DOE/OR/21548-014

United States Department Of Energy

GEOPHYSICAL/GEOTECHNICAL INVESTIGATION SAMPLING PLAN

REV. 1

WELDON SPRING SITE REMEDIAL ACTION PROJECT

GEOPHYSICAL/GEOTECHNICAL INVESTIGATION SAMPLING PLAN

U.S. DEPARTMENT OF ENERGY

WSSRAP

JULY, 1988

REV. 1

TABLE OF CONTENTS

Section	Title	Page
1.0	INTRODUCTION	1
1.1	Purpose and Scope of Plan	1
1.2	Relevant Site History	2
1.3	Evaluation of Previous Studies	3
1.3.1	Background	3
1.3.2	Geotechnical Investigations	5
1.3.2.1	U.S. Army Corps of Engineers (1955)	6
1.3.2.2	Henry M. Reitz (1964)	9
1.3.2.3	Bechtel National, Inc. (1984)	12
1.3.2.4	Bechtel National, Inc. (1987)	19
1.3.3	Geophysical Surveying	23
1.3.3.1	Scope and Purpose of Surveys	25
1.3.3.2	Data Validity	32
1.3.3.3	Validity of Methods	43
1.3.3.4	Data Sufficiency	44
1.3.4	Summary	45
1.4	Justification for Further Investigations	47
1.4.1	Rationale	47
1.4.2	Disposal Facility Siting	47
1.4.3	Data Sufficiency/Validity	48
1.4.3.1	Geotechnical Drilling	48
1.4.3.2	Geotechnical Lab Testing	49
1.4.3.3	Geophysical Surveys	57
1.4.4	Data Requirements	60
1.4.5	Data Collection Methods	61
1.4.5.1	Geotechnical Drilling and Sampling	61
1.4.5.2	Geotechnical Lab Testing	63
1.4.5.3	Geophysical Surveys	63

Section	Title	Page
2.0	PROPOSED SCOPE OF WORK	65
2.1	Geotechnical Drilling	65
2.1.1	Purpose and Scope	65
2.1.2	Drilling Locations	66
2.1.3	Drilling Equipment and Methods	68
2.1.4	Drilling and Sampling Procedures	70
2.1.5	Decontamination	71
2.2	Geophysical Surveys	72
2.2.1	Purpose	72
2.2.2	Survey Layout	73
2.2.3	Geophysical Methods	74
2.2.4	Survey Techniques	77
3.0	ANALYTICAL REQUIREMENTS	78
3.1	Geotechnical Laboratory Testing	78
3.1.1	Site Soils	78
3.1.2	Laboratory Tests	79
3.2	Geophysical Surveys	84
3.2.1	Data Reduction Methods	84
3.2.2	Data Analysis	85
3.2.3	Models	86
4.0	QUALITY ASSURANCE	87
4.1	Geotechnical Drilling and Sampling	88
4.2	Geotechnical Lab Analysis	88
4.3	Geophysical Surveys	89

Section	Title	Page
5.0	DATA DOCUMENTATION	91
5.1	Geotechnical Samples	91
5.1.1	Sample Transfer/Chain-of-Custody Records	91
5.1.2	Test Records	92
5.1.3	Borehole Logs	93
5.1.4	Photographs	94
5.1.5	Calculations	95
5.2	Geophysical Surveys	95
5.2.1	Test Records	95
5.2.2	Equipment Calibration	96
5.2.3	Assumption Documentation	96
5.2.4	Computer Runs	97
5.2.5	Data Reduction and Analysis	97
5.3	Daily Logs	98
6.0	REFERENCES	99
	APPENDICES	

LIST OF TABLES

Table No.	Description	Page
1-1	Geophysical Surveys Performed at WSS	24
1-2	Purpose of Geophysical Studies at WSS	26
1-3	Correlation of Seismic, Resistivity, and Geological Results Raffinate Pit Area	40
1-4	Seismic Refraction Results, DSI (1986)	42
1-5	Applicability of Previous Site Investigations to Permanent Disposal Facility Design	46
1-6	Summary of Valid Geotechnical Test Data From Previous Studies	53
1-7	Minimum Number of Laboratory Tests Required on Foundation Materials	58
3-1	Suggested Minimum Number of Geotechnical Laboratory Tests	80

LIST OF FIGURES

Figure No.	Description	Page
1-1	Area to be Evaluated for Proposed Disposal Cell	4
1-2	Geophysical Survey Plan-Weston Geophysical Corp. (1983)	27
1-3	Geophysical Survey Plan-Weston Geophysical Corp. (1984)	28
1-4	Magnetometer and Electrical Resistivity Survey Locations-Weston Geophysical Corp.	29
1-5	Geophysical Survey Plan-Detection Sciences, Inc.	30
1-6	Terrain Conductivity Contour Map Showing Areal Limits of the Survey	31
1-7	Summary of Geophysical Data	33
1-8	Seismic Profiles Lines 1, 2, 3, 4, & 5	34
1-9	Seismic Profiles Lines 10, 11, & 12	35
1-10	Seismic Profiles Raffinate Pit No. 3 Lines 1, 2, & 3	38
1-11	Seismic Profiles A and B (Plate 2)	41
2-1	Tentative Boring Locations and Geophysical Lines	67

APPENDICES

Appendix	Description
A	Summary of Valid Data from Previous Investigations
B	Specifications WP024-01 and WP024-02, Geotechnical Drilling and Sampling Characterization
C	Addendum No. 01 to WP024
D	Specification WP028, Geotechnical Investigation
E	Addenda Nos. 01 and 02 to WP028
F	Specification WP029, Geotechnical Laboratory Testing
G	Proposed Modification to Specification WP029
H	Specification WP091, Geotechnical Coring and Sampling
I	Environmental Chain of Custody Form
J	Work Plan-Geophysical Investigation Specification 3589-SC-WP028 Weldon Spring Site

SECTION 1

INTRODUCTION

1.0 INTRODUCTION

1.1 Purpose and Scope of Plan

This sampling plan presents a rationale and procedures for further geotechnical and geophysical investigations of the Weldon Spring Site (WSS). The proposed investigation will gather the additional data necessary to derive required geotechnical design parameters and evaluate suitability of the WSS for constructing a long-term waste disposal facility.

This document reviews data from the previous geotechnical and geophysical investigations for adequacy and sufficiency. The plan then describes additional geotechnical and geophysical investigations required to fully characterize the proposed disposal facility site.

The proposed investigation categories are:

- Surface geophysical surveys
- Geotechnical drilling and sampling
- Geotechnical laboratory testing

The surface geophysical surveys will integrate various techniques to characterize soil and bedrock units. Geotechnical drilling and sampling will provide information to correlate geophysical measurements with known subsurface conditions. The disturbed and undisturbed samples collected during geotechnical drilling will be tested for a broad range of engineering parameters. These data will be used for engineering design of the disposal facility and to demonstrate suitability of the site.

1.2 Relevant Site History

The Weldon Spring Site is located about 30 miles west of St. Louis and 14 miles southwest of St. Charles, Missouri. From 1941 to 1944 the Department of the Army operated the Weldon Spring Ordnance Works for the production of trinitrotoluene (TNT) and dinitrotoluene (DNT).

In 1956, the Atomic Energy Commission acquired approximately 205 acres of the original Weldon Spring Ordnance Works for use as a uranium feed materials plant. During plant operation (until 1966), four pits were excavated for storage of raffinate sludge from the plant.

In 1984, Bechtel National, Inc. (BNI) performed a detailed geological investigation for a long-term residual radioactive materials storage area (BNI, 1984). This investigation found that the raffinate pit area was suitable for long-term storage.

In 1986, BNI performed a hydrogeological investigation to provide information for siting a disposal facility on the 217-acre site of the former uranium feed materials plant (BNI, 1987), which appeared to be acceptable for the long-term storage of low-level radioactive and hazardous wastes. Favorable site features included:

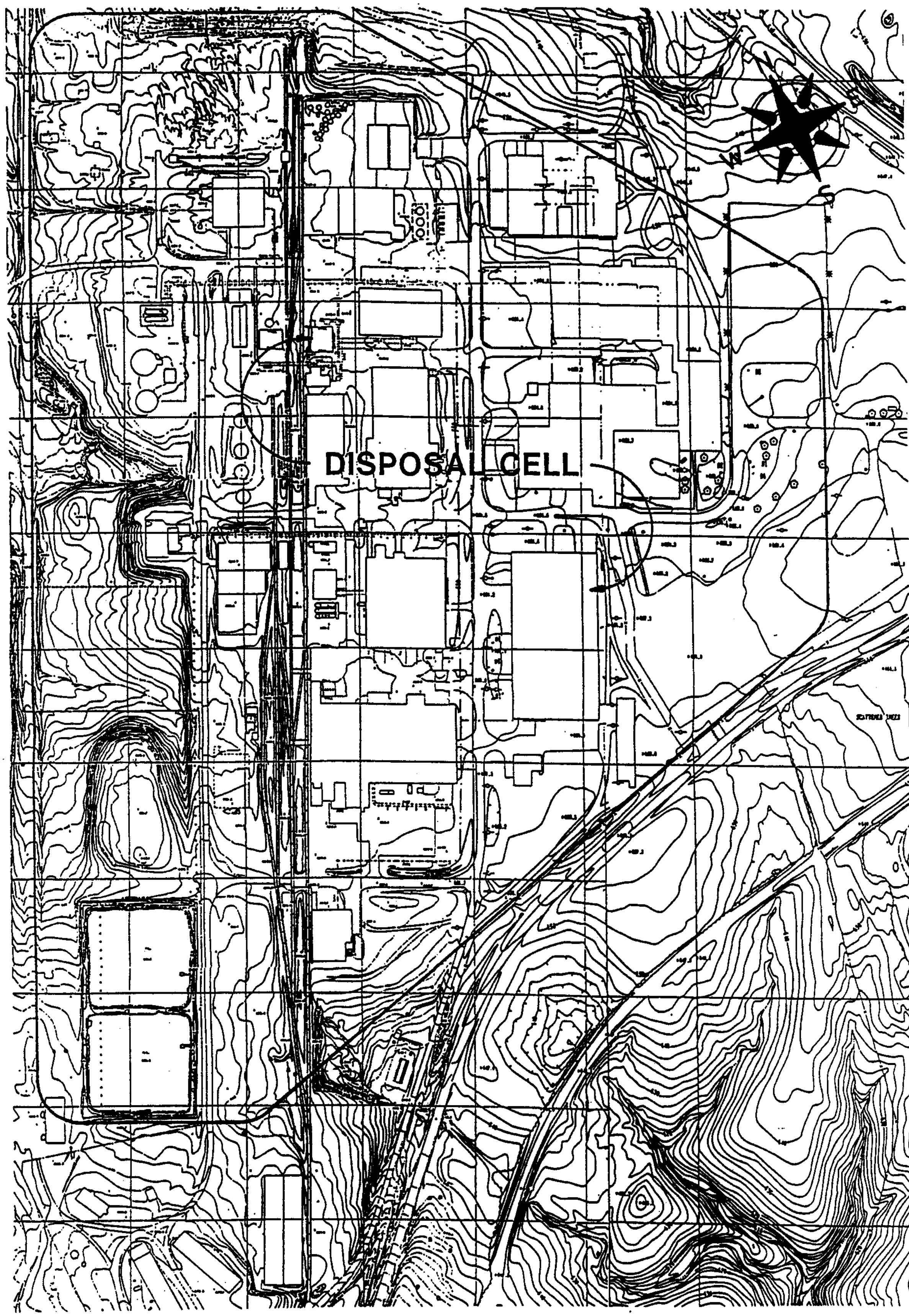
- Thick overburden
- Strong, cohesive soils
- No well developed surface drainage
- Good sorbtive soil characteristics for radionuclides
- Native soils that are stable for engineered slopes
- Proximity to wastes
- Situated on surface drainage divide

