharge and Sediment

Time	Clar/Clr. Discharge	Lithology/ Grain Size	pH	Conductivity	Temp.	Sal.
1310	Red/dirty	Clay and fines		1780	25°C	1.6
1335	Red/dirty	Clay and fines		1910	24°C	1.1
1406	Red/dirty	Clay and fines		1905	25°C	1.0
1445	Red/dirty	Clay and fines		2070	26°C	1.0

001592

RADIAN CORPORATION

APPENDIX B-3

MONITOR WELL CONSTRUCTION DETAILS

001593

RADIAN CORPORATION

APPENDIX B-3

MONITOR WELL CONSTRUCTION DETAILS*

	MW-8	MW-9	MW-10
PVC Surface Casing (12in)	0-9.5	0-10	0-10
PVC Protective Casing (8 in)	0-44	0-41.5	0-77
Cement Bentonite	0-44 0-78	0-41.5 0-76	0-77 0-77
Bentonite Seal	78-84	76-82	77-81
Sand Pack	84-101	82-101	81-101
Screen	86-96	84-94	83-93
Sediment Trap	96-98.5	94-96.5	93-95.5
Total Depth	101	101	100.5

* All depths recorded in feet.

001594

RADIAN CORPORATION

APPENDIX B-4

DETERMINATION OF SCREEN SLOT SIZE AND SAND PACK ANALYSIS

001595

RADIAN CORPORATION

APPENDIX B-4

SAND PACK ANALYSIS AND DETERMINATION OF SCREEN SLOT SIZE

Data:

Grain size analysis data for MW-3

Sieve Size	% Passing
10	100
40	99.8
60	99.8
200	48.8

Assumption & Design Procedures:

a) Design criteria for water wells (Source: Groundwater and Wells, F.G. Driscoll)

- For naturally developed wells use screen slot size equal to 60% to 50% material passing. If screen slot size less than .01 inches, then use of a filter pack is advisable.
- In Gulf Coast area, well screen slot sizes as small as 0.006 inches have successfully produced reasonable yields.
- If filter pack is designed, screen slot size should be able to retain 90% of pack. Filter pack should have uniformity coefficient of approximately 2, however, a coefficient of 4-5 may work.

b) Design criteria for Monitoring Well (Source: Groundwater and Wells, F.G. Driscoll)

- Slot size should retain a high percentage of filter pack.
- Filter pack should have a D^{50} of 2 times the D^{50} of soil and a uniformity coefficient of 2-3 (a more conservative design than water wells).

c) Design of Filters for Drains (Source: Geotechnical Engineering Manual, Roy E. Hunt)

- Piping Criteria:
  D^{15} of filter < 4 to 5 times D^{85} of soil
- Permeability Criteria:
  $$\frac{D^{15}\text{(filter)}}{D^{15}\text{(soil)}} > 4 \text{ and } < 20 \text{ to } 40$$

001596

RADIAN CORPORATION

Assumptions and Calculations:

D^{85} of soil = .18 mm
D^{50} of soil = .075 mm
D^{15} of soil = < .005 mm extrapolated

- Well needs a sand pack.

- Screen size limit = .006 inch
  = .15 mm

Any smaller sieve may cause plugging and yield problems.

- Desired Pack characteristics

  -- Screen should retain 80 - 90% of filter pack
  $D^{15} \leq$ .15 mm

  -- D^{50} (filter) $\simeq$ 2 x D^{50} (soil)
  $\simeq$ 2 x .075
  $\simeq$ .15 mm

  If the desired uniformity coefficient of 2-3 is void, a value of less than 80 - 90% may be retained.

  -- D^{15} (filter) < 4 x .18
  < .72 mm

  -- D^{15} (filter) > 4 x .005, > .020
  < 20 x .005, < .1 mm

- Review #4 sand from Tex-Blast

Sieve No.	Size	% Retained
30	0.6 mm	0 - 10
40	.42	40 - 70
80	.18	95 - 100
100	.16	99.8

  -- Very little will pass through screen
  D^{15} (filter) << 0.15 mm

  -- D^{50} of filter is much larger than 2 x D^{50} of soil (0.15 mm)

  -- D^{15} (filter) ($\simeq$ .2 mm) < 4 x .18

  -- $\frac{D^{15}\text{(filter)}}{D^{15}\text{(soil)}} = \frac{.2}{.005}$
  = > 4 <40

001597

RADIAN CORPORATION

#4 sand passes all criteria except
D^{50} (filter) $\simeq$ 2 x D^{50} (soil)

Design Based upon Bureau of Reclamation
(Source: Todd, 1980)

Uniformity Coeff of Aquifer $\simeq \frac{0.1 > 3}{.03}$

As per Todd Design Criteria is

Screen slot size < 10% passing pack material
Sandpack:
If uniformity is 1 - 2.5 D^{50} (filter) < 9 D^{50}(soil)
If uniformity is 2.5 - 5.0 D^{50} (filter) < 12 D^{50} (soil)

Check No. 4 sand

9 x D^{50} soil = 9 x .075
= .675 mm

D^{50} (filter) << .675 mm

Screen size of .15 mm will allow < 10 of sandpack

Based upon these calculations it is believed that No.4 sand with above characteristics should be suitable for sandpack.

001598

RADIAN CORPORATION

APPENDIX C

SUMMARY OF ANALYTICAL METHODS AND PRESERVATION REQUIREMENTS

001599

SAMPLE METHODS AND PRESERVATION REQUIREMENTS

Sample	Sample Type	No.	Container	Size	Analytical Parameter	Analytical Procedrues	Preservation	Maximum Holding Time
Water Well	Water	1	Glass, Teflon-lined septum	40 ml	TCE	8010	Cool, 4°C	14 days
Soil & Sediment	Soil	51	Glass, Teflon-lined cap	100 grams	TCE	8010	Cool, 4°C	14 days
		4		40 grams	PCB	8080		7 days before and
		1		100 grams	POP	8270, 8240	Cool, 4°C	40 days after
		3		100 grams	Dioxin	8280		extraction
Shallow Soil Boring	Soil	37	Glass, Teflon-lined cap	100 grams	TCE	8010	Cool, 4°C	14 days
		18		40 grams	PCB	8080		7 days before and
		4		100 grams	POP	8270, 8240	Cool, 4°C	40 days after
		1		100 grams	Dioxin	8280		extraction
Deep Soil Boring	Soil	50	Glass, Teflon-lined cap	100 grams	TCE	8010	Cool, 4°C	14 days
		4		40 grams	PCB	8080		7 days before and
		1		100 grams	POP	8270, 8240	Cool, 4°C	40 days after extraction
Monitor Well	Soil	16	Glass, Teflon-lined cap	100 grams	TCE	8010	Cool, 4°C	14 days
		4		40 grams	PCB	8080		7 days before and
		1		100 grams	POP	8270		40 days after extraction
Groundwater	Water	15	Glass, Teflon-lined cap	40 ml	TCE	8010	Cool, 4°C	14 days
		4		40 ml	VPOP	CL624	Cool, 4°C	14 days
Storm Water	Water	7	Glass, Teflon-lined cap	1 liter	PCB	8080	Cool, 4°C	14 days
		2		40 ml	POP	CL624, CL625	Cool, 4°C	7 days before and 40 days after extraction
Ambient Air	Air	4	Filter in Plastic Bag		Particles	Gravimetric	Cool, 4°C	7 days before and
					PCB	8080		40 days after extraction

RADIAN CORPORATION

001600

RADIAN CORPORATION

APPENDIX D
GEOTECHNICAL ANALYSIS

001601

RADIAN CORPORATION

APPENDIX D
GEOTECHNICAL ANALYSIS

Three soil cores were selected for grain size analysis at the ITS site. Samples were selected from the intermediate water-bearing zone or underlying clay (see Table 1).

The analytical results are summarized in Table 2. The sample collected from MW-9 contains about 43% fine-sized sand and 57% fines (silts and clays). This is in comparison to a slightly sandier intermediate water-bearing sand sample (MW3;SB3) analyzed during Phase I work, which contained 52% fine sand and 48% silt and/or clay sized material.

The other two samples (MW8;ST15 and MW10; SS16) collected from the clay immediately underlying the intermediate aquifer are similar, with 100% of the material passing sieve #200, 96% passing #325, 84-88% of the material smaller than 0.01 inches diameter, 71% finer than 0.005 inches, and 41-46% less than 0.001 inches. These results favorably agree with the clay sample (MW3;SB4) analyzed and reported in Phase I work.

001602

RADIAN CORPORATION

TABLE 1

GEOTECHNICAL SAMPLE DESCRIPTION AND LOCATION

Sample Identification	Lithology	Depth (Feet)	Horizon	Tests Performed
MW-8; ST-15	stiff red clay	89-91	below the intermediate aquifer	grain size analysis hydrometer
MW-9; ST-15	reddish tan clayey sand	84-85.5	intermediate aquifer	grain size analysis hydrometer
MW-10; SS-16	stiff red clay	89-91	below the intermediate aquifer	grain size analyis hydrometer

Key to Abbreviations:

MW - Monitor Wells
ST - Shelby tube
SS - Split barrel

RADIAN CORPORATION

TABLE 2

GEOTECHNICAL SAMPLE ANALYSIS

Sample Identification	Grain Size Analysis Percent (%) Passing Sieve No.s:					Hydrometer		
	40	100	200	270	325	0.01"	0.005"	0.001"
MW-8; ST-15			100		96	88	71	41
MW-9; ST-15	100	96	57	24	10			
MW-10; SS-16			100		96	84	71	46

Note: Mesh numbers are for U.S. Standard Sieves: 40 mesh = 0.42mm, 200 mesh = 0.074 mm, 270 mesh = 0.053 mm, 325 mesh = 0.044 mm.

001604

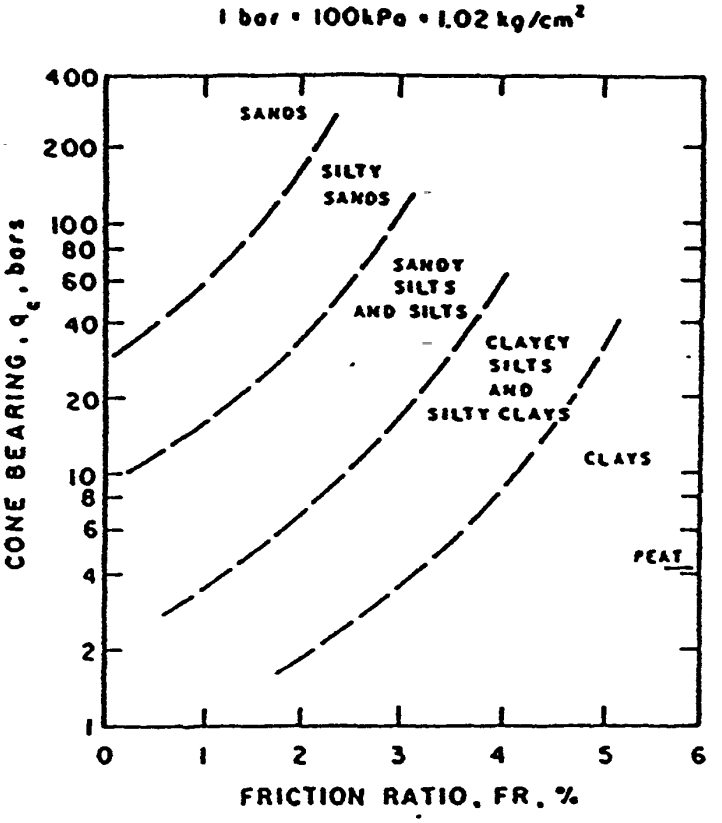
RADIAN CORPORATION

APPENDIX E

CONE-PENETROMETER SOUNDINGS

001605

RADIAN CORPORATION



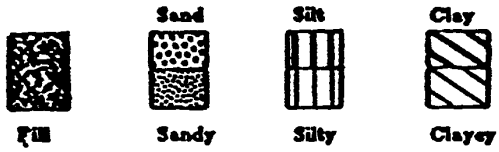
CAMPANELLA AND ROBERTSON CLASSIFICATION CHART

001606

RADIAN CORPORATION

Key to Soil Classification and Symbols

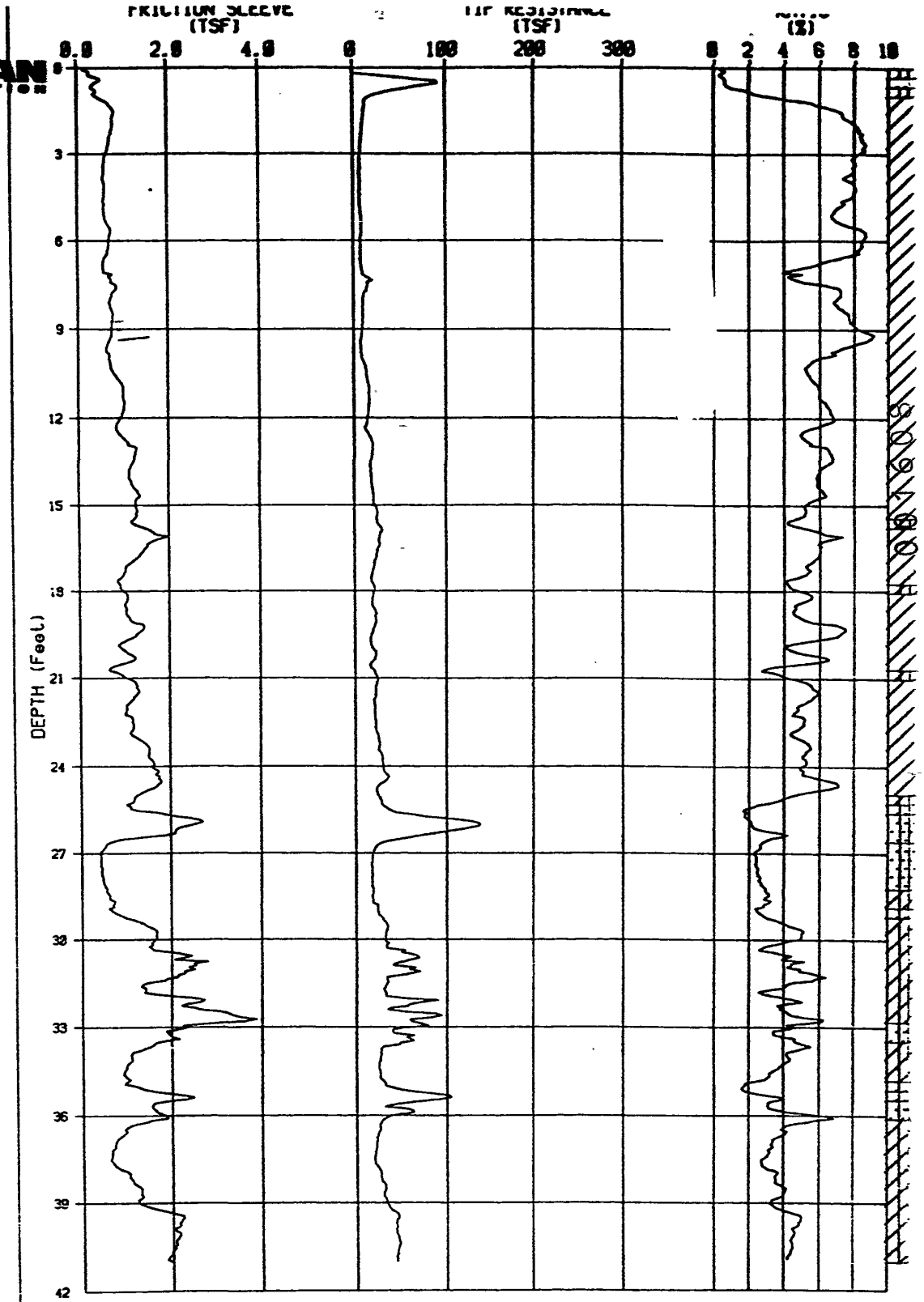
SOIL TYPE
(Shown in Symbol Column)