Seventy-five acres (Figure 1-1) have been selected for more detailed investigation as a disposal facility site. This area has been selected based largely on the thickness and quality of overburden soils. The 75-acre area is the subject of this plan.

1.3 Evaluation of Previous Studies

1.3.1 Background

Several investigations and geotechnical testing programs have been performed at the site. These studies included drilling, trenching, geotechnical laboratory testing, and surface geophysical surveys. These investigations were designed for purposes other than locating a disposal facility within the



REFERENCE : SURDEX CORP., 1987

FIGURE 1-1

AREA TO BE EVALUATED FOR PROPOSED DISPOSAL CELL

75-acre area and, therefore, lack sufficient detail to characterize the proposed disposal facility site.

During previous investigations, over 75 borings were drilled in the chemical plant and raffinate pit areas. These borings include test borings for construction of buildings and borings for installation of monitoring wells. In addition to borings, 21 trenches were excavated into the undisturbed soils of the raffinate pits and chemical plant areas. Soil samples were obtained and some geotechnical laboratory testing was performed. Seismic refraction, electrical resistivity, electromagnetic, and magnetometer surveys were also performed. The following sections describe these previous studies, the quality of data generated, and applicability to the current study.

1.3.2 Geotechnical Investigations

The completed geotechnical sampling studies are discussed individually. Reports evaluated include:

- U.S. Army Corps of Engineers (1955)
- Henry M. Reitz (1964)
- Bechtel National, Inc. (1984)
- Bechtel National, Inc. (1987)

1.3.2.1 U.S. Army Corps of Engineers (1955)

Investigation Purpose

Subsurface explorations were initiated by the St. Louis District, U.S. Army Corps of Engineers (COE), at Weldon Spring, Missouri under the direction of the United States Atomic Energy Commission in November 1954. The field investigation took place during November and December 1954. The final report was completed in February 1955. The purpose of the investigation was to gather geotechnical data for general foundation design work.

Drilling and Sampling Scope

A total of eight boreholes were advanced into limestone bedrock using "standard truck-mounted rotary drilling equipment." However, no depths were recorded on the boring logs, so no depth information is available. Four- or eight-inch augers were used to advance the boreholes to bedrock. It is not known whether hollow-stem or solid augers were used. Fractured rock was penetrated with a 4.75-inch roller bit.

Undisturbed soil samples were taken at two boreholes by driving 4.75-inch thin-walled Shelby tubes. At one borehole, disturbed samples were taken using a Standard Penetration Test (SPT) with a split-spoon sampler. Rock cores were obtained with NX diamond bits.

Sampling Adequacy

Standard drilling and sampling methods were used by the COE during this investigation. Augering is an acceptable means for advancing a borehole in shallow clays. Shelby tubes and split-spoons are standard equipment for taking undisturbed and disturbed samples respectively.

No information is available on the drilling or sampling procedures. Augering is a simple operation unless it is affected by adverse soil conditions such as flowing sands or caving. Since boring logs generally indicated clays and silts, the drilling method and procedures are assumed to be appropriate.

Since no information on sample recovery or sample characteristics is given in the boring logs, other sampling validity estimates must be used. Based on laboratory test results, some disturbance in the Shelby tube samples is apparent. There is no way to determine whether the disturbance resulted from sampling, sample handling, or testing procedures. Therefore, no conclusions can be drawn regarding sampling validity.

The COE boring logs were valid for the investigation though they are inadequate in content. Individual soil descriptions, sample recovery rates, intermediate and total borehole depths, and groundwater data are not reported. This incomplete record prevents a direct comparison of the COE data with subsequent site investigations.

Sampling Sufficiency

Eight boreholes were sufficient for the scope and extent of the COE foundation investigation. Each borehole was appropriately advanced to bedrock. Continuous Shelby tube sampling was done in two boreholes, and split-spoon sampling was done in one borehole.

Scope of Lab Testing

The following geotechnical laboratory tests were run on the COE samples:

LABORATORY TEST	NO. OF TESTS
Moisture content	83 (a)
Atterberg limits	15
Proctor compaction	1 (b)
Consolidation	2
Unconfined compression (undisturbed)	11
Unconfined compression (remolded)	5
Direct shear	
(CU) (consolidated-undrained)	1
(CD) (consolidated-drained)	2
(UU) (unconsolidated-undrained)	2

(a) Includes moisture tests apparently made on auger cuttings

(b) Assumed to be Standard Proctor

Data Validity

The laboratory soil tests were valid for their purpose. These results must be considered invalid for disposal cell siting, however, since results cannot be correlated with sufficient confidence to specific soil types. The Proctor compaction is the only test considered valid.

1.3.2.2 Henry M. Reitz (1964)

Investigation Purpose

In 1963, Henry M. Reitz Consulting Engineers performed investigations to determine geotechnical characteristics of soils underlying the proposed new raffinate pit. The final report for this investigation was completed in January 1964.

Drilling and Sampling Scope

A total of 12 boreholes were advanced using "mechanical" and "hand" augering equipment. Five mechanical auger borings extended to rock with borehole depths ranging from approximately 19 to 33 feet. Seven hand auger borings, with depths ranging from approximately 5 to 20 feet, were terminated within the soil overburden. No information is provided in the report on whether hollow-stem or solid augers were used. No information on sampling procedures is given.

Undisturbed soil samples were taken at three boreholes at a depth of approximately 10 feet. Disturbed samples were also taken at one of these boreholes.

Sampling Adequacy

The drilling and sampling methods were valid for the raffinate pit sludge. Their validity to disposal cell siting cannot be determined however, since no information was provided on sampling methods, sample recovery or soil characteristics.

The Reitz boring logs appear to be reasonable for their purpose, but are inadequate for current disposal cell siting needs. Sample recovery rates, depths to soil changes, and groundwater data are not reported. Also, based on limited correlation with Atterberg limits testing, it appears that some soil descriptions on the boring logs may not correspond to the Unified Soil Classification System (USCS). However, the logs do provide some useful overburden depth information.

Sampling Sufficiency

Twelve boreholes were generally adequate for the limited scope and extent of this raffinate pit investigation. The extent of sampling is not sufficient for present needs. From laboratory test data, it appears that only three undisturbed samples were retrieved. The method by which these samples were taken is not known. In addition, it cannot be determined if sufficient disturbed samples were retrieved, since no information can be found regarding this aspect of the sampling program.

Scope of Lab Testing

The following geotechnical laboratory tests were conducted on collected samples:

LABORATORY TEST	NO. OF TESTS
Moisture content	70
Atterberg limits	2
Compaction	2 (a)
Permeability	3
Vane shear strength (peak)	29 (b)
Vane shear strength (continuous)	27 (b)
Triaxial shear strength (UU-remolded)	5

(a) ASTM-D698 (Standard Proctor)

(b) Vane type, method and test procedure unknown

Data Validity

As with the 1955 Corps of Engineers investigation, test results cannot be correlated to specific soil type due to inadequate depth information reported on the boring logs. Therefore, test results must be considered invalid for disposal cell siting except for the Atterberg limit and compaction tests.

1.3.2.3 Bechtel National, Inc. (1984)

Investigation Purpose

Bechtel National, Inc. (BNI) conducted a geologic site characterization study of the raffinate pits area between December 1982 and November 1984 to:

- Define the site stratigraphy
- Describe the lithology and general conditions of each geologic unit
- Determine the existence of groundwater and how it relates to the geology

Field work was performed between December 1982 and April 1983. Laboratory soil sample testing was completed by McClelland Engineers in July 1983 and the final report was issued by BNI in November 1984.

Drilling and Sampling Scope

A total of 26 holes, with depths ranging from approximately 15 to 150 feet (average depth of about 30 feet), and 15 test pits, with depths ranging from approximately 15 to 27 feet (average depth of about 22 feet), were advanced into the overburden in the raffinate pits area. Eight-inch hollow-stem augers and NX core drilling equipment were used for the holes. A backhoe with a 3-cubic-yard bucket was used for excavating test pits.

Undisturbed Shelby tube soil samples were taken from four boreholes on the dikes that contain raffinate pits nos. 3 and 4. All other borehole soil samples were taken using split-spoon samplers. No samples were obtained from any of the test pits.

Sampling Adequacy

The drilling and sampling methods used were appropriate for the BNI site investigation. Hollow-stem augering and NX core drilling are preferred methods of drilling on a contaminated site. Shelby tubes were used to acquire undisturbed samples. The procedures used for drilling and sampling are well documented in the investigation report.

The Bechtel boring and trenching logs appear to be generally complete and adequately documented. However, descriptions of the soil in the boring logs lack detail. A "generic" soil description is used for each soil type; the identical description is repeated in all borehole logs whenever a certain soil type is encountered. Thus, localized differences were not noted giving the impression that each of the soil types is uniform throughout the area investigated. Specific and distinct descriptions are given for each soil type in the test pit logs.

Sampling Sufficiency

Borehole depths are insufficient for present needs. Only eight of the 26 boreholes extended to competent bedrock. This is inadequate to define bedrock contours or to determine overburden thickness in the area of the site to be investigated. More boreholes located at greater distances from the raffinate pits are needed to help define overall geologic structure.

The extent of sampling is not sufficient for the present requirement. Four boreholes were sampled using Shelby tubes. All of these borings were located on raffinate pit dikes. Additional Shelby tube samples are needed from boreholes situated entirely within the natural soils. Disturbed sample coverage was sufficient for the BNI investigation. Current requirements include undisturbed sample testing in addition to disturbed sample testing.

Scope of Lab Testing

The following geotechnical laboratory tests were conducted on samples collected for this investigation:

LABORATORY TEST	NO. OF TESTS
Moisture content	75 (a)
Dry unit weight	59 (a)
Specific gravity	20
Atterberg limits	22
Gradation	22
Triaxial shear strength	
(CD multistage)	8
(CD multi-specimen)	3
(CU multistage)	5
(CU multi-specimen)	4
Permeability	5 (b)

(a) Includes data from triaxial shear strength tests

(b) Results from consolidation phase of triaxial shear strength tests

Data Validity

The documentation of soil samples, soil types, and laboratory testing is adequate for purposes of design. The test results are valid for disposal cell siting unless otherwise stated.

Dry unit weight, specific gravity, moisture content, Atterberg limits, and gradation tests are basic soil identification tests that are relatively simple to perform. These test values are valid and useful.

Triaxial shear strength tests were performed on laboratory consolidated soil samples under both drained and undrained conditions. Consolidated-drained tests (CD) and consolidated-undrained tests (CU) with pore-pressure measurements were conducted using both one-specimen multistage test procedures

procedures and three-specimen multi-specimen test procedures. CD tests provided data on effective (long-term or drained) soil shearing strengths, and CU tests with pore-pressure measurements provided data on both effective and total (short-term or undrained) soil shearing strengths.

Only six of the 20 triaxial strength test results reflect natural in-situ soils, while the remaining 14 tests were carried out on remolded dike fill materials. Of the six tests run on the natural soils, four triaxial test results applied to the Ferrelview Clay (three CD multistage tests and one CU multi-specimen test) and two triaxial test results applied to the Clay Till (one CD multistage test and one CD multi-specimen test).

Only two of the six applicable triaxial test results appear accurate. Both of these tests were carried out on Ferrelview Clay soils. For the remaining four tests, effective strength friction angles are reported to vary from 0 to 10 degrees, which is not typical for soils tested under drained loading conditions. The two "acceptable" triaxial test results report more reasonable effective strength friction angles of approximately 30 degrees.

There are a number of reasons why most of the strength test results may be inaccurate and, therefore, inadequate for purposes of design. These reasons are detailed below based on the laboratory test data presented by McClelland Engineers (1983).

- There appears to be a lack of consistent failure criteria for the first and second stages of multistage triaxial strength tests. Typically, the maximum deviator stress, principal stress ratio, or some predetermined maximum strain value is chosen to define sample failure (Bowles, 1982; Lambe and Whitman, 1969; Terzaghi and Peck, 1967; U.S. Dept. of the Navy, 1982; Wroth, 1984). However, it is not readily apparent what failure criteria have been chosen for these tests. As a result, it is possible that during the first stages of the test, the samples may have failed and been sheared to such an extent that a failure plane could have developed and remained despite subsequent consolidation during the next stage. This would weaken the specimen, and test results would significantly underestimate effective friction angles and overestimate cohesion for a drained test.

- Many samples were not sufficiently back-saturated before testing took place. Approximately one-half of the soil samples were back-saturated to a pore-pressure "B" parameter of less than 0.90, and some samples were back-saturated only to B = 0.65. The parameter B expresses the ratio of the change in pore-pressure to the change in total stress, and can be thought of as the portion of the total stress which is being carried by the pore water (Lambe and Whitman, 1969; U.S. Dept.

of the Navy, 1982). For testing clayey soils, "B" parameters should be as close to 1.0 as possible in order to fully saturate the sample (Lambe and Whitman, 1969; Mitchell, 1976).

- Some samples were reported to lengthen slightly after initial consolidation was completed. This tends to discredit either the validity of the data reporting or the manner in which the samples were consolidated. Regardless of the source of this error, the test results for these samples are not valid.

- The length to diameter ratio (L/D) for some samples appears to be too low when compared to accepted triaxial test procedures. Generally, L/D for triaxial shear strength specimens should fall between 2.2 and 2.7; however, L/D values as low as 1.7 were reported for some samples in this study. The effect of this procedural error again causes some doubt on the usefulness of these test results.

Consolidation data from the triaxial strength tests were recorded in the form of time curves. However, no void ratio or vertical strain versus log-pressure curves were presented, so no direct determination of compression characteristics and preconsolidation pressures is possible. There may be some means of determining desired consolidation characteristics from the basic test data, but the means are not readily apparent from existing laboratory data. The consolidation data cannot be considered useful for design purposes because of the triaxial strength test data concerns and, in particular, the reported sample lengthening after laboratory consolidation.

Some qualitative consolidation information can be obtained from the triaxial strength test data. Stress paths from the two "reasonable" triaxial test results show dilative behavior and induced negative pore-pressures, which suggest that the Ferrelview Clay may be overconsolidated (Bowles, 1982; Lambe and Whitman, 1969; Mitchell, 1976). This should be verified through additional consolidation testing as part of this program.

Permeability data resulting from the consolidation phase of triaxial strength testing appear to be inconsistent. Therefore, values associated with these tests are suspect, and the permeability data are not considered useful for design purposes.

1.3.2.4 Bechtel National, Inc. (1987)

Investigation Purpose

Bechtel National, Inc. (BNI) performed a hydrogeological characterization study to:

- Provide a groundwater monitoring system to determine if contaminants from the site have degraded groundwater quality
- Evaluate the site geology and hydrogeology for utilization of the site as a waste disposal facility

Field work was conducted between January 1986 and August 1986. The final report was completed by BNI in July 1987.

Drilling and Sampling Scope

A total of 35 boreholes with depths ranging from 54 to 94 feet and five test pits with a consistent depth of about 15 feet were located around the chemical plant area and north of the raffinate pits. Six-inch OD hollow-stem augers and both NQ and NXB wireline core drilling equipment were used. A backhoe was used to excavate the test pits.

Generally, boreholes were sampled at 5-foot intervals with split-spoon samplers. One or two undisturbed samples per borehole were obtained from 24 of the borings. Undisturbed sampling was accomplished using 3-inch OD Shelby tubes. Samples were not obtained from the test pits.

Sampling Adequacy

The drilling and sampling methods were appropriate for this hydrogeological study. Hollow-stem augering and NQ or NXB core drilling are preferred drilling methods in contaminated soils and rock. Casing was not installed in boreholes to seal possible contamination pathways prior to rock coring. Shelby tubes were used for reliable geotechnical testing.

The boring and test pit logs appear valid, generally complete, and adequately documented. Specific and distinct descriptions are given for each soil type within each borehole documenting localized variations in soil characteristics.

Sampling Sufficiency

For the scope of this hydrogeological study, the extent of the borehole and trenching plan was sufficient since this study incorporated data from boreholes previously drilled by BNI in 1984. Each borehole extended into reasonably competent limestone bedrock.

The extent of sampling is not sufficient for present design needs. Only one or two Shelby tube samples were taken in each borehole. Undisturbed sampling was not done in about one-third of the borings. Undisturbed sampling apparently was not a priority for this study, as indicated by the minimal number of laboratory tests requiring undisturbed samples. Disturbed samples were obtained at approximately 5-foot intervals.

Scope of Lab Testing

The following geotechnical laboratory tests were run on samples collected for this investigation:

Laboratory Test	No. of Tests
Moisture content	25
Dry unit weight	33
Specific gravity	32
Atterberg limits	30
Gradation	40
Centrifuge moisture equivalent	20
Cation exchange capacity	5
Distribution ratio	5

Data Validity

Documentation of soil samples, soil types, and laboratory testing were adequate. It is assumed that the tests were properly performed and that the results are valid unless otherwise stated.

Dry unit weight, specific gravity, moisture content, Atterberg limits and gradation test results are basic soil identification tests that are relatively simple to perform. These test values are valid and useful.

Results from the centrifuge moisture equivalent tests appear to be reasonable, although there is a fairly wide variation in test

Results from the centrifuge moisture equivalent tests appear to be reasonable, although there is a fairly wide variation in test values. As expected, the Ferrelview Clay shows the highest test value, while the Basal Till exhibits the lowest. This is consistent with the types of materials involved. The fine-grained Ferrelview Clay should retain more moisture than either the sandy Clay Till or the gravelly Basal Till.

Both cation exchange capacity and distribution ratio measure chemical characteristics of the soil and pore water interactions. The test results appear to be reasonable although there is a wide variation in values. An insufficient number of test results is available for each soil type. Therefore, the test results are inadequate for design purposes.

1.3.3 Geophysical Surveying

Three geophysical investigations were carried out at the Weldon Spring Site (WSS) between 1982 and 1987 by Weston Geophysical Corporation (WGC) and Detection Sciences, Inc. (DSI) under contract to Bechtel National, Inc. (WGC, 1983; WGC, 1984; DSI, 1986). The studies utilized a total of five different geophysical techniques. Table 1-1 lists the geophysical techniques used, survey dates, and the survey subcontractors.