Predominant type shown heavy

001607

RADIAN CORPORATION

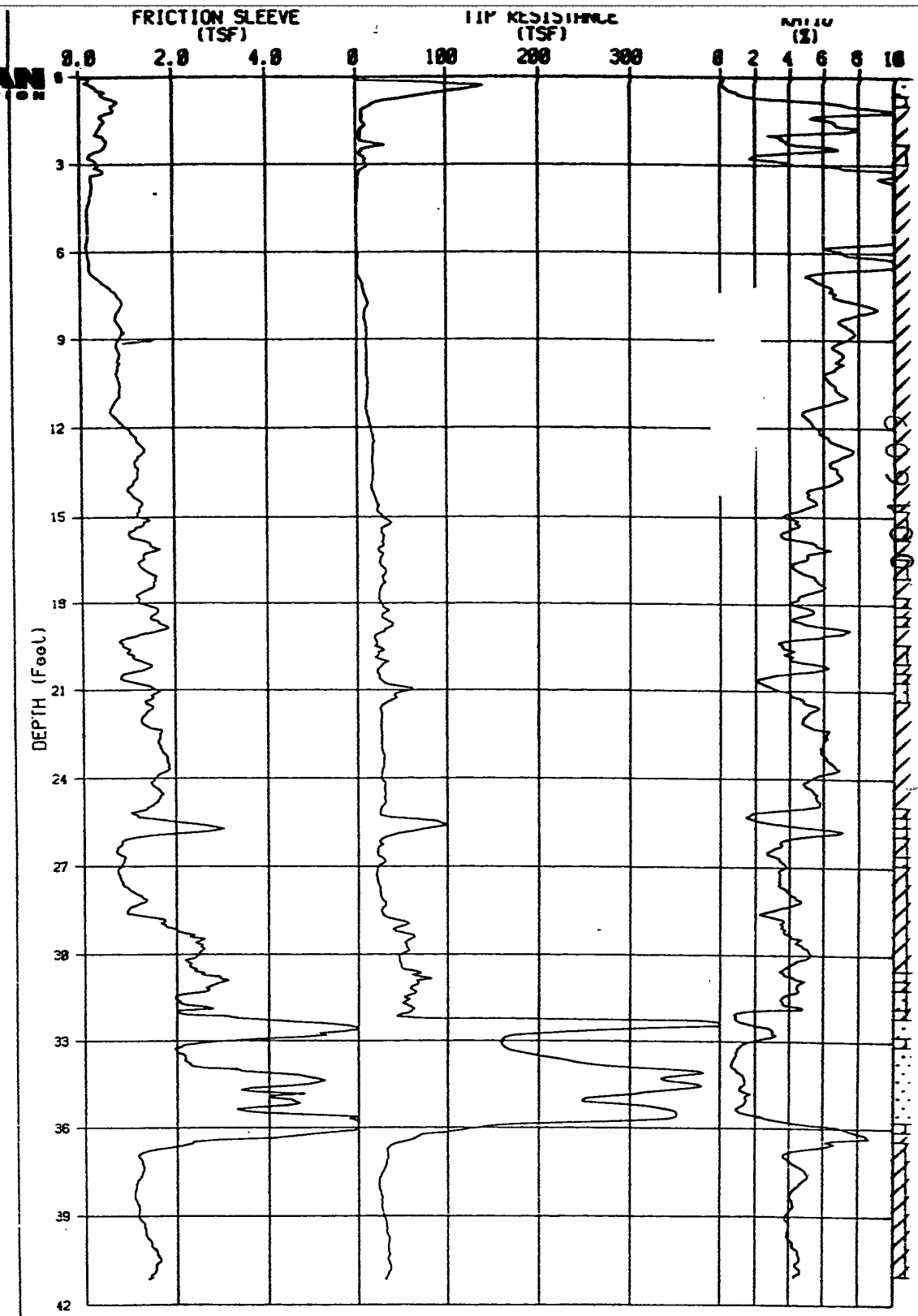


JOB NUMBER : 88-0022 CPT NUMBER : C-1 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

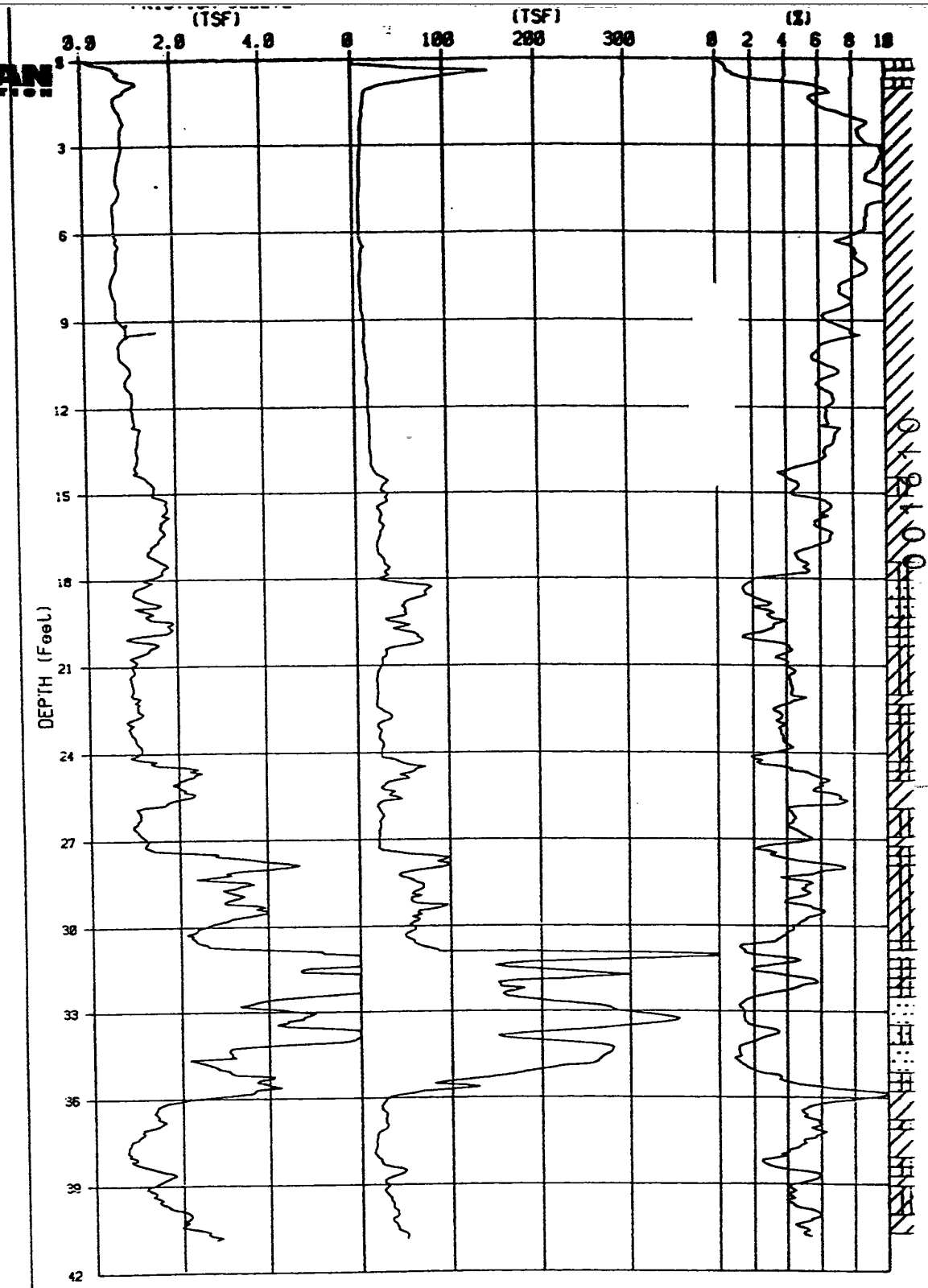


JOB NUMBER : 88-0022 CPT NUMBER : C-2 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

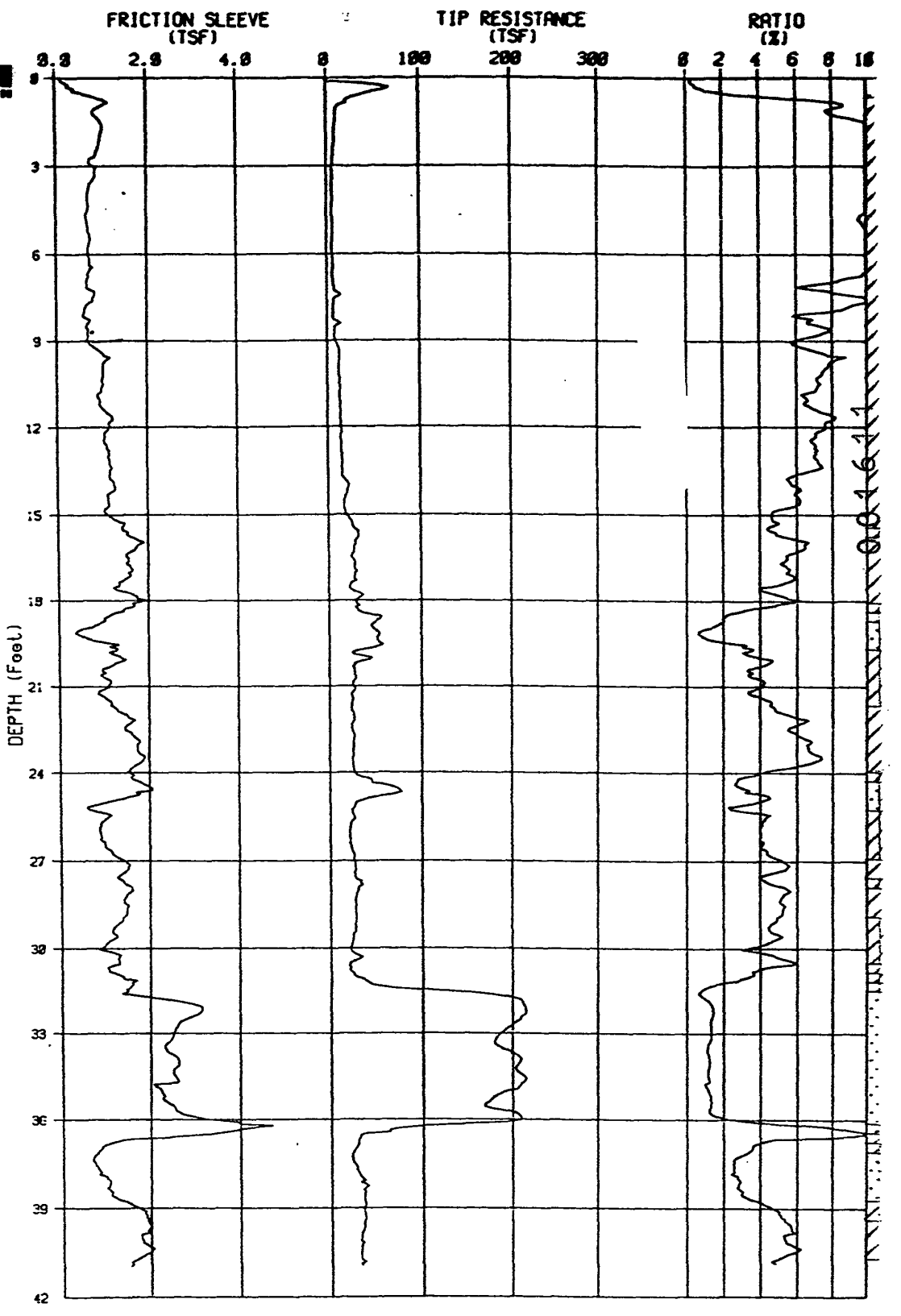


JOB NUMBER : 88-0022 CPT NUMBER : C-3 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION



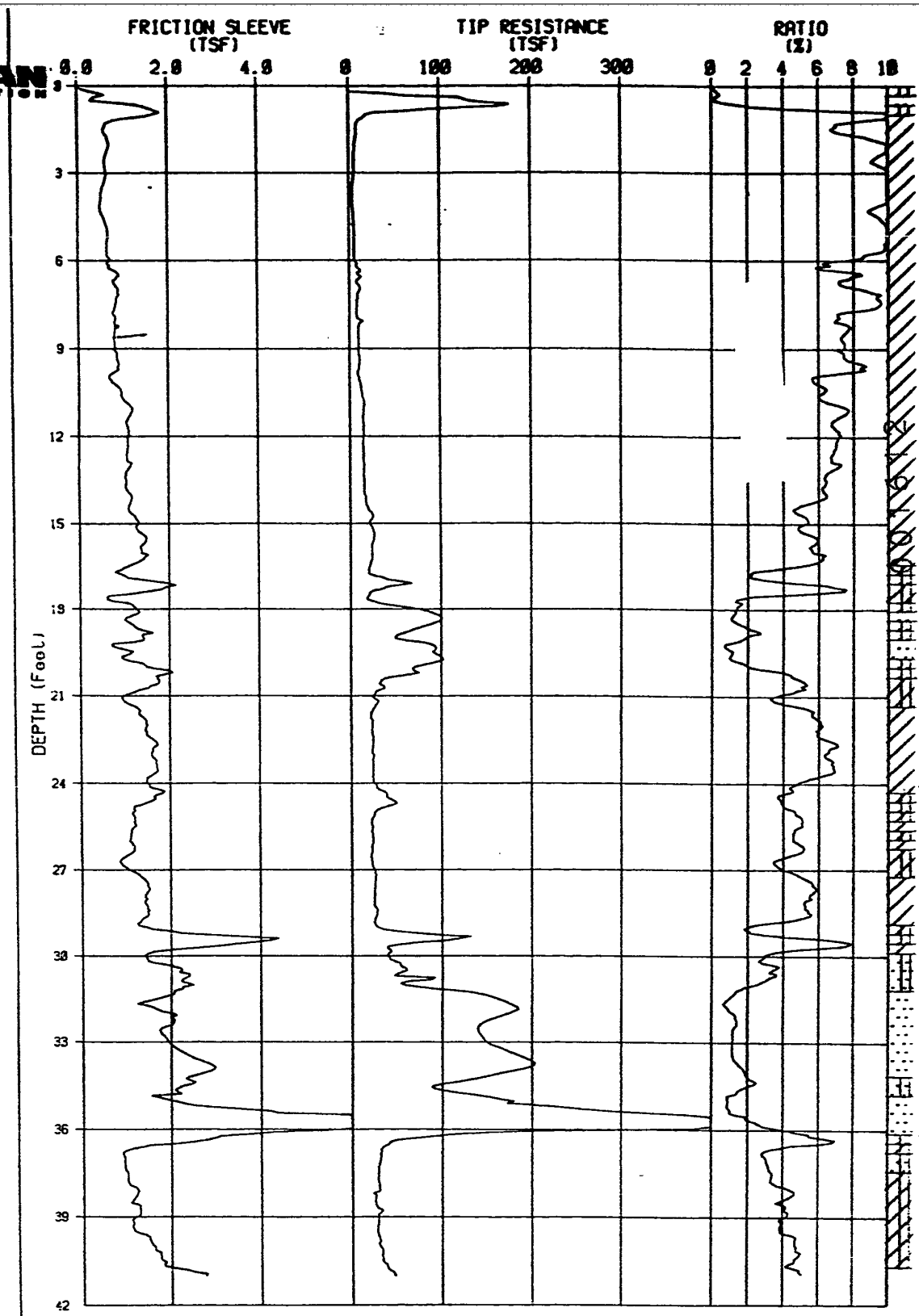
JOB NUMBER : 88-0022 CPT NUMBER : C-4 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

001611

RADIAN CORPORATION

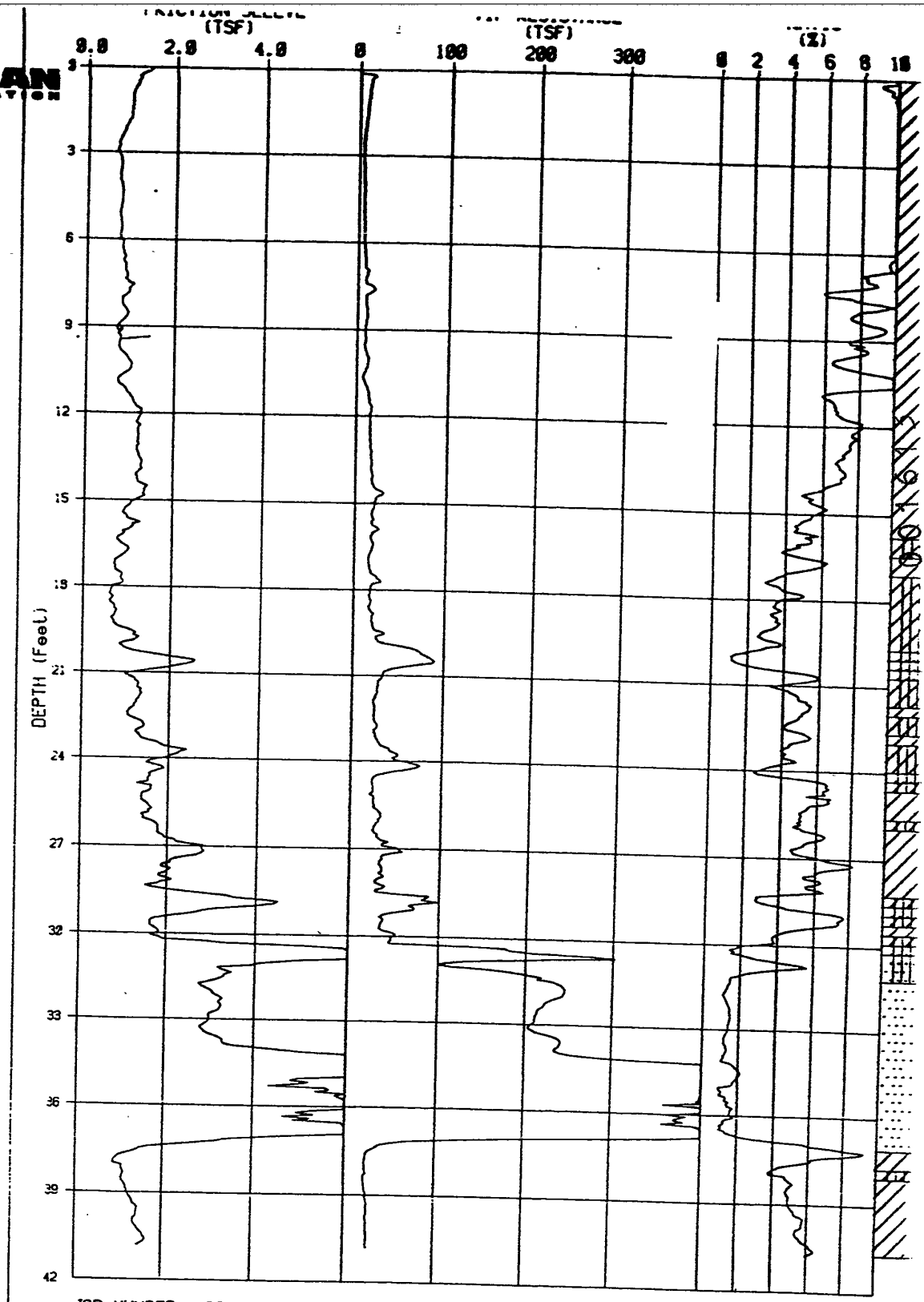


JOB NUMBER : 88-0022 CPT NUMBER : C-5 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

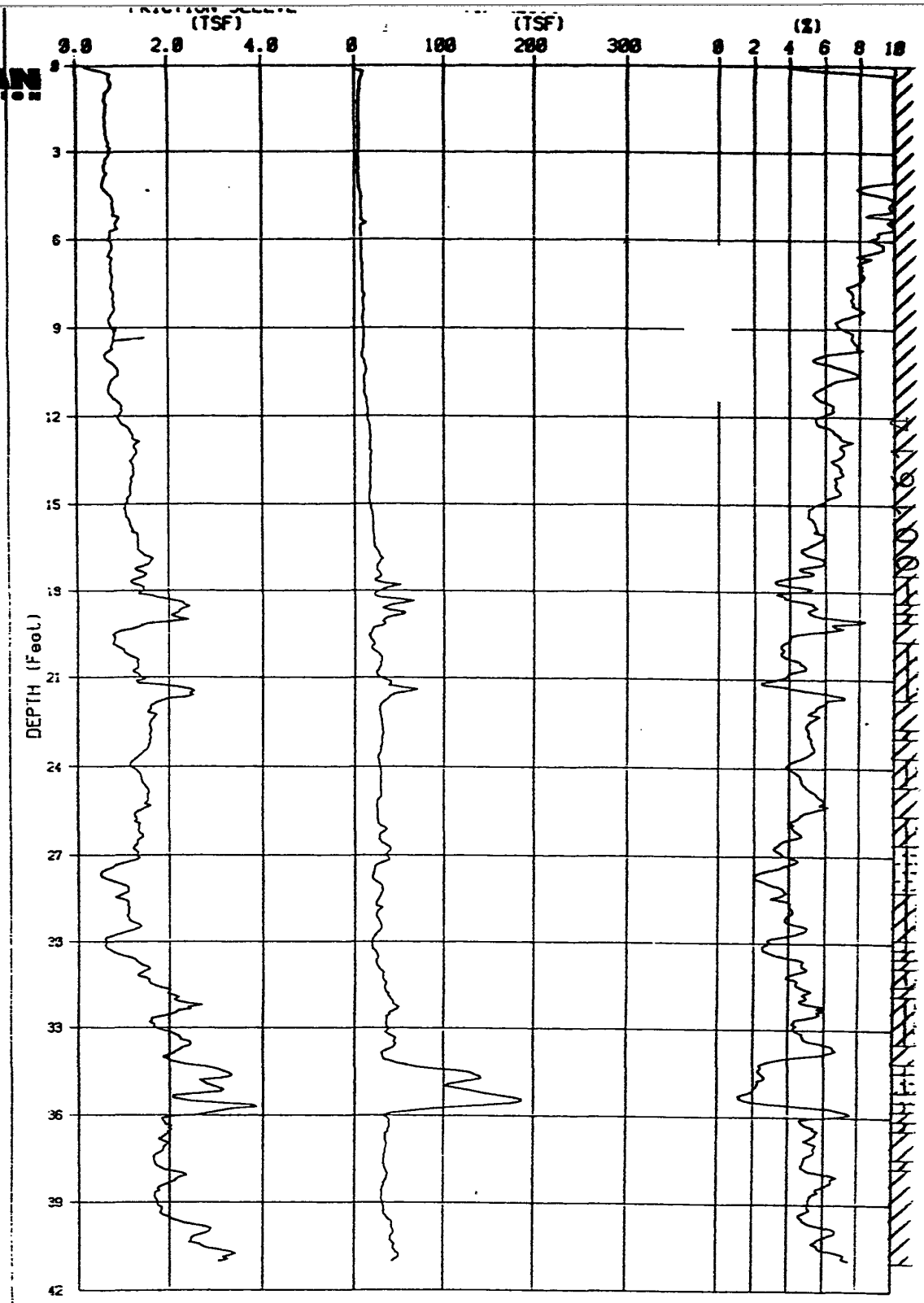


JOB NUMBER : 98-0022 CPT NUMBER : C-6 DATE : 03-01-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

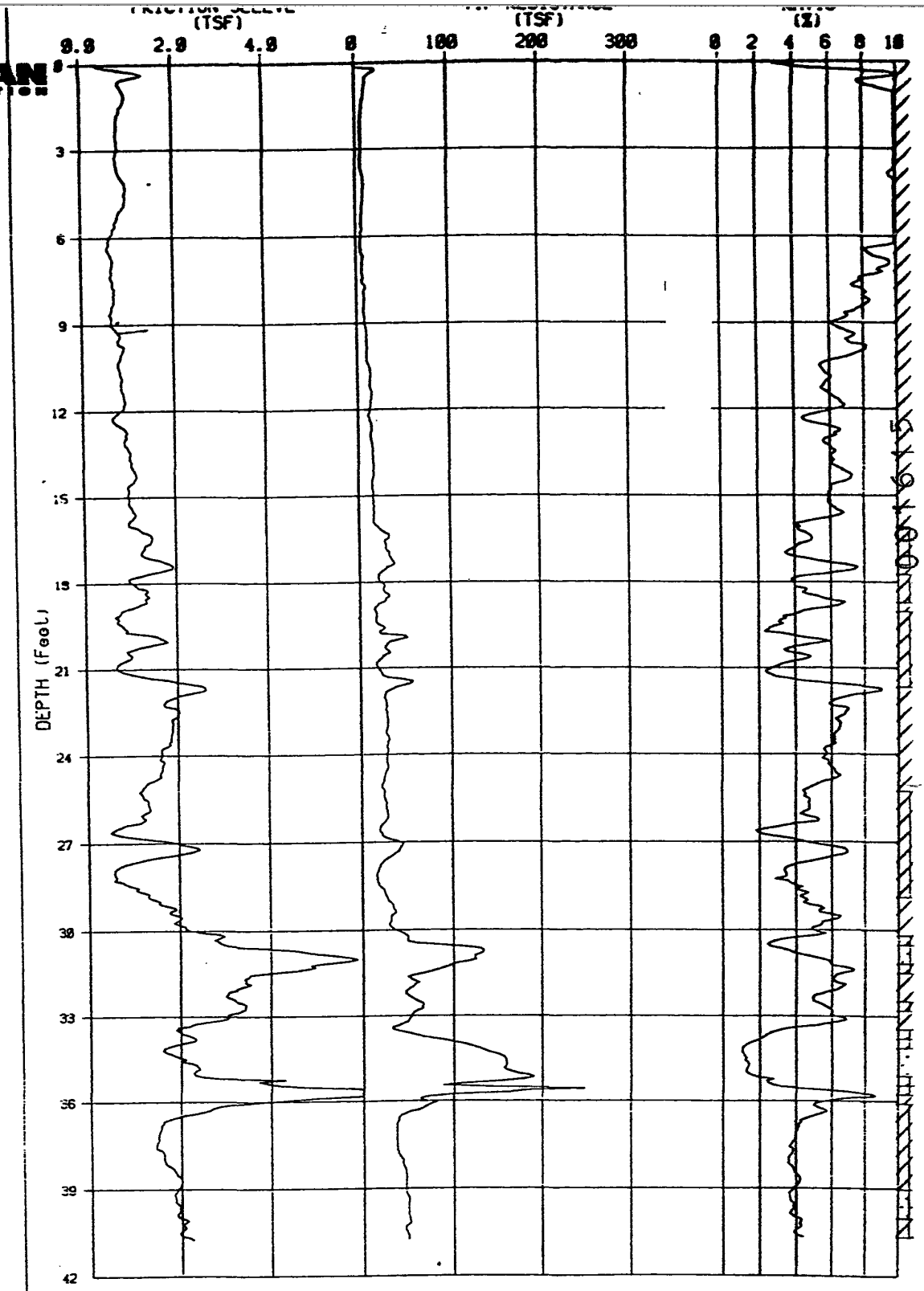


JOB NUMBER . 88-0022 CPT NUMBER : C-7 DATE . 03-01-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