TABLE 1-1

GEOPHYSICAL SURVEYS PERFORMED AT WSS

SURVEY METHOD	DATE	COMPANY
Seismic Refraction	Feb/March 1986	Detection Sciences, Inc.
Electromagnetic	February 1986	"
Seismic Refraction	March/April 1984	Weston Geophysical Corp.
Electrical Resistivity	March/April 1984	"
Seismic Refraction	December 1982	"
Electrical Resistivity	December 1982	"
Self Potential	December 1982	"
Magnetometer	December 1982	"

1.3.3.1 Scope and Purpose of Surveys

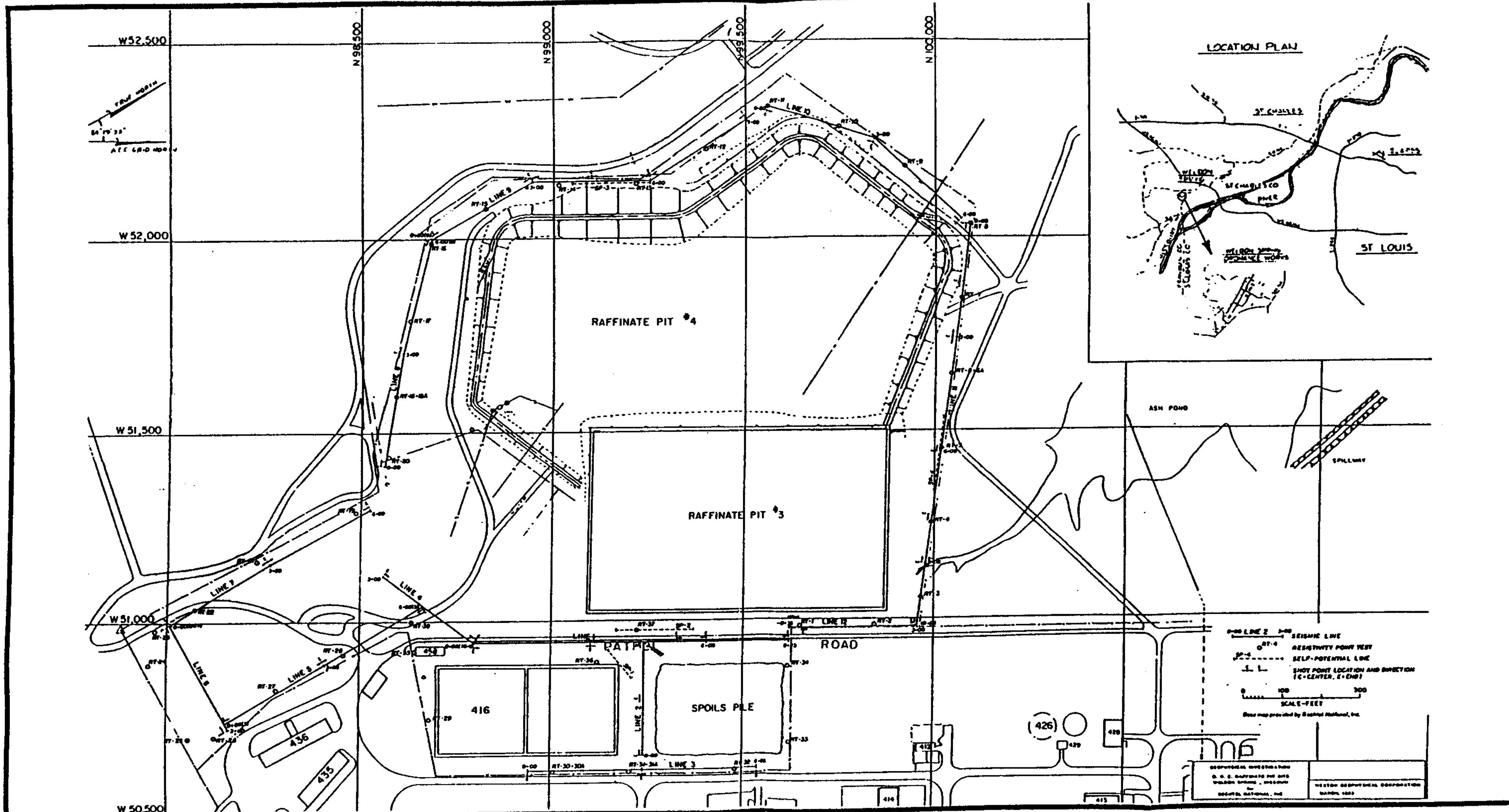
Each of the three investigations utilized multiple geophysical techniques. The combination of several survey methods and subsequent correlation of results can be used to corroborate and enhance the findings of a single method and provide more detailed information on the subsurface. However, in some instances, a particular survey was employed to investigate a specific parameter. Table 1-2 lists the general purpose of each geophysical survey method performed at WSS.

Most of the geophysical surveys performed by Weston Geophysical Corp. in 1982-84 were carried out in the vicinity of the raffinate pits area (Figure 1-2 and 1-3). Magnetometry and some electrical resistivity surveys were performed at five tentative monitoring well locations denoted as A through E on Figure 1-4. The seismic refraction and electromagnetic studies performed by Detection Sciences, Inc. were performed in the area north of Raffinate Pit 4 and east of raffinate pits 1 and 2 as shown on Figures 1-5 and 1-6. Results of these studies and their applicability to the current investigation are discussed in the following sections.

TABLE 1-2

PURPOSE OF GEOPHYSICAL STUDIES AT WSS

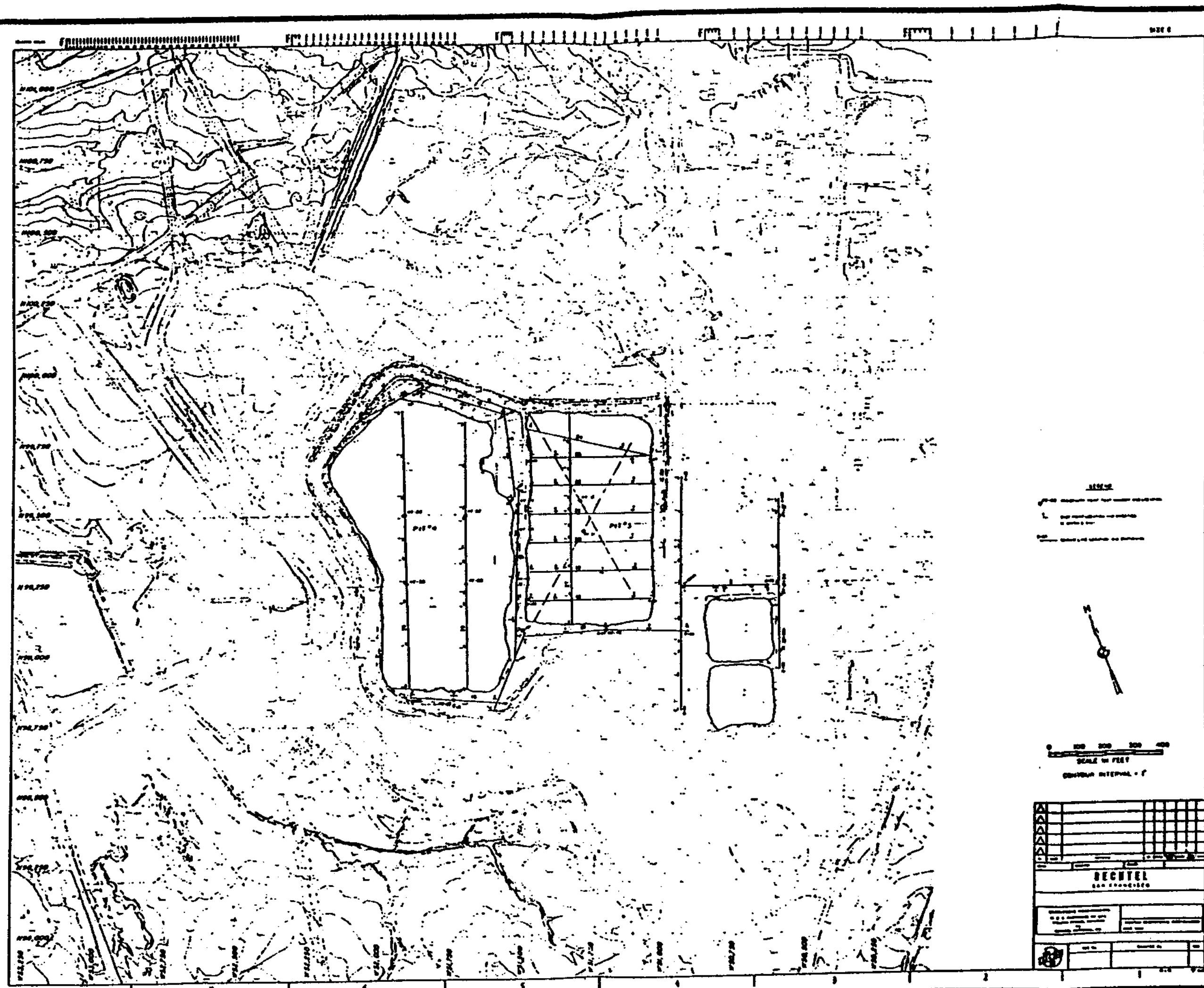
METHOD	PURPOSE
Seismic Refraction	Provide subsurface information regarding the overburden thickness and depth to rock, seismic velocities, and characteristics of bedrock.
Electromagnetic	Identify contaminant plumes in the groundwater and provide a basis for selecting monitoring well locations.
Electrical Resistivity	Provide information on subsurface layering and depths including depth to groundwater.
Self Potential	Detect background potentials from fluid streaming, bioelectric activity or variations in the electrolytic concentration in water.
Magnetometry	Detect buried metal objects (e.g. abandoned process lines) in the overburden at proposed monitoring well locations.



SOURCE : WESTON GEOPHYSICAL CORP., 1983

FIGURE 1-2

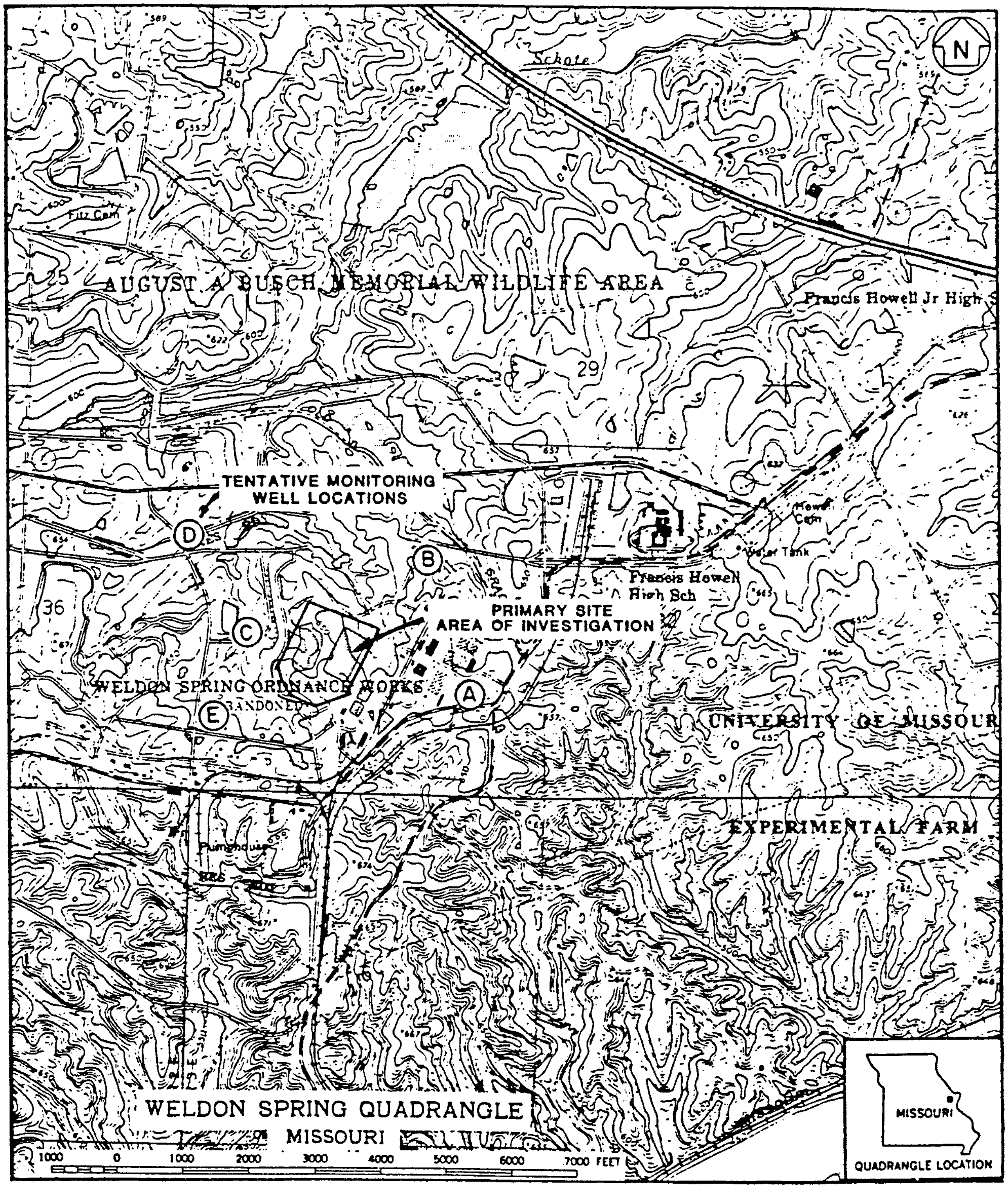
GEOPHYSICAL SURVEY PLAN - WESTON GEOPHYSICAL CORP.



SOURCE : WESTON GEOPHYSICAL CORP., 1984

FIGURE 1-3

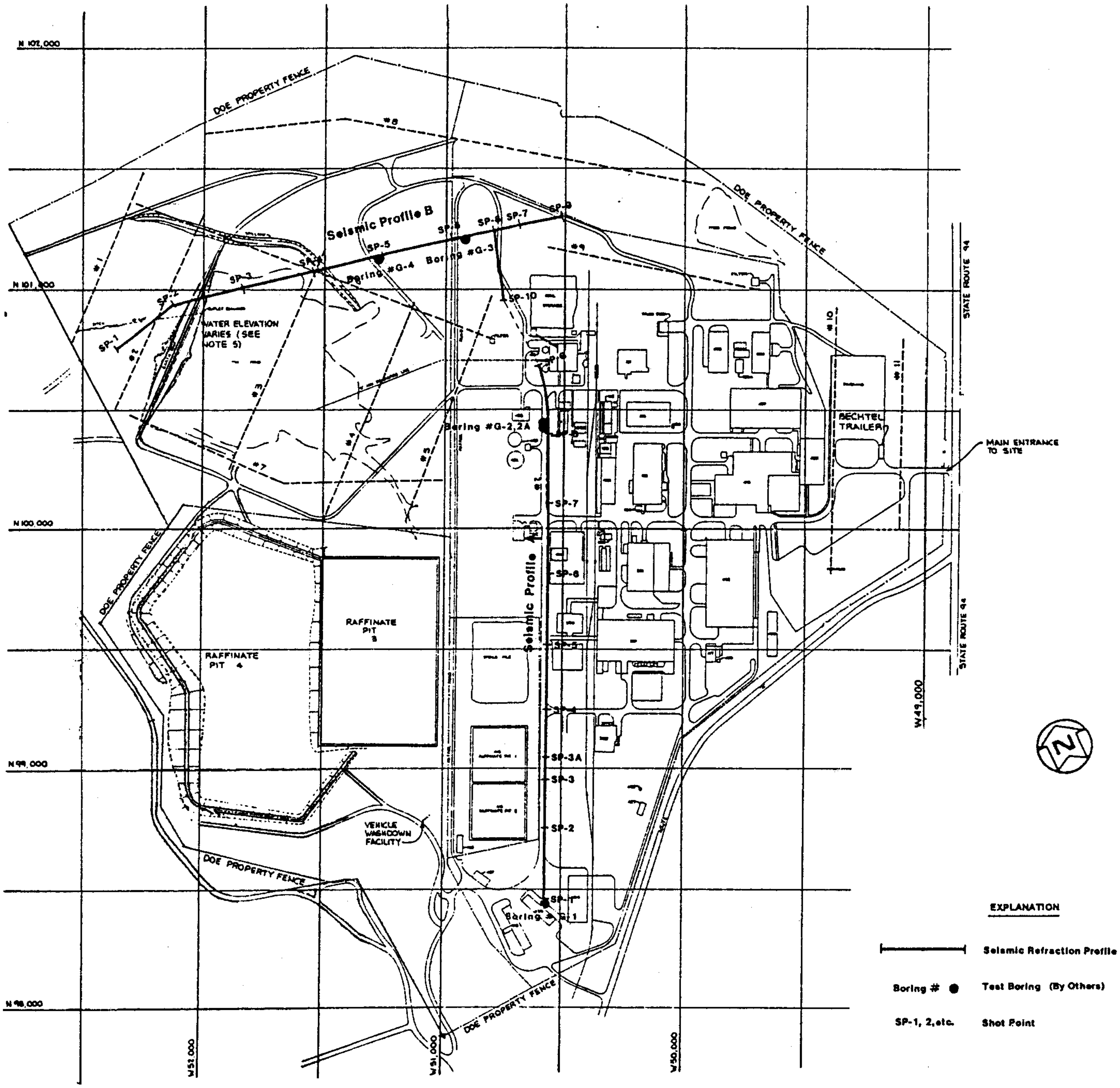
GEOPHYSICAL SURVEY PLAN - WESTON GEOPHYSICAL CORP.



REFERENCE : USGS QUADRANGLE, WELDON SPRING, MO

FIGURE 1-4

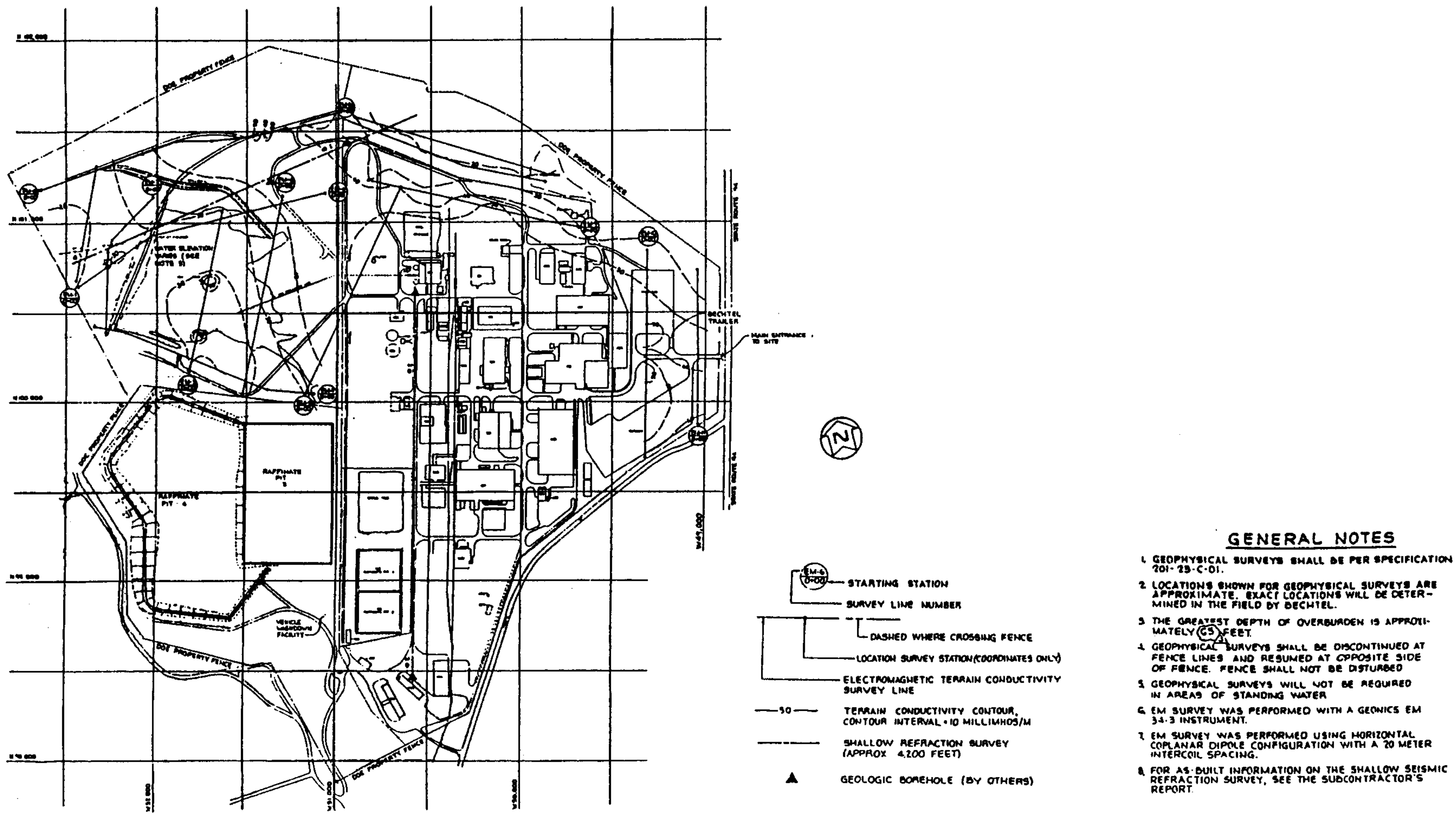
MAGNETOMETER AND ELECTRICAL RESISTIVITY SURVEY LOCATIONS-WESTON GEOPHYSICAL CORP.