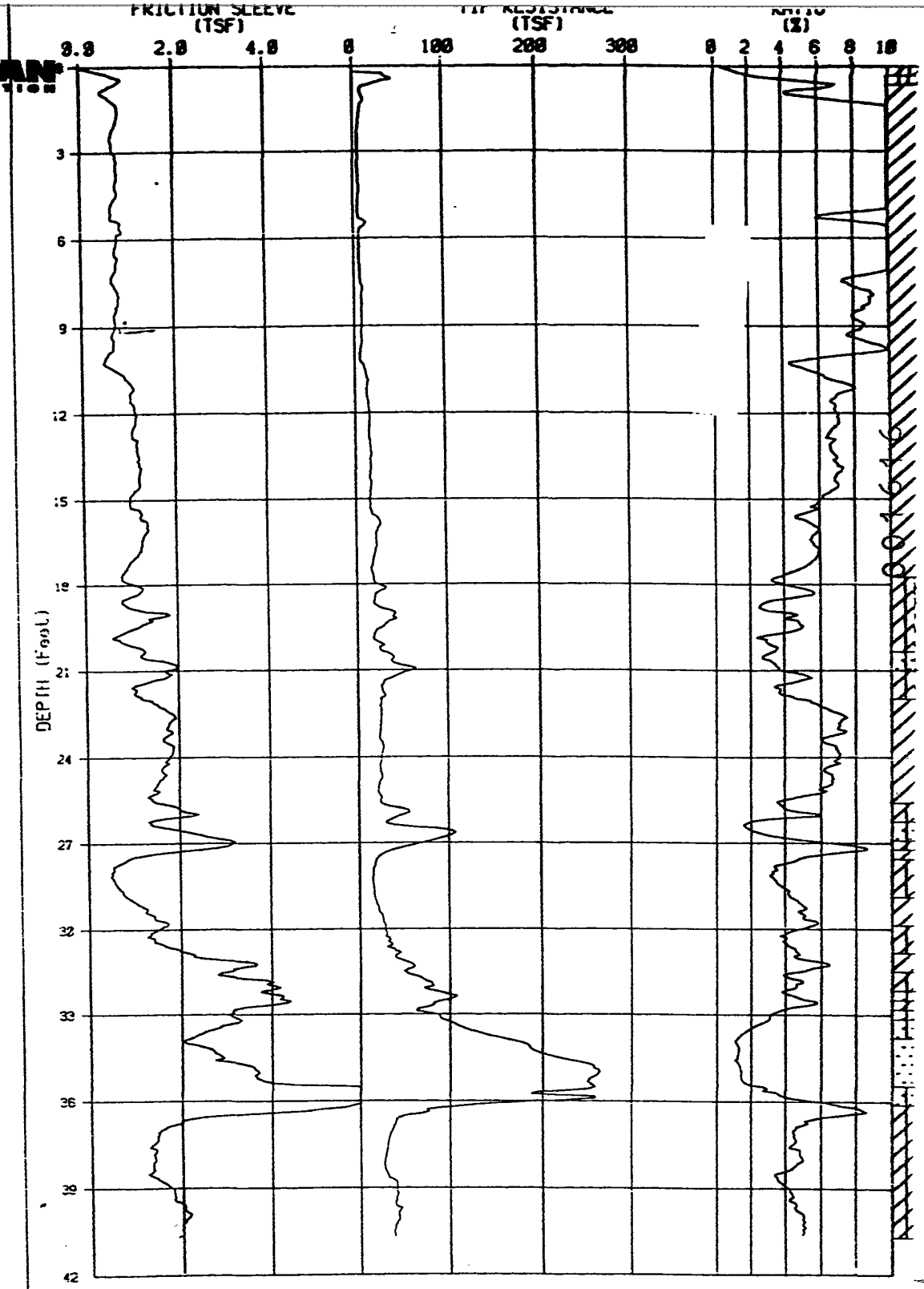


JOB NUMBER . 88-0022 CPT NUMBER . C-8 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

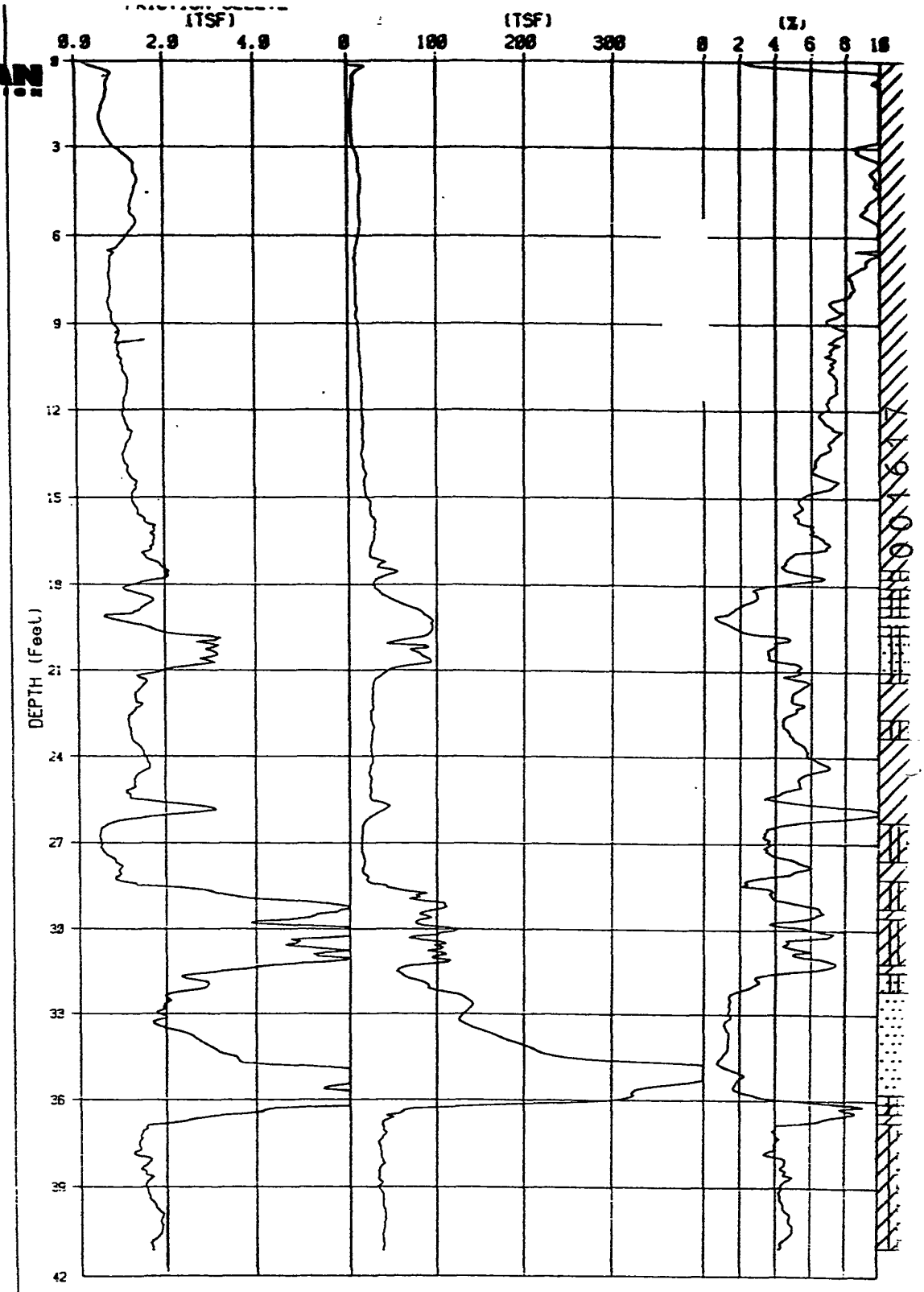


JOB NUMBER . 88-0022 CPT NUMBER : C-9 DATE : 03-01-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