SOURCE : DETECTION SCIENCES, INC., 1986

FIGURE 1-5

GEOPHYSICAL SURVEY PLAN - DETECTION SCIENCES, INC.



SOURCE : DETECTION SCIENCES, INC., 1986

FIGURE 1-6

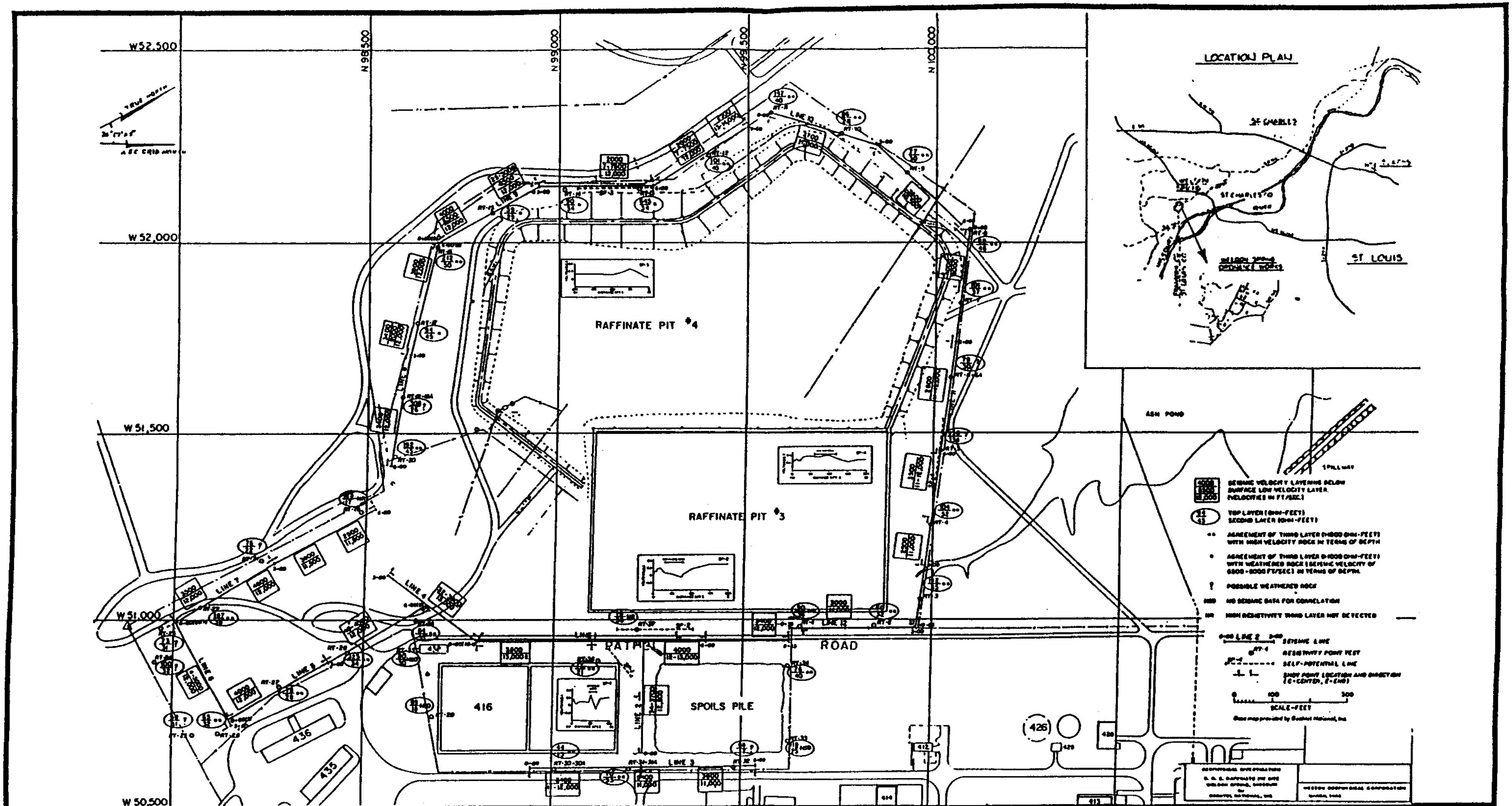
TERRAIN CONDUCTIVITY CONTOUR MAP SHOWING AREAL LIMITS OF THE SURVEY

1.3.3.2 Data Validity

Weston Geophysical Corp., 1982

The seismic refraction, electrical resistivity, and self potential survey results are summarized on Figure 1-7. The study area is characterized by a near-surface low velocity layer (1,200 to 1,800 ft/sec), underlain by a more consolidated layer (2,000 to 5,400 ft/sec), which in turn is underlain by bedrock (11,000 to 13,000 ft/sec). The depth to bedrock varies between 30 and 60 feet (DSI, 1986). Survey lines closest to the proposed disposal cell area were compared with drillhole information to test the accuracy of the surveys. Survey results from lines 1, 2, 3, 10, 11, and 12 are shown on Figures 1-8 and 1-9. Data from drillholes B19A, B17, B21, and G15, located in the vicinity of these lines and penetrating bedrock, correlate well with the seismic survey results.

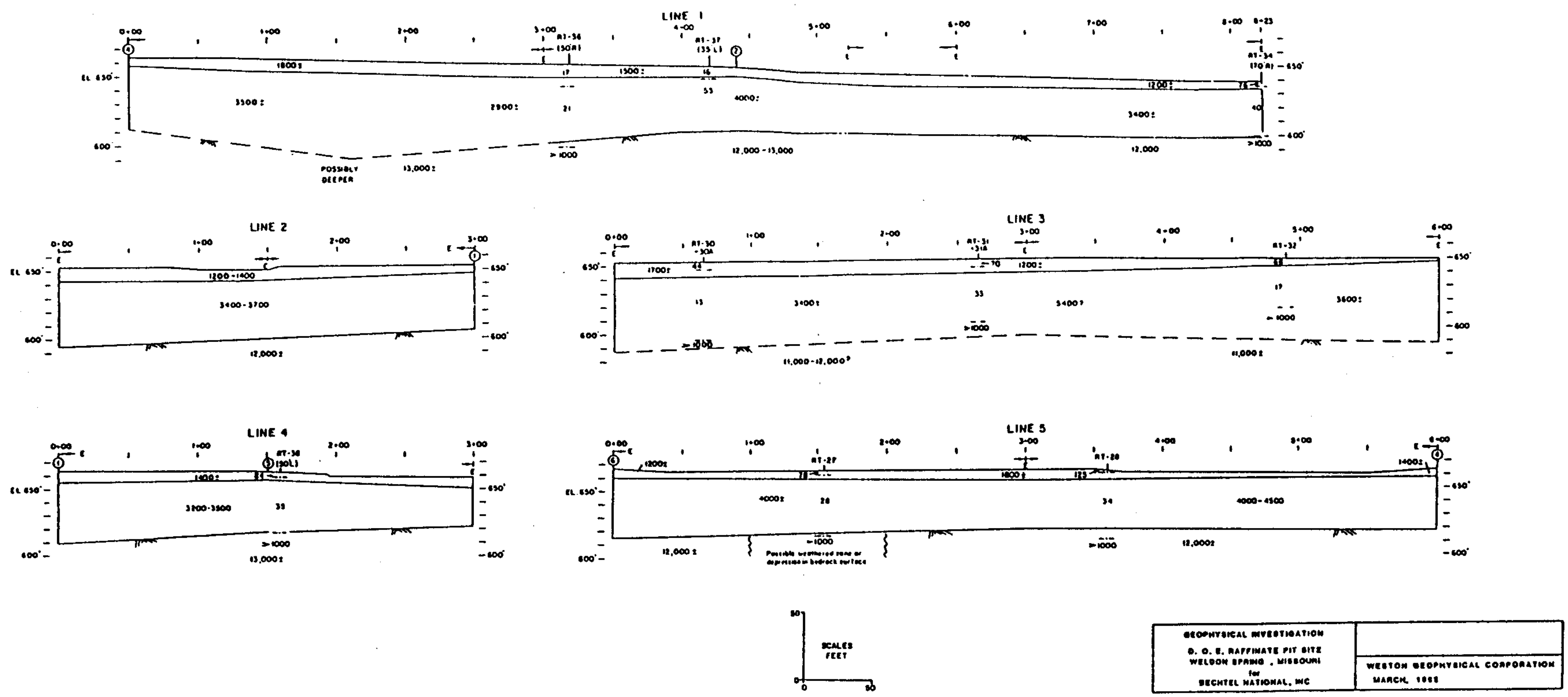
One discrepancy is that the weathered bedrock surface was characterized as overburden because of its relatively low velocity. The bedrock depths determined by seismic refraction apparently delineate the less fractured, more competent limestone and not the actual top of bedrock. From an engineering standpoint, this competent rock boundary is probably more significant than the top of weathered rock. This fractured bedrock layer has an average thickness of 10 feet in