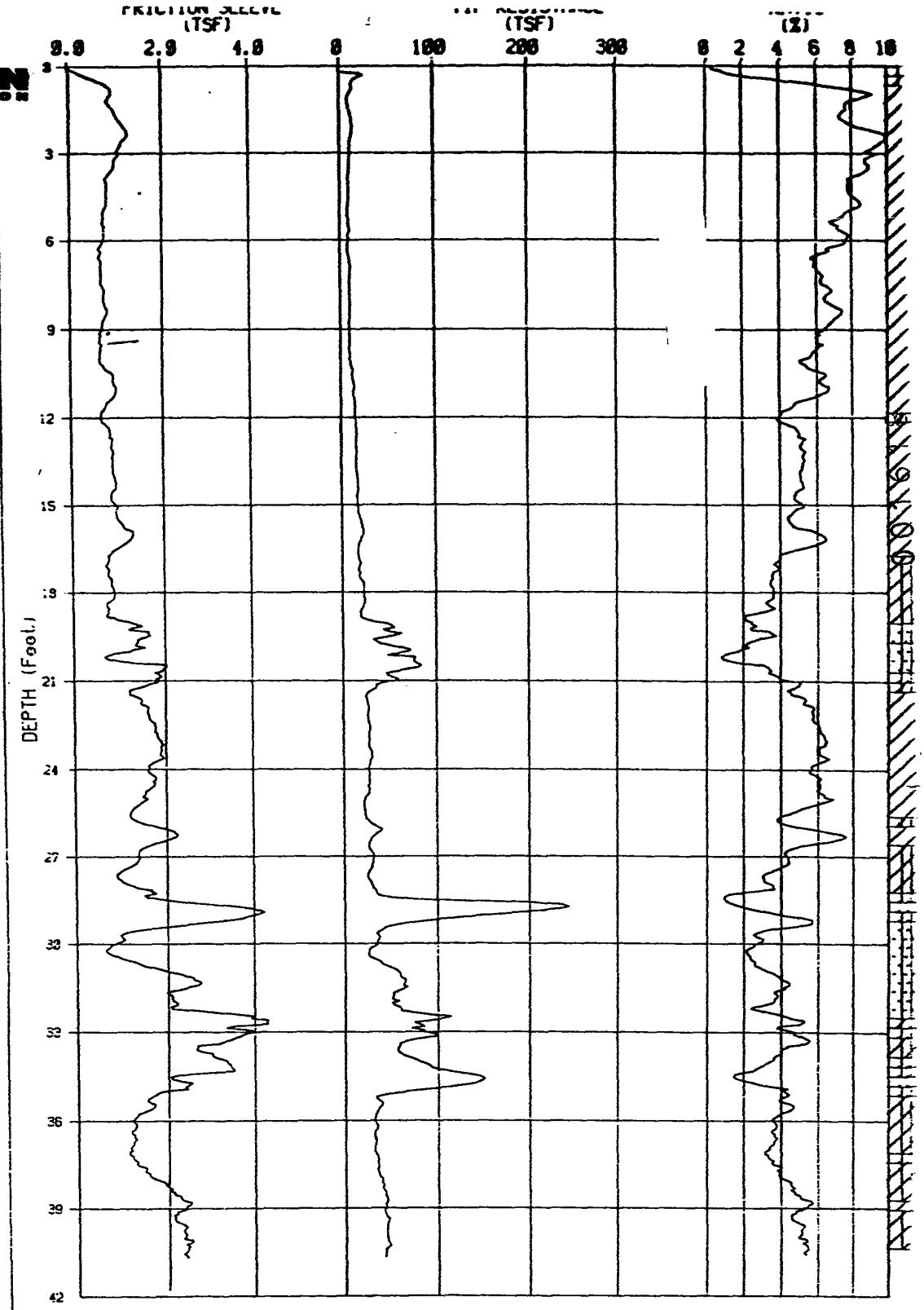


JOB NUMBER : 88-0022 CPT NUMBER : C-10 DATE : 03-01-1988

ELEVATION : 0.00 CONE NUMBER: FSCKE370

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

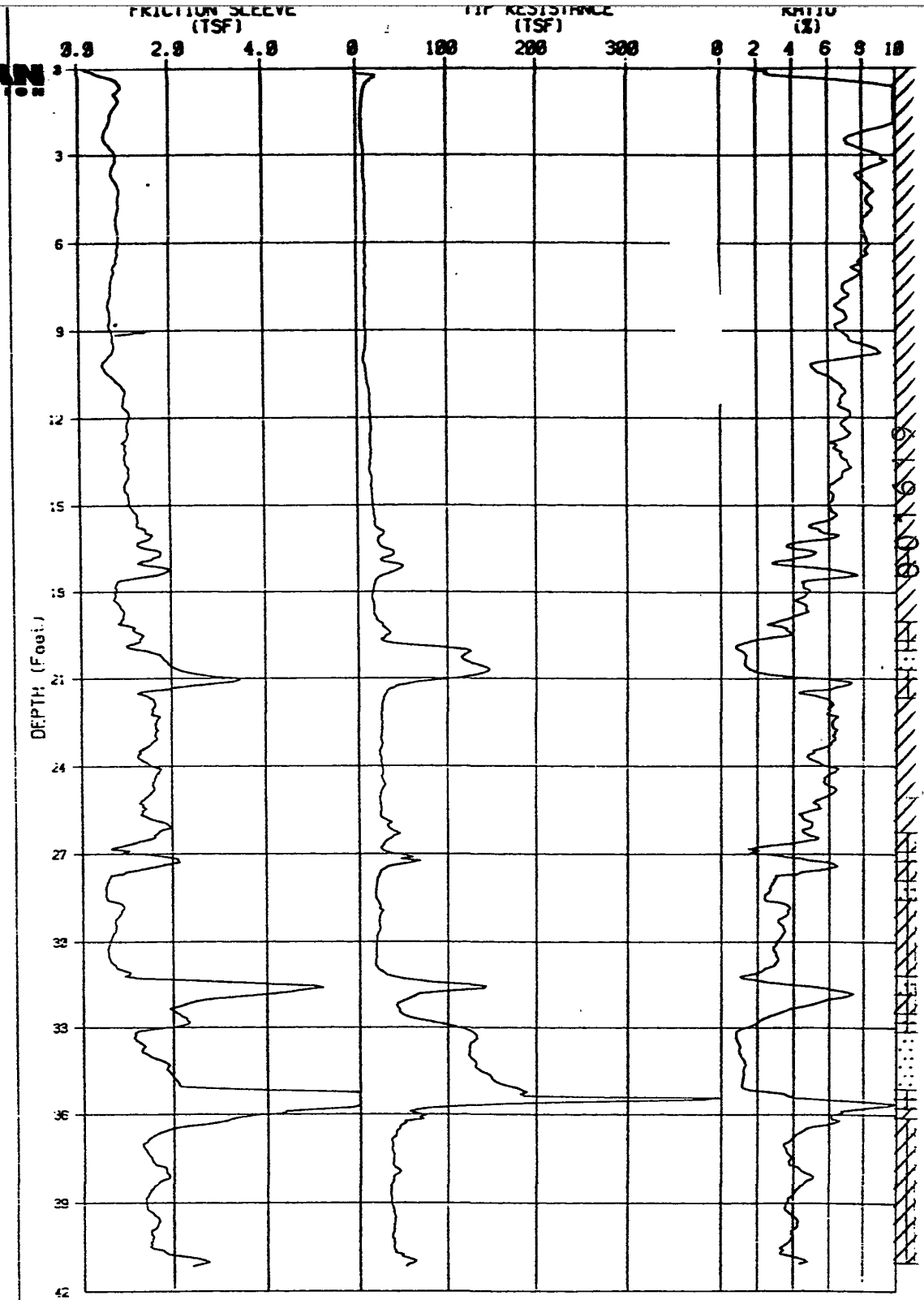


JOB NUMBER . 98-0022 CPT NUMBER : C-11 DATE . 03-16-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

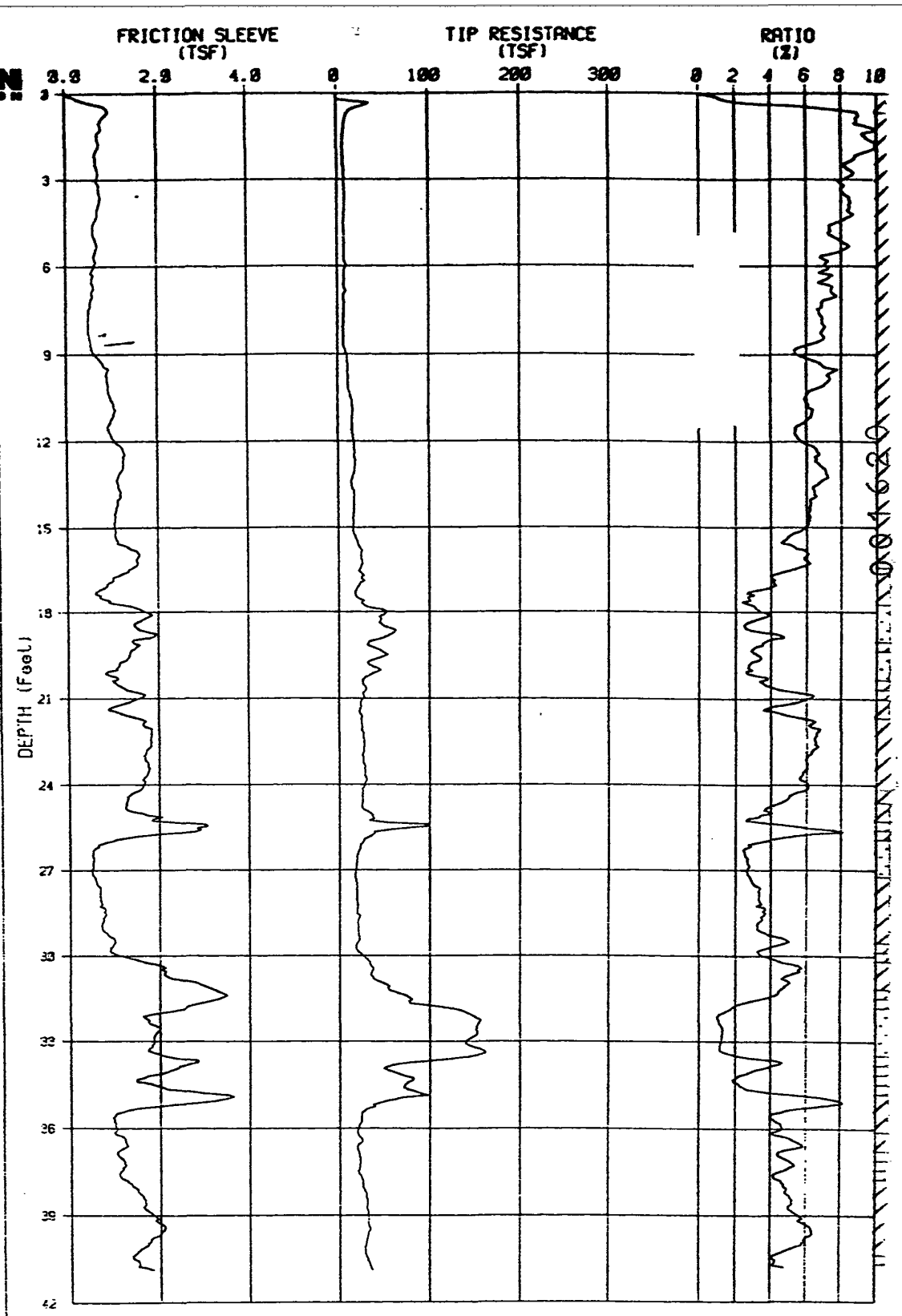


JOB NUMBER : 88-0022 CPT NUMBER : C-12 DATE : 03-16-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION



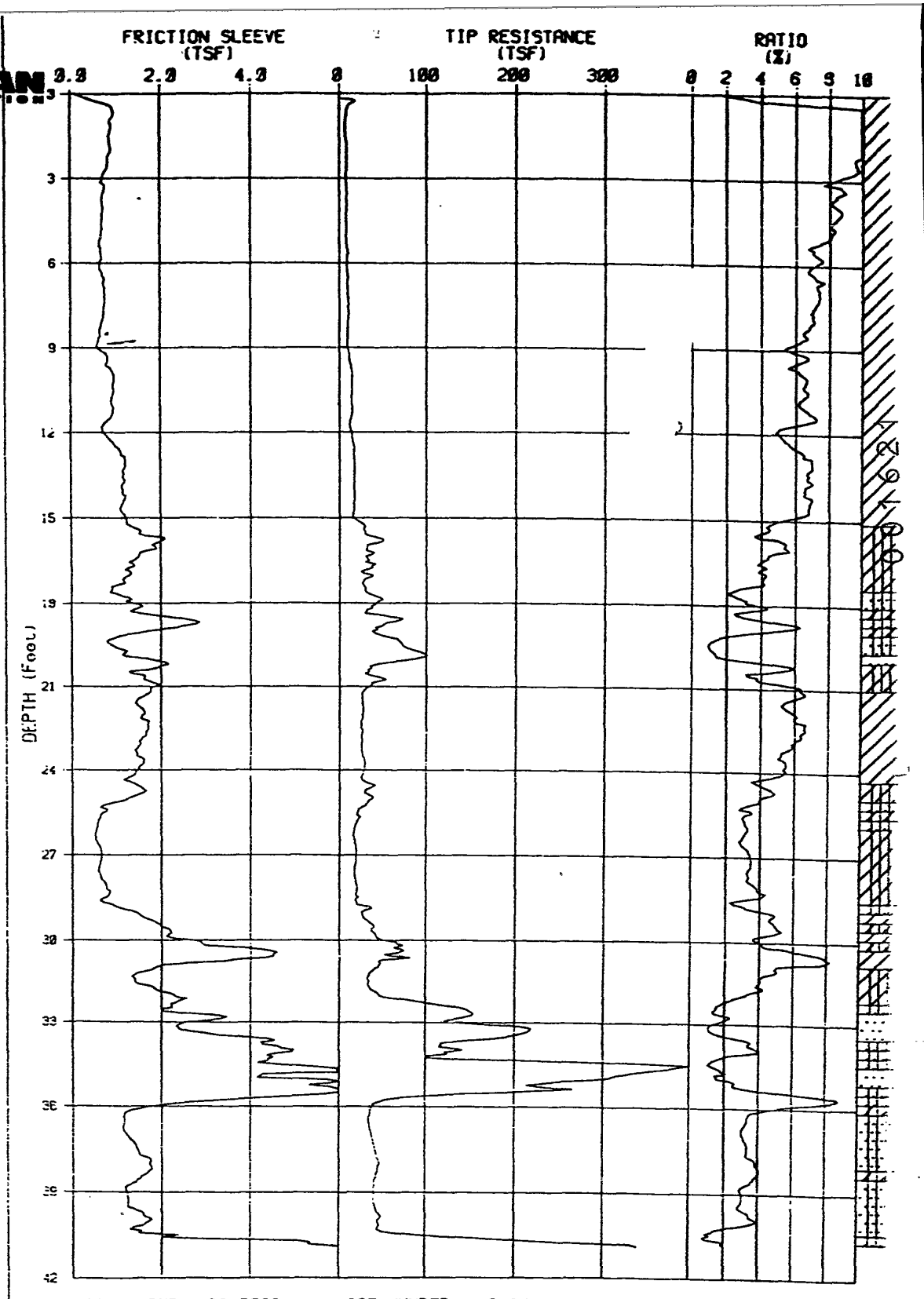
JOB NUMBER . 88-0022 CPT NUMBER . C-13 DATE . 03-16-1988

ELEVATION . 0.00 CONE NUMBER. F5CKE365

FUGRO GEOSCIENCES, INC

001620

RADIAN CORPORATION

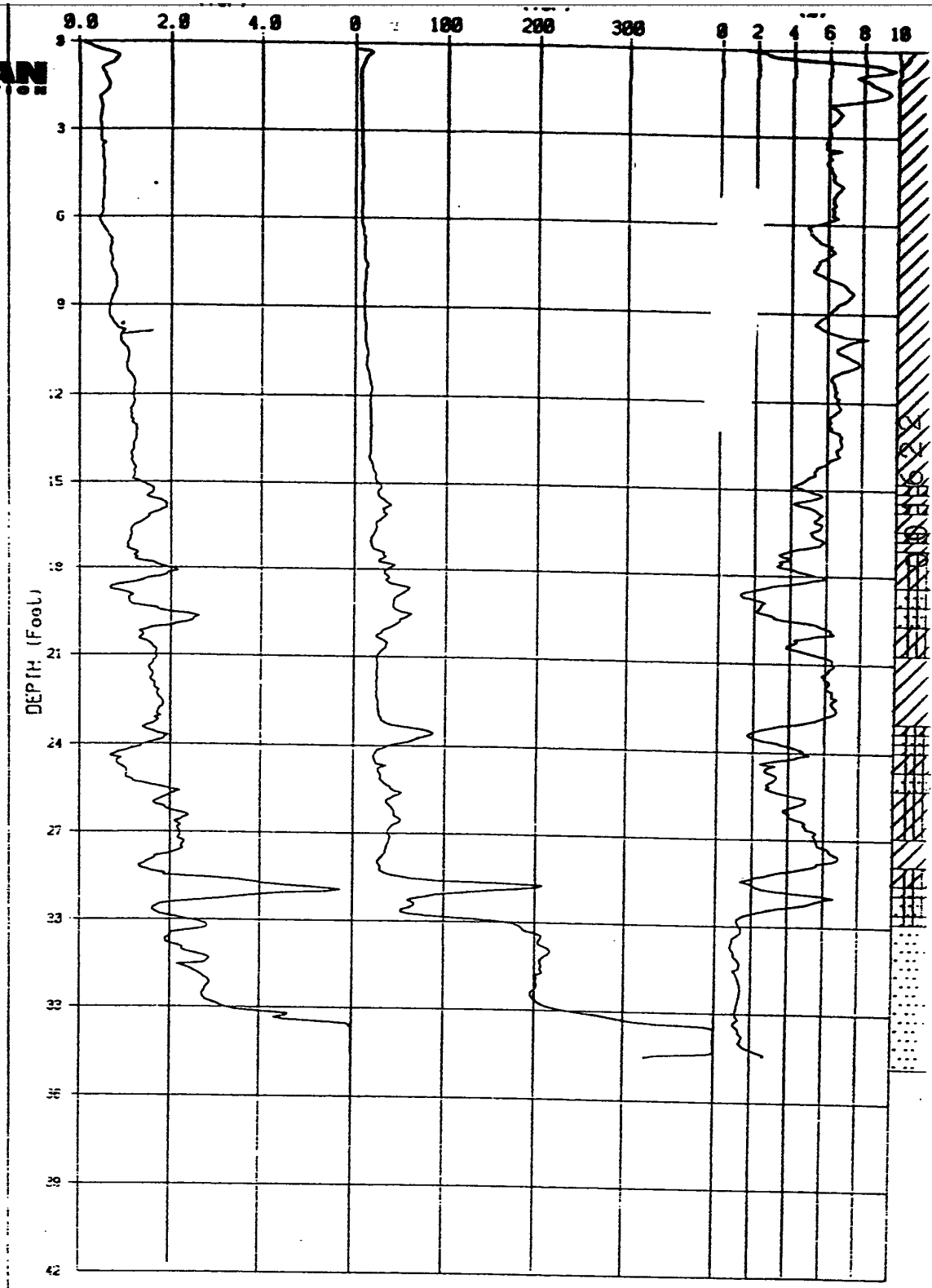


JOB NUMBER : 88-0022 CPT NUMBER : C-14 DATE : 03-16-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

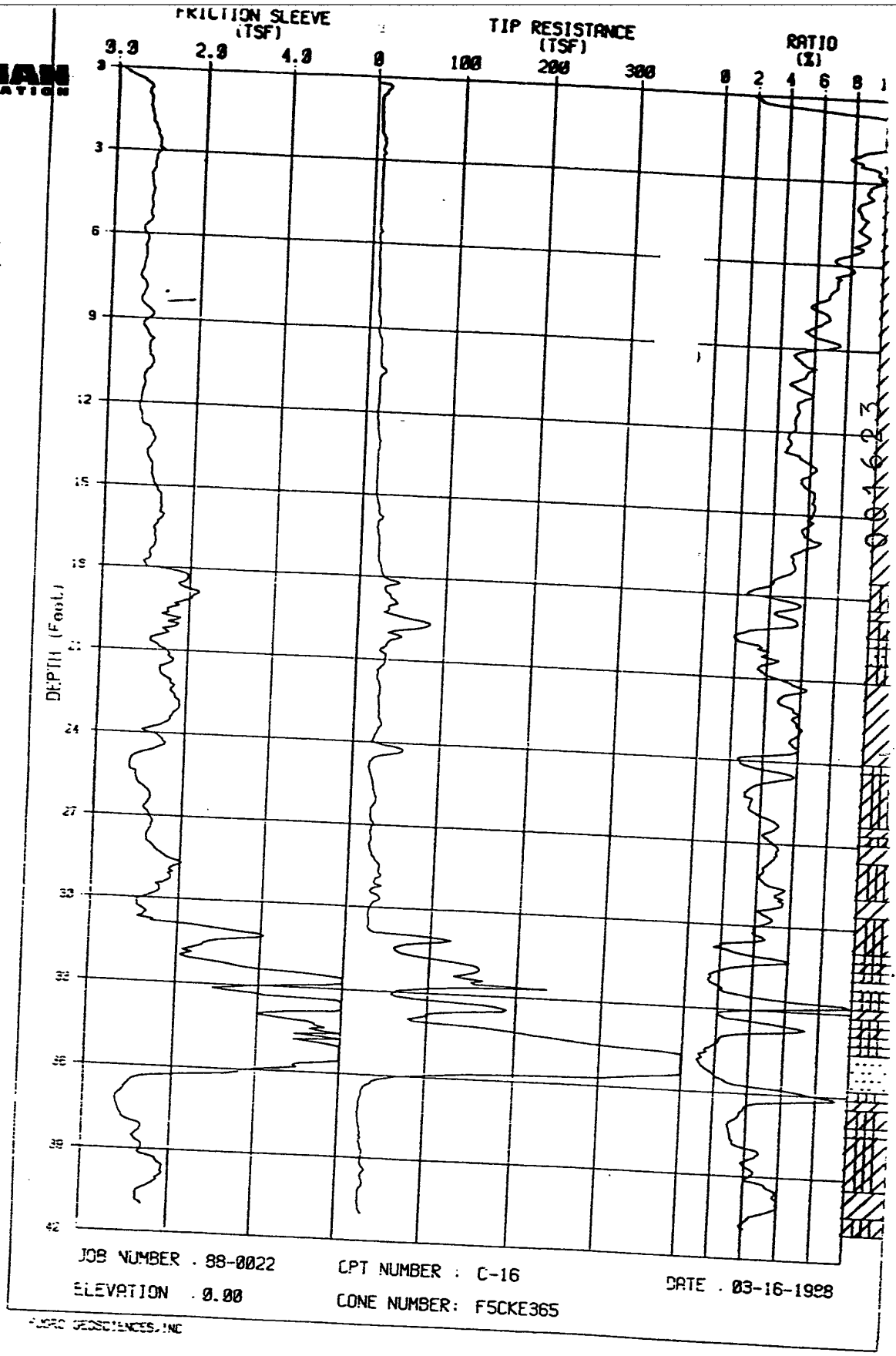


JOB NUMBER . 88-0022 CPT NUMBER : C-15 DATE . 03-16-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION



JOB NUMBER . 88-0022

ELEVATION . 0.00

CPT NUMBER : C-16

CONE NUMBER: F5CKE365

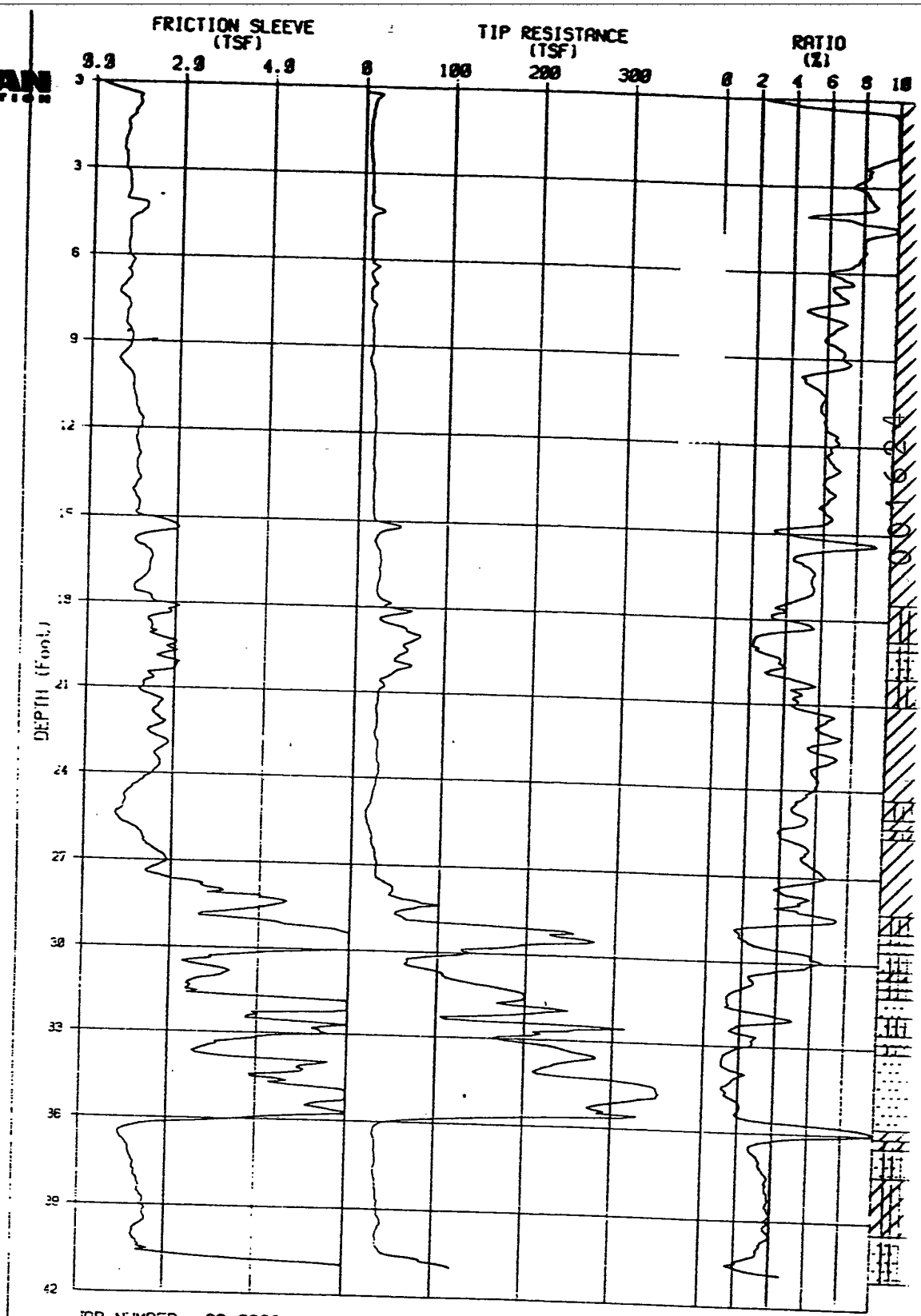
DATE . 03-16-1988

FUGRO GEOSCIENCES, INC

001623

001623

RADIAN CORPORATION

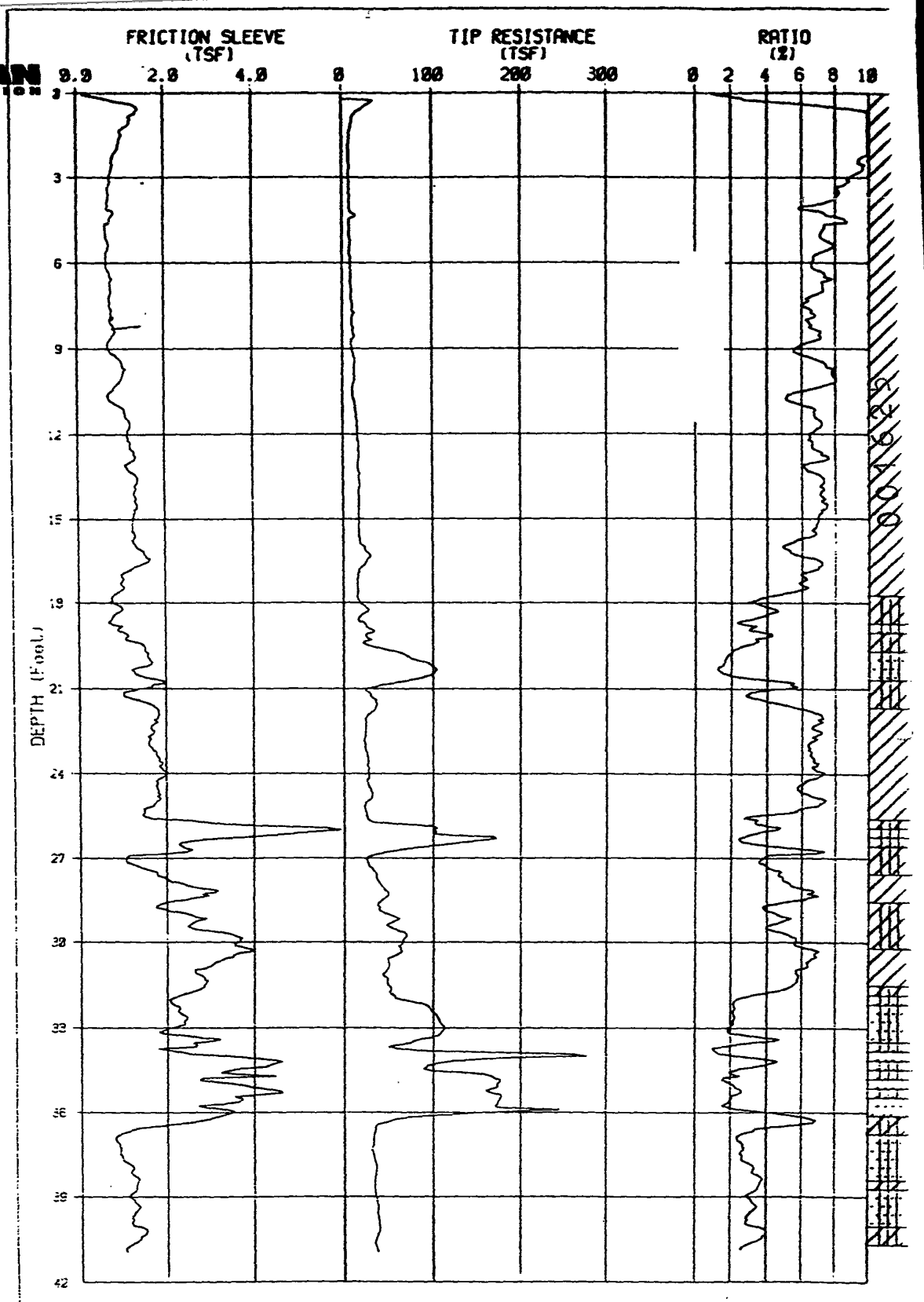


JOB NUMBER . 98-0022 CPT NUMBER . C-17 DATE . 03-16-1998

ELEVATION : 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

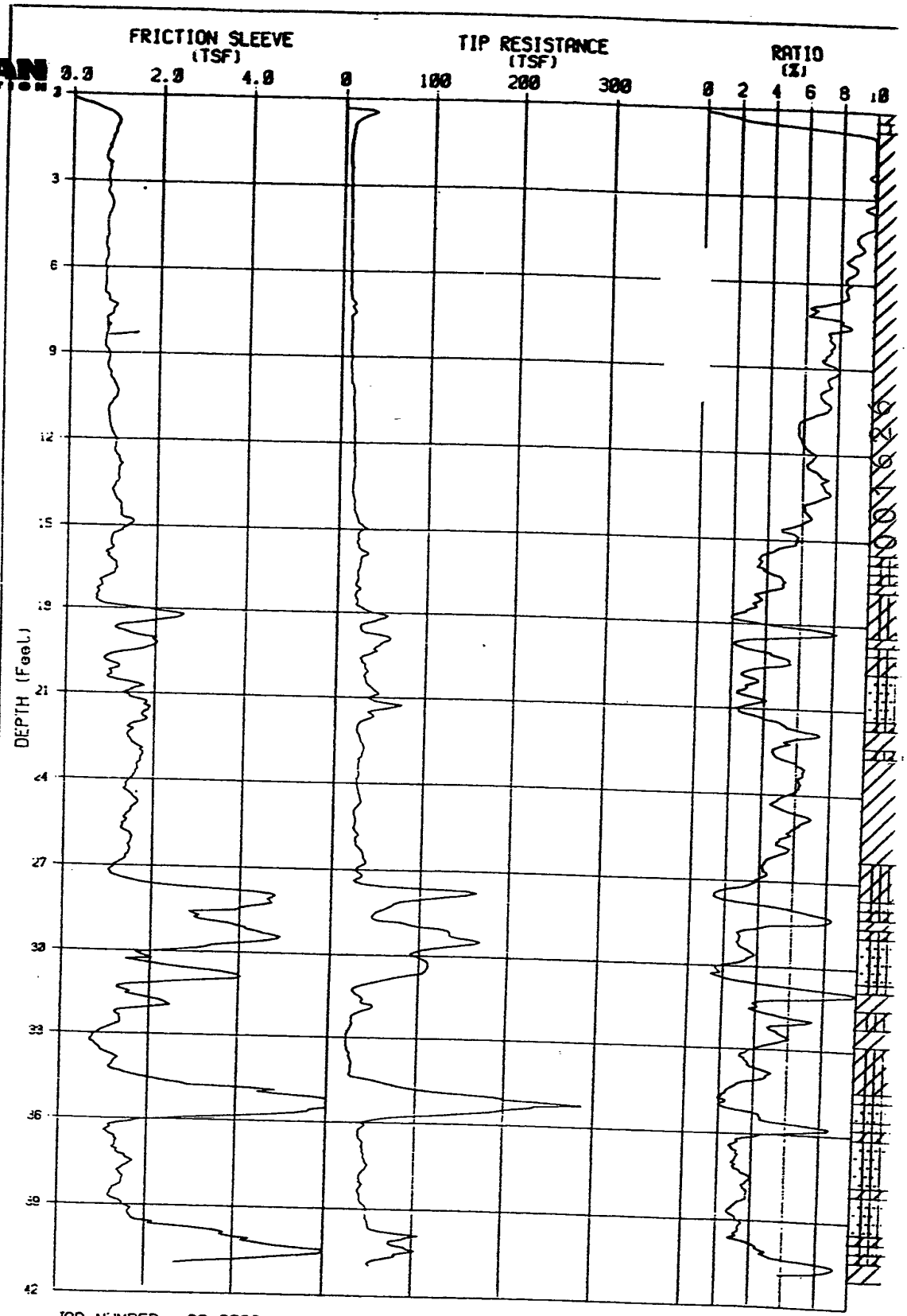
RADIAN CORPORATION



JOB NUMBER . 88-0022 CPT NUMBER . C-18 DATE . 03-16-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE365

RADIAN CORPORATION

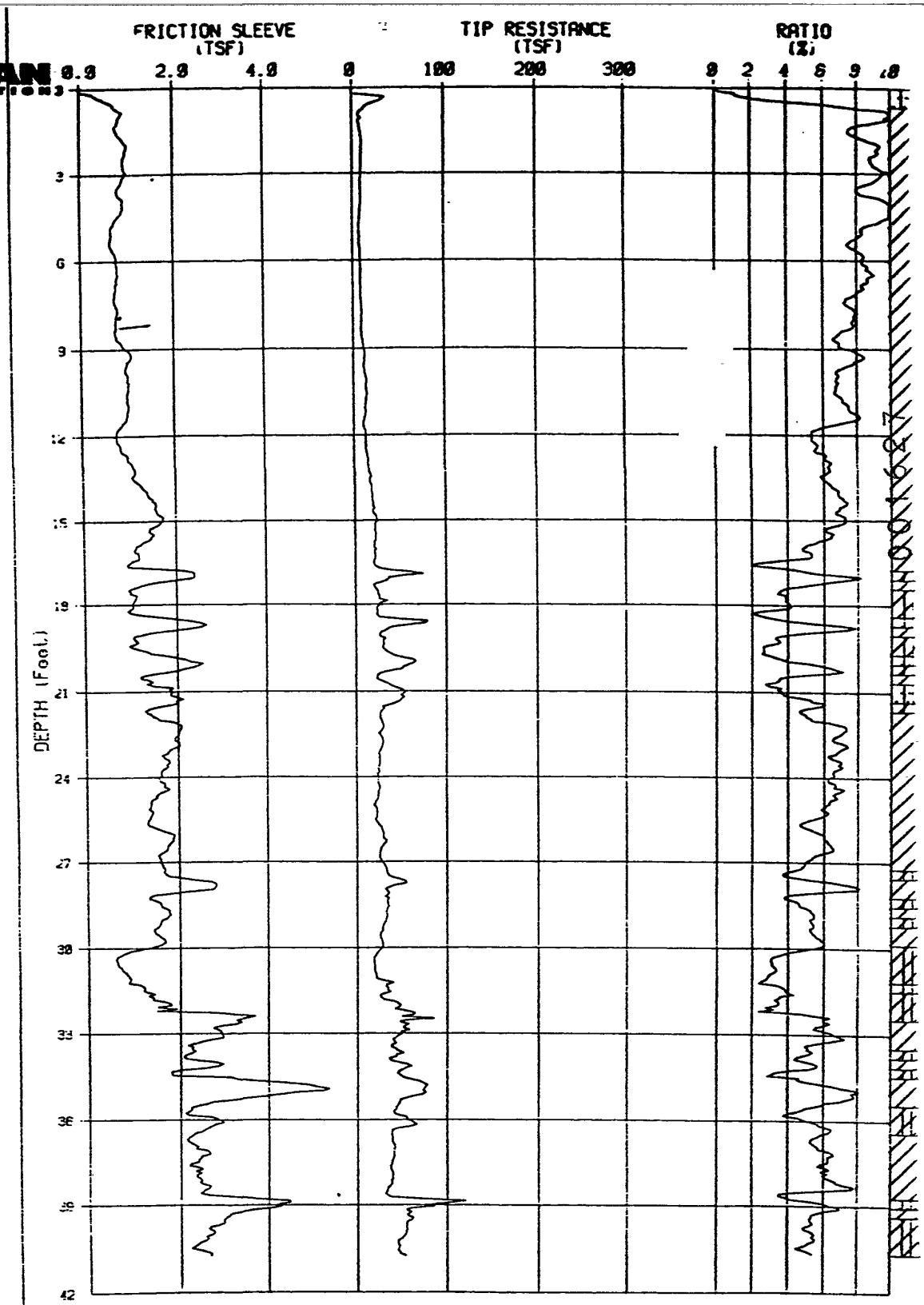


JOB NUMBER . 88-0022 CPT NUMBER . C-19 DATE . 03-16-1988

ELEVATION . 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION



JOB NUMBER : 88-0022 CPT NUMBER : C-20 DATE : 03-16-1988

ELEVATION : 0.00 CONE NUMBER: F5CKE365

FUGRO GEOSCIENCES, INC

RADIAN CORPORATION

APPENDIX F

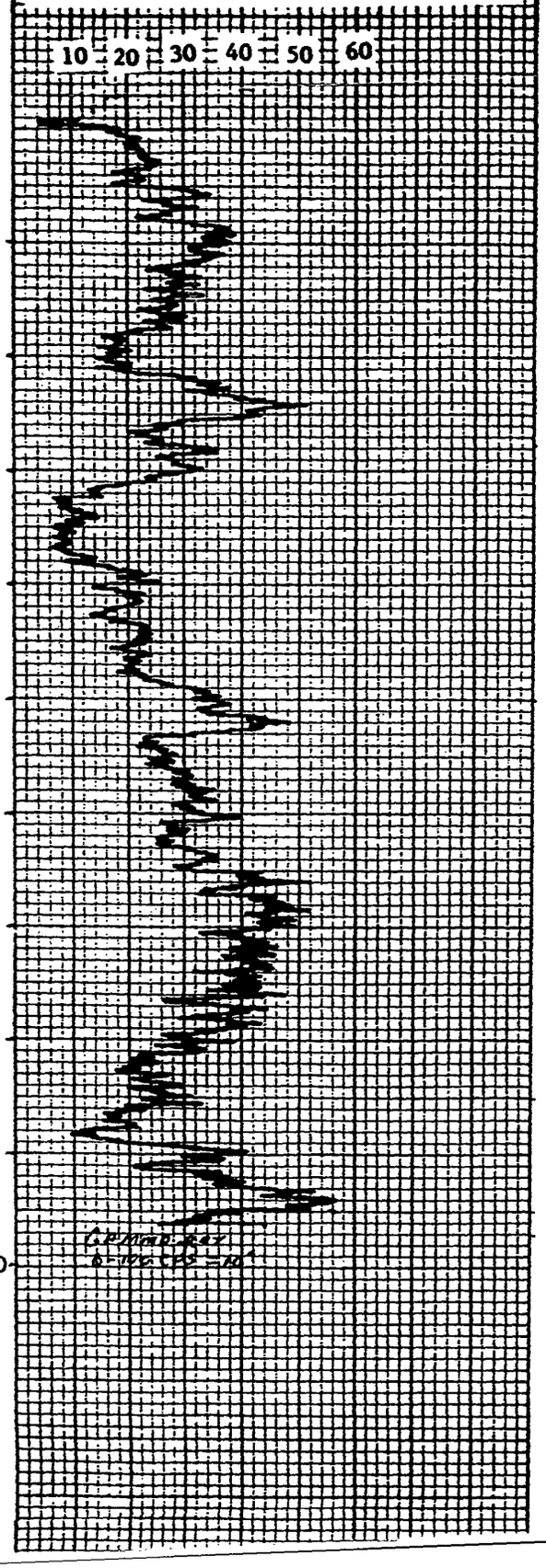
GAMMA RAY LOGS

001628

MONITOR WELL 8

RADIAN CORPORATION

GAMMA RAY LOG SCALE
(100 counts per second=10 inches)



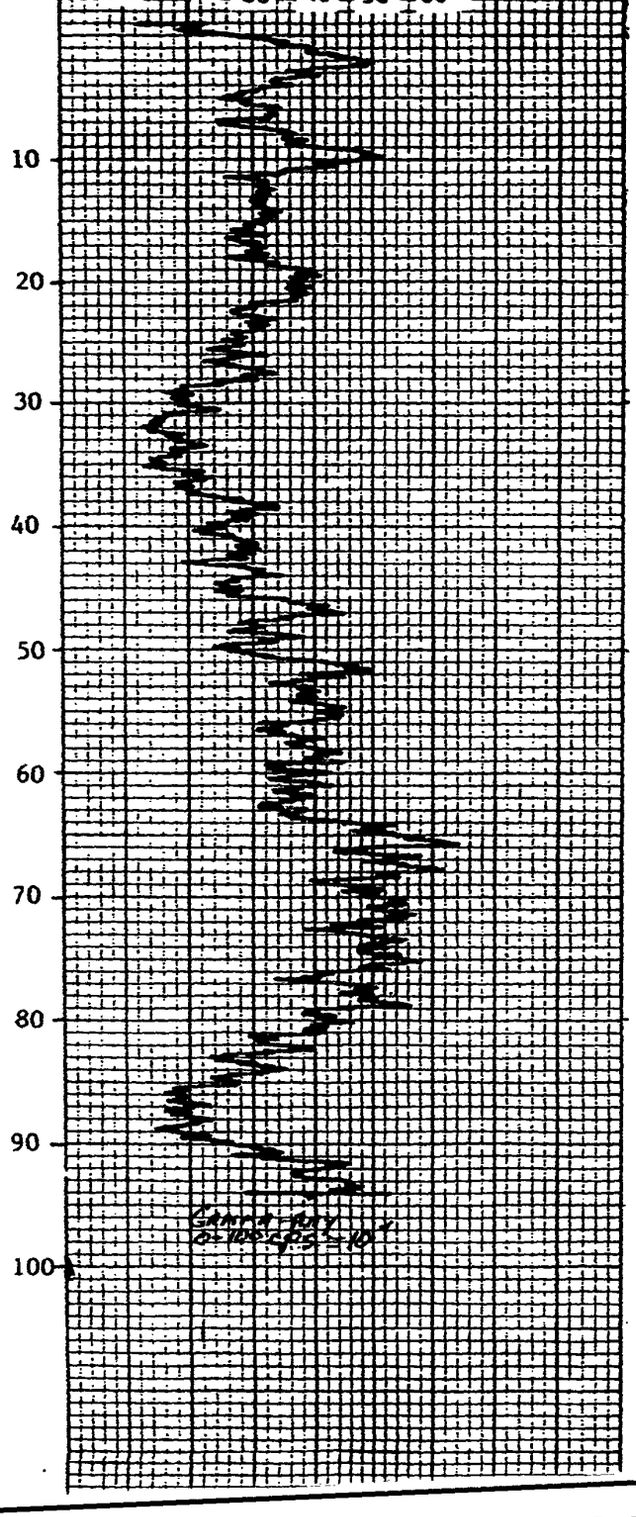
001629

RADIAN CORPORATION

MONITOR WELL 9

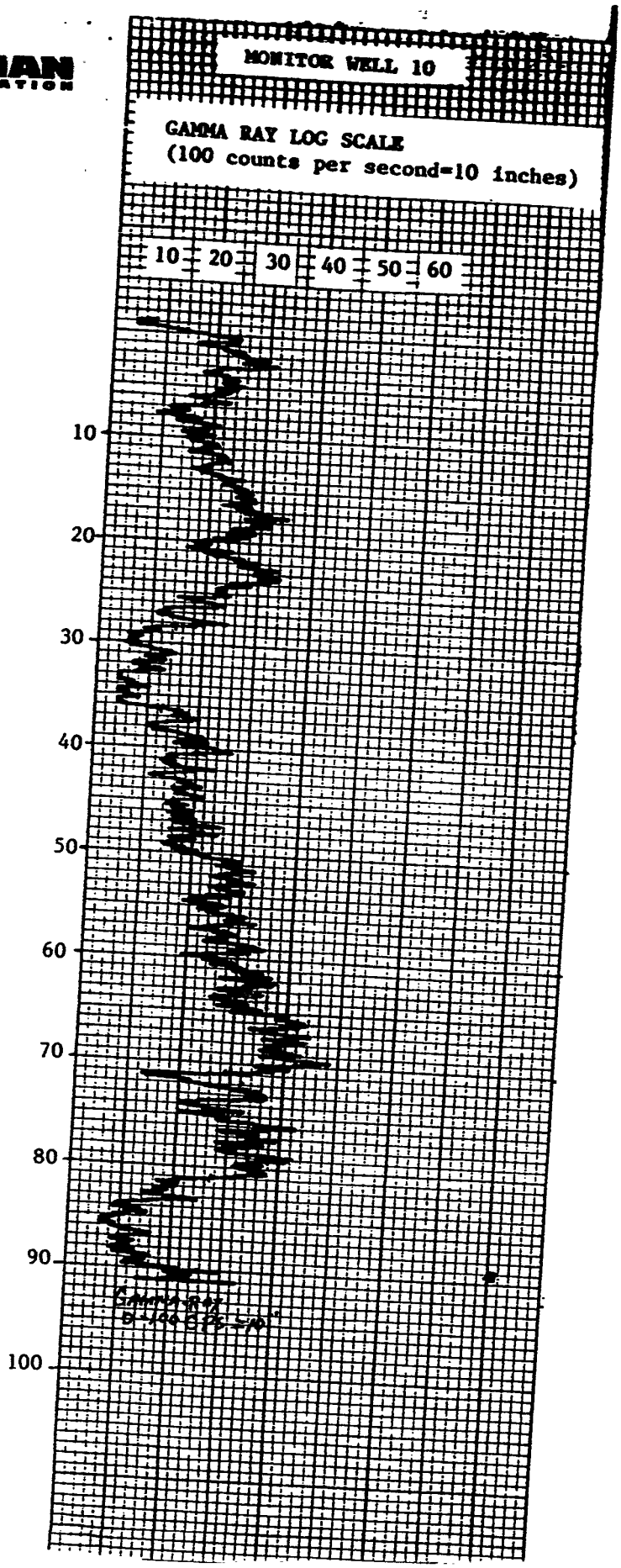
GAMMA RAY LOG SCALE

(100 counts per second=10 inches)