SOURCE : WESTON GEOPHYSICAL CORP., 1983

FIGURE 1-7

SUMMARY OF GEOPHYSICAL DATA

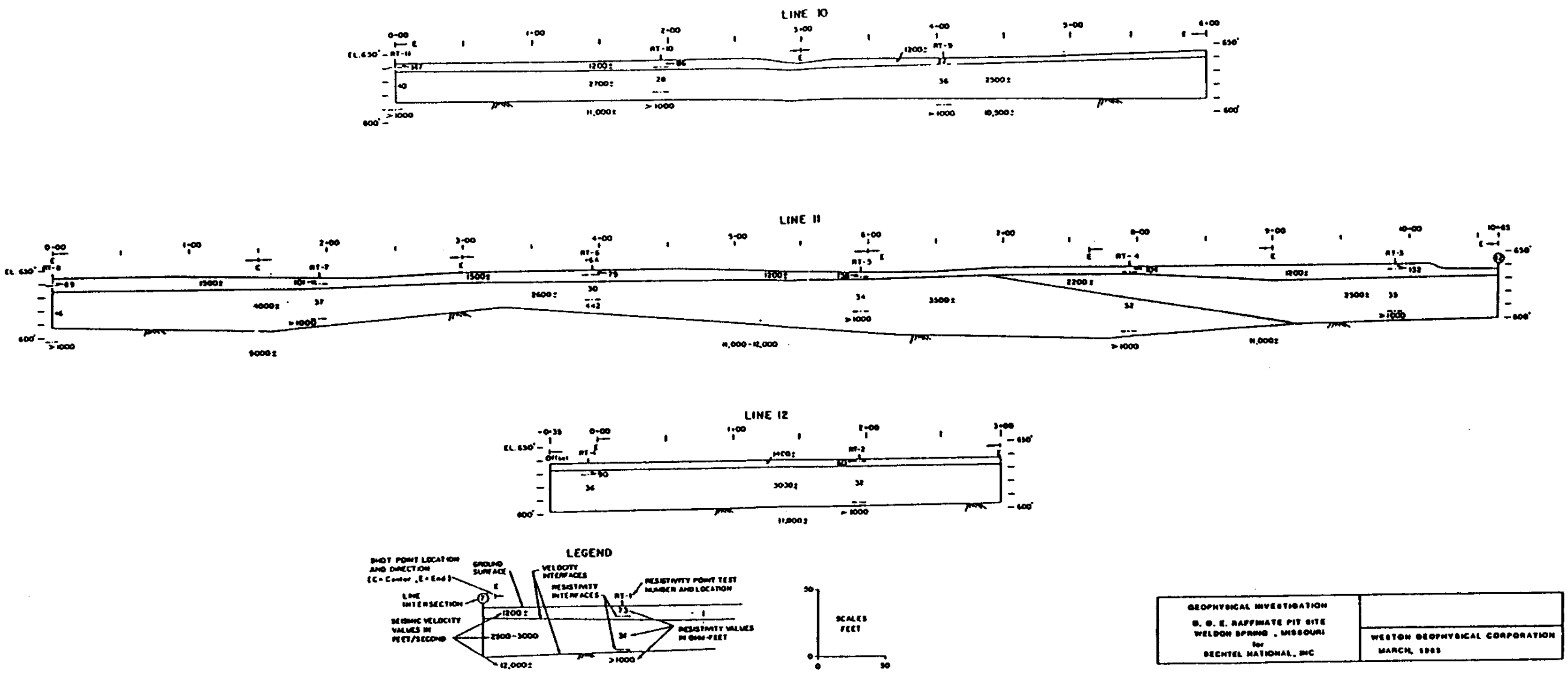


NOTE : SEE FIGURE 1-9 FOR EXPLANATION .

SOURCE : WESTON GEOPHYSICAL CORP., 1983

FIGURE 1-8

SEISMIC PROFILES LINES 1, 2, 3, 4 & 5



SOURCE : WESTON GEOPHYSICAL CORP., 1983

FIGURE 1-9

SEISMIC PROFILES LINES 10, 11 & 12

most drillholes, but is 19 feet thick in hole G15 as indicated by low rock quality designation (RQD) values. A second discrepancy between borehole and geophysical information results from the similar seismic velocities of various overburden layers. This causes layers with similar velocities (densities) to be grouped into a single unit.

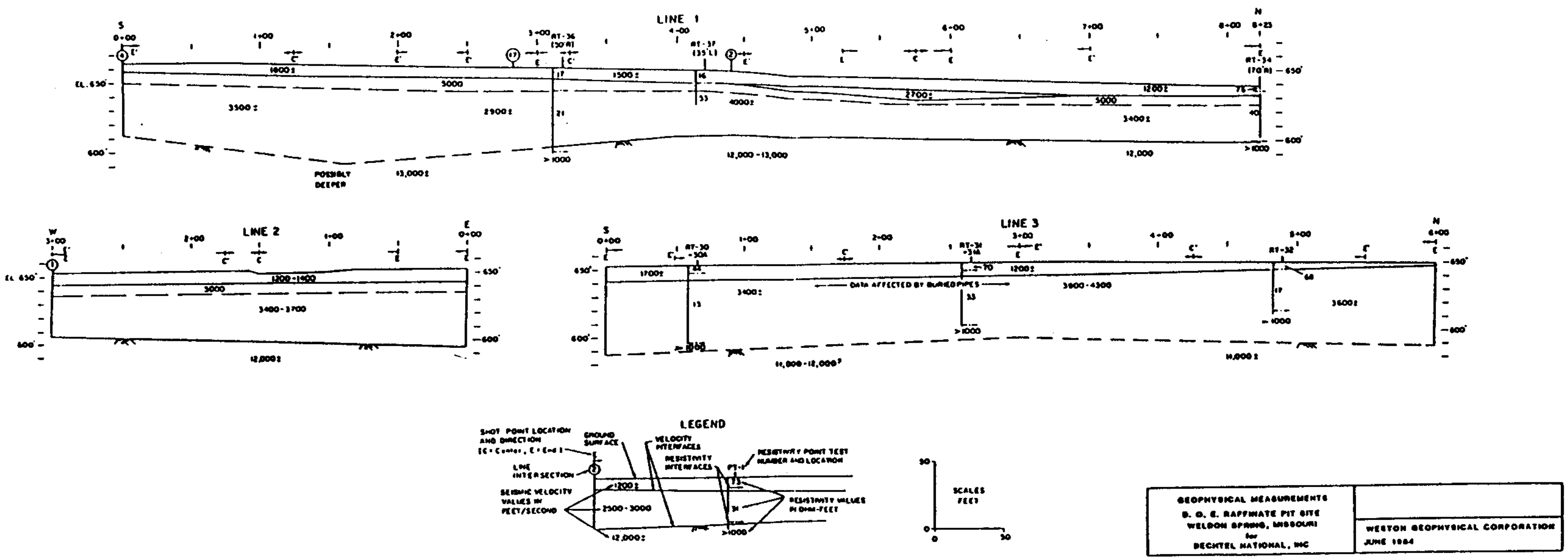
The electrical resistivity values indicate a three-layer subsurface condition which correlates well with seismic refraction data. Results range from 60 to 150 ohm-feet for the uppermost layer, 30 to 50 ohm-feet for the thick intermediate layer, and over 1,000 ohm-feet for bedrock. These values appear to be consistent with expected resistivity. Correlation of the seismic refraction results with electrical resistivity surveys is shown on Figures 1-8 and 1-9. Results obtained by these methods appear consistent. Although original field data was not included in the reports, the data appears to be accurate and the results valid.

The self potential data appear to be accurate. The results are plotted on Figure 1-7. Only lines SP-1 and SP-2 reveal anomalies indicated by potential reversals. These negative anomalies were identified as a characteristic of fluid streaming, a condition that is typical of permeable materials. However, the soils in the area consist of impermeable clays, clayey silts, and silty clays as demonstrated by the boring logs and supported by low resistivity values. Therefore, the correlation of the SP anomalies with existing groundwater conditions is questionable. Magnetometric and electrical resistivity survey data appear accurate and results seem to have valid and reasonable interpretations.

Weston Geophysical Corp., 1983-1984

Seismic refraction surveys conducted in and around raffinate pits 3 and 4 revealed a rather complicated overburden structure (Figure 1-10). Seismic velocities under the ponds suggest the presence of four layers. This may be explained by an increase in moisture content. The seismic velocity of the overburden increases with moisture content to approximately 5,000 ft/sec when saturated. Lower velocity materials may be present beneath the ponds, but were not detected due to higher velocity, saturated surface material. The seismic refraction interpretation is based on the assumption that seismic velocity increases with depth.

A comparison of interpreted seismic data with borehole logs indicated that the bedrock depth determined from the seismic survey is not the top of rock but the depth to competent, less-fractured rock. The bedrock surface was characterized as overburden because of its relatively low velocity due to its weathered and fractured condition.



SOURCE : WESTON GEOPHYSICAL CORP., 1984

FIGURE 1-10

SEISMIC PROFILES OF RAFFINATE PIT NO. 3, LINES 1,2 & 3

Electrical resistivity results generally correlate well with the seismic refraction interpretation. In some instances, the depth to top of bedrock was less than the seismic results as shown on Figure 1-10. The geophysical results from the investigations in the raffinate pit area have characterized the subsurface as shown on Table 1-3.

Detection Sciences, Inc., 1986

Seismic refraction survey results (Figures 1-5 and 1-11) indicate four layers in the subsurface. These are described in Table 1-4. Borehole logs, however, indicate eight or more layers in the subsurface. This can be explained by the similarity in seismic velocities of various overburden layers resulting in layers with similar velocities (densities) grouped into a single unit. A further complication in interpretation results from groundwater within unconsolidated soils which increases the apparent velocity of the material and may mask the presence of underlying lower velocity material.

Results from the DSI investigation appear to be reasonable and consistent with the borehole logs. The seismic results also generally agree with previous investigations performed near the raffinate pits.