001630

RADIAN CORPORATION



001631

RADIAN CORPORATION

APPENDIX G-1

DETERMINATION OF HYDRAULIC CONDUCTIVITY

001632

RADIAN CORPORATION

Falling Head Test Data
MW-8

Distance from ground level to "new" static water level	21.27'
Distance from top of "new" static water level to "original" static water level	4.65'
Bottom of aquifer and screen	96'
Height of water column before start of test	74.73'

$H = D = 74.73$ ft (896.76 in)

$r_w = 3$ in

$r_c = 1$ in

$L = 10$ ft (120 in)

$Y_o = 4.65$ ft (55.8 in)

$Yt = 22.56$ in.

001633

RADIAN CORPORATION

Hydraulic Conductivity Calculation for MW-8

$$\ln Re/rw = \left(\frac{1.1}{\ln(H/rw)} + \frac{c}{L/rw} \right)^{-1}$$

$$= \left(\frac{1.1}{\ln(896.76 \text{ in}/3 \text{ in})} + \frac{2.45}{120 \text{ in}/3 \text{ in}} \right)^{-1}$$

$$= \left(\frac{1.1}{\ln(298.92 \text{ in})} + 0.06125 \right)^{-1}$$

$$= \left(\frac{1.1}{5.70} + 0.06125 \right)^{-1}$$

$$= (0.192 + 0.06125)^{-1}$$

$$= (0.254)^{-1}$$

$$K = \frac{r_c^2 \ln(Re/rw)}{2L} \frac{1}{t} \ln(Y_o/Y_t)$$

$$= \frac{(1 \text{ in})^2 * 3.933}{2\ (120 \text{ in})} \frac{1}{330} \ln\left(\frac{55.8 \text{ in}}{22.56 \text{ in}}\right)$$

$$= (0.0163)(0.0030)(0.905)$$

$$= 0.0000443 = 4.43 * 10^{-5} \text{ in/sec}$$

$$= 4.43 * 10^{-5} \text{ in/sec} * \frac{1 \text{ ft}}{12\text{in}} * \frac{3600 \text{ sec}}{\text{hour}} * \frac{24 \text{ hr}}{\text{day}}$$

$$= 0.318 \text{ ft/day}$$

001634

RADIAN CORPORATION

Hydraulic Conductivity Calculation for MW-9

$$\ln Re/rw = \frac{1.1}{\ln(H/rw)} + \frac{c}{L/rw}^{-1}$$

$$= \frac{1.1}{\ln(852.36\ in/3\ in)} + \frac{2.45}{120\ in/3\ in}^{-1}$$

$$= \frac{1.1}{\ln(284.12\ in)} + 0.06125^{-1}$$

$$= \frac{1.1}{5.649} + 0.06125^{-1}$$

$$= (0.194 + 0.06125)^{-1}$$

$$= 3.906$$

$$K = \frac{r_c^2 \ln(Re/rw)}{2L} \frac{1}{} \ln(Y_o/Y_t)$$

$$= \frac{(1\ in)^2 * 3.906}{2\ (120\ in)} \frac{1}{300} \ln \frac{42.24\ in}{5.4\ in}$$

$$= (0.0162)(0.0033)(2.056)$$

$$= 0.000109\ in/sec = 1.09 * 10^{-4}\ in/sec$$

$$= 1.09 * 10^{-4}\ in/sec * \frac{1\ ft}{12in} * \frac{3600\ sec}{hour} * \frac{24\ hr}{day}$$

$$= 0.784\ ft/day$$

001635

RADIAN CORPORATION

Falling Head Test Data
MW-9

Distance from ground level to "new" static water level	22.97'
Distance from top of "new" static water level to "original" static water level	3.52'
Bottom of aquifer and screen	94'
Height of water column before start of test	71.03'

$H = D = 71.03$ ft (852.36 in)

$r_w = 3$ in

$r_c = 1$ in

$L = 10$ ft (120 in)

$Y_o = 3.52$ ft (42.24 in)

$Yt = 5.4$ in.

001636

RADIAN CORPORATION

Falling Head Test Data
MW-10

Distance from ground level to "new" static water level	22.49'
Distance from top of "new" static water level to "original" static water level	4.42'
Bottom of aquifer and screen	93'
Height of water column before start of test	70.51'

$H = D = 70.51$ ft (846.12 in)

$r_w = 3$ in

$r_c = 1$ in

$L = 10$ ft (120 in)

$Y_o = 4.42$ ft (53.04 in)

$Yt = 4.32$ in.

001637

RADIAN CORPORATION

Hydraulic Conductivity Calculation for MW-10

$$\ln Re/rw = \left(\frac{1.1}{\ln(H/rw)} + \frac{c}{L/rw} \right)^{-1}$$

$$= \left(\frac{1.1}{\ln(846.12 \text{ in}/3 \text{ in})} + \frac{2.45}{120 \text{ in}/3 \text{ in}} \right)^{-1}$$

$$= \left(\frac{1.1}{\ln(282.04 \text{ in})} + \frac{2.45}{40} \right)^{-1}$$

$$= \left(\frac{1.1}{5.642} + 0.06125 \right)^{-1}$$

$$= (0.194 + 0.06125)^{-1}$$

$$= 3.902$$

$$K = \frac{r_c^2 \ln(Re/rw)}{2L} \frac{1}{t} \ln(Y_o/Y_t)$$

$$= \frac{(1 \text{ in})^2 * 3.902}{2(120 \text{ in})} \frac{1}{330} \ln\left(\frac{53.04 \text{ in}}{4.32 \text{ in}}\right)$$

$$= (0.0162)(0.0030)(2.507)$$

$$= 0.0001218 \text{ in/sec} = 1.21 * 10^{-4} \text{ in/sec}$$

$$= 1.21 * 10^{-4} \text{ in/sec} * \frac{1 \text{ ft}}{12\text{in}} * \frac{3600 \text{ sec}}{\text{hour}} * \frac{24 \text{ hr}}{\text{day}}$$

$$= 0.87 \text{ ft/day}$$

001638

RADIAN CORPORATION

APPENDIX G-2
DETERMINATION OF STATIC WATER LEVELS

Shallow Monitor Wells

Well Identification	Top of Casing Elevation Above M.S.L. (feet)	Distance to Water Level (feet)	Elevation of Groundwater Above M.S.L. (feet)
Date of Measurement: 1-27-88			
MW-1	50.02	10.45	39.57
MW-2	49.70	9.27	40.43
MW-4	48.70	8.55	40.15
MW-5	49.49	8.72	40.77
MW-6	51.29	10.59	40.7
MW-7	50.33	9.479	40.85
Date of Measurement: 2-22-88			
MW-1	50.02	10.76	39.26
MW-2	49.70	9.76	39.94
MW-3	48.70	9.03	39.67
MW-5	49.49	9.25	40.24
MW-6	51.29	11.07	40.22
MW-7	50.33	9.94	40.39
Date of Measurement: 3-22-88			
MW-1	50.02	9.52	40.50
MW-2	49.70	8.72	40.98
MW-4	48.70	8.02	40.68
MW-5	49.49	7.99	41.5
MW-6	51.29	9.84	41.45
MW-7	50.33	8.64	41.69
Date of Measurement: 4-8-88			
MW-1	50.02	9.46	40.56
MW-2	49.70	8.22	41.48
MW-4	48.70	7.49	41.21
MW-5	49.49	7.56	41.93
MW-6	51.29	9.41	41.88
MW-7	50.33	8.18	42.15

RADIAN CORPORATION

APPENDIX G-2
DETERMINATION OF STATIC WATER LEVELS
(Continued)

Intermediate Monitor Wells

Well Identification	Top of Casing Elevation Above M.S.L. (feet)	Distance to Water Level (feet)	Elevation of Groundwater Above M.S.L. (feet)
Date of Measurement: 4-6-88			
MW-8	50.05	27.92	22.13
MW-9	47.97	26.48	21.49
MW-10	49.55	27.21	22.34
Date of Measurement: 4-25-88			
MW-8	50.05	28.03	22.02
MW-9	47.97	26.58	21.39
MW-10	49.55	29.2	20.35
Date of Measurement: 7-8-88			
MW-8	50.05	28.60	21.45
MW-9	47.97	27.15	20.82
MW-10	49.55	29.75	19.8

RADIAN CORPORATION

APPENDIX G-3

CALCULATION OF HYDRAULIC GRADIENT

001641

RADIAN CORPORATION

APPENDIX G-3
CALCULATION OF HYDRAULIC GRADIENT

Procedure:

- Static water levels were posted for all monitor wells at the ITS site;
- Flow lines were interpolated between all monitor wells;
- The difference in static water levels between MW-4 and MW-6 was calculated;
- The distance perpendicular to flow lines running through MW-4 and MW-6 was measured;
- The difference in static water level was divided by the distance perpendicular to flow lines running through each of the two locations; and
- This calculation was performed on each of 4 sets of water level measurements (uppermost water-bearing zone) and three sets of the intermediate water-bearing zone.

001642

Calculations: uppermost water-bearing zone

1/27/88: 0.62 ft/181.25 ft = 0.0034 ft/ft
2/22/88: 0.57 ft/181.25 ft = 0.0031 ft/ft
3/22/88: 0.82 ft/181.25 ft = 0.0045 ft/ft
4/08/88: 0.72 ft/181.25 ft = 0.0039 ft/ft

$$\text{Average} = \frac{0.0034\ \text{ft/ft} + 0.0031\ \text{ft/ft} + 0.0045\ \text{ft/ft} + 0.0039\ \text{ft/ft}}{4}$$

= 0.0149 ft/ft / 4
= 0.0037 ft/ft

Calculation: intermediate water-bearing zone

4/07/88: 0.64 ft/75 ft = 0.0085 ft/ft
4/25/88: 1.67ft/200 ft = 0.0083 ft/ft
7/08/88: 1.65ft/200 ft = 0.0082 ft/ft

$$\text{Average} = \frac{0.0085\ \text{ft/ft} + 0.0083\ \text{ft/ft} + 0.0082\ \text{ft/ft}}{3}$$

= 0.025 ft/ft / 3
= 0.0083 ft/ft

RADIAN CORPORATION

APPENDIX G-4
GROUNDWATER VELOCITY CALCULATIONS

001643

RADIAN CORPORATION

APPENDIX G-4
GROUNDWATER VELOCITY CALCULATIONS

Formula:

$$V = \frac{-K \ \Delta h/\Delta l}{n}$$

Where:

V	=	Velocity
-K	=	Hydraulic conductivity, feet/day
$\Delta h/\Delta l$	=	Hydraulic gradient
n	=	Porosity

Uppermost Water-Bearing Zone

MW-1: V = -0.632 ft/day * 0.0037 ft/ft * 365 days/yr = |0.85| ft/yr

V/n = |0.85| ft/yr ÷ 0.30 = 2.83 ft/yr

MW-2: V = -2.03 ft/day * 0.0037 ft/ft * 365 days/yr = |2.74| ft/yr

V/n = |2.74| ft/yr ÷ 0.30 = 9.13 ft/yr

MW-4 V = -0.87 ft/day * 0.0037 ft/ft * 365 days/yr = |1.17| ft/yr

V/n = |1.17| ft/yr ÷ 0.30 = 3.9 ft/yr

MW-5 V = -0.82 ft/day * 0.0037 ft/ft * 365 days/yr = |1.10| ft/yr

V/n = |1.10| ft/yr ÷ 0.30 = 3.66 ft/yr

MW-6 V = -1.6 ft/day * 0.0037 ft/ft * 365 days/yr = |2.16| ft/yr

V/n = |2.16| ft/yr ÷ 0.30 = 7.20 ft/yr

MW-7 V = -1.45 ft/day * 0.0037 ft/ft * 365 days/yr = |1.95| ft/yr

V/n = |1.95| ft/yr ÷ 0.30 = 6.52 ft/yr

001644

RADIAN CORPORATION

Intermediate Water-Bearing Zone

MW-8 V = -0.31 ft/day * 0.0083 ft/ft * 365 days/yr = |0.93| ft/yr

V/n = |0.93| ft/yr ÷ 0.30 = 3.1 ft/yr

MW-9 V = -0.78 ft/day * 0.0083 ft/ft * 365 days/yr = |2.36| ft/yr

V/n = |2.36| ft/yr ÷ 0.30 = 7.87 ft/yr

MW-10 V = -0.87 ft/day * 0.0083 ft/ft * 365 days/yr = |2.63| ft/yr

V/n = |2.63| ft/yr ÷ 0.30 = 8.78 ft/yr