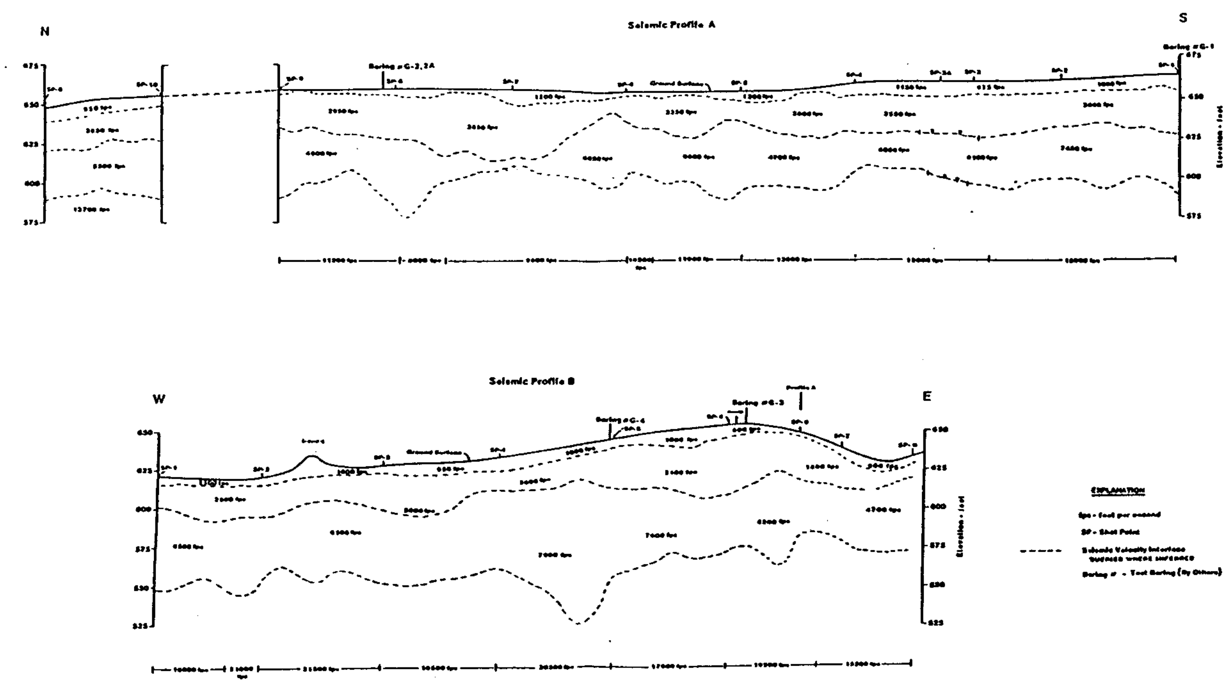
The electromagnetic (EM) surveys (Figure 1-6) were affected by buried metallic debris, pipes, and power lines. Most of the

TABLE 1-3

CORRELATION OF SEISMIC, RESISTIVITY, AND GEOLOGICAL RESULTS, RAFFINATE PIT AREA

SEISMIC VELOCITY (ft/sec)	RESISTIVITY (ohm-ft)	MATERIAL
1,200	80 to 130	Silty clay
2,400 to 3,800	30 to 50	Unsaturated clays and clay tills
7,000 to 9,000	Greater than 1,000	Basal tills, cherty clays, and weathered bedrock
10,000 to 13,000	Greater than 1,000	Bedrock

Source: Weston Geophysical Corp., 1983



SOURCE : DETECTION SCIENCES, INC., 1986

FIGURE 1-11

SEISMIC PROFILES A AND B (PLATE 2)

TABLE 1-4

SEISMIC REFRACTION RESULTS

Layer	Velocity ft/sec	Material
1	950-1,200	Topsoil, loess (up to 15 feet thick)
2	1,800-5,000	Overburden, weathered bedrock
3	4,000-7,650	Weathered bedrock
4	8,000-25,500	Competent bedrock

Source: Detection Sciences, Inc., 1986

observed terrain conductivities were interpreted based on the known geology and hydrology of the area. In the Ash Pond area, results indicated southwest to northeast groundwater flow. North of the chemical plant, a high conductivity (50 mmhos/m) may indicate degraded groundwater quality. East of the chemical plant, the high conductivities were interpreted as a possible expression of a solution feature. These interpretations cannot be verified at present due to the lack of drillhole information.

1.3.3.3 Validity of Methods

The geophysical methods used in the investigations were acceptable techniques and fulfilled the program objectives. Magnetometry was used only to detect magnetic anomalies at proposed monitoring well locations. The method was appropriate and the results suggested changes in proposed well locations at some sites. The accompanying electrical resistivity surveys provided additional support in characterizing the subsurface materials.

Seismic refraction surveys were most useful for determining depth to competent bedrock. Accuracy increased considerably once drillhole logs were correlated with seismic profiles. Seismic survey limitations were recognized and subsequent interpretations were more accurate.

Electrical resistivity surveys support the results of the refraction studies by providing independent data that could be correlated with the seismic studies. Interpretations were similar and usually did not differ by more than 5%, except in some instances where interpretations varied by 15% to 20%. The Wenner electrode configuration was used. It is a common and acceptable technique. Computer programs such as INVERSE were used to interpret the data and model the subsurface. This method is more accurate than manual matching of resistivity curves.

Electromagnetic traverses generally provided valid data. The presence of cultural features (power lines, subsurface pipes, and metallic structures) precluded surveys from being carried out near the chemical plant site.

The self potential technique is basically used to investigate shallow contaminant plumes. It provides qualitative information on the extent and degree of contamination. The negative anomalies detected in some areas at WSS could be interpreted as either fluid streaming or variations in the water chemistry of overburden material.

1.3.3.4 Data Sufficiency

The data obtained from previous geophysical investigations at WSS were applicable for interpretations of the subsurface in and around the raffinate pits. The data obtained were sufficient for the scope of the BNI investigations. The coverage extended only slightly into the proposed disposal facility area. Based on the existing data, subsurface interpretations in the disposal facility area must be extrapolated from the raffinate pit area and correlated to borehole logs. Insufficient coverage in the disposal facility area needs to be augmented by additional geophysical studies.

1.3.4 Summary

Previous site investigations have been thoroughly reviewed and evaluated to determine applicability of the results for present disposal facility design requirements. Table 1-5 summarizes the findings of sections 1.3.2 and 1.3.3 regarding adequacy and sufficiency of data and investigative methods. In general, there is a lack of coherence among the studies because they were conducted for different objectives. None of the previous investigations are considered to be directly applicable and sufficient for current needs. Much of the data is useful but incomplete. As described in the previous sections, much more detail is required to obtain the engineering parameters necessary for the engineering design. The additional data requirements are discussed in Section 1.4.

TABLE 1-5

APPLICABILITY OF PREVIOUS SITE INVESTIGATIONS TO PERMANENT DISPOSAL FACILITY DESIGN

	Corps of Engineers	Henry M. Reitz	BNI (1984)	BNI (1987)	Geophysical Surveys
Purpose	General Foundation Design	Raffinate Pit Design	Geohydrologic Characterization of Raffinate Pits Area	Site G.W. Monitoring and Geohydrologic Characterization	Raffinate Pits Investigation
Location	SP/DF	RP	RP	DF	RP & AP
No. Borings	8	12	26	35	N/A
Sampling Adequacy	o	--	o	*	o
Sampling Sufficiency	--	--	o	o	*
Data Validity	o	--	o	o	*

+ = Directly applicable and sufficient.
* = Generally applicable, some deficiencies.
o = Somewhat applicable, important deficiencies.
-- = Poor, many deficiencies.

AP = Ash Pond area
RP = Raffinate Pits area
DF = Disposal Facility area
SP = Steam Plant area

1.4 Justification for Further Investigations

1.4.1 Rationale

This sampling plan proposes further site investigations necessary to demonstrate suitability of the site as a satisfactory disposal facility. Data analyses and interpretation will yield engineering characteristics of soil and bedrock affecting disposal facility performance. The following sections provide a rationale for the proposed investigations including:

- Siting decisions concerning the disposal facility
- Sufficiency and validity of the proposed data gathering
- Data requirements to establish disposal facility design criteria
- Objectives of the specific data collection methods
- Methods of data analysis and possible need for additional studies

1.4.2 Disposal Facility Siting

Siting a waste disposal facility requires a foundation that will remain stable for the facility design life. Surface stability processes such as erosion and settlement can be observed and measured. Subsurface conditions that may affect stability can be observed directly only by trenching or drilling. Remote sensing by geophysical methods gives an indirect indication of subsurface conditions that usually require corroboration by drillholes.

The proposed investigation must demonstrate that the selected site is currently stable and has a high probability of remaining stable for at least 1,000 years. The results from the investigation described in this plan together with knowledge of the site geology will aid in assessing whether these criteria can be met.

1.4.3 Data Sufficiency/Validity

To characterize a disposal facility site, data must be collected. This data must be representative and accurate and the results must be reproducible. The following sections describe the methods that will be followed to obtain sufficient and valid data.

1.4.3.1 Geotechnical Drilling

To adequately characterize an area such as the proposed disposal facility locale, preliminary boreholes should be placed approximately 200 to 500 feet apart, with additional borings used to investigate critical locations or anomalous conditions (Bowles, 1982; U.S. Dept. of the Navy, 1982). All borings should be drilled into competent bedrock, so that sufficient overburden thickness and bedrock elevation data can be collected (U.S. EPA, 1987). The location of some of the boreholes should coincide with proposed geophysical survey line locations so that the boring results can confirm the geophysical data. Such a baseline of corroborated data can then be used to more accurately interpret the geophysical results over the entire site. The proposed drilling program is discussed in Section 2.1.

Because the site may be contaminated, wash type borings which could spread contaminants from upper to lower soils, or to bedrock, are inappropriate (U.S. EPA, 1975; U.S. EPA, 1987). Percussion drilling is not appropriate since water is required within the borehole to slurry the cuttings for removal and since it is not recommended for undisturbed sampling (U.S. Dept. of the Navy, 1982). Auger boring is the preferred method of soil drilling and particularly hollow-stem augers which serve as a casing to keep the borehole open during drilling. Since water is not required to flush the soil cuttings to the surface in auger drilling, the potential for downhole contamination is minimized.

1.4.3.2 Geotechnical Lab Testing

The sampling plan objectives relative to the geotechnical laboratory testing program are to determine the quality of the reported data and verify that it is acceptable for its intended end use. The EPA (U.S. EPA, 1976; U.S. EPA, 1982) indicates that the data quality considered to be acceptable must be defined as quantitatively as possible. Because of the inherent variability of soils and rocks and the requirement for a quantitative acceptability standard, a statistical sampling and testing plan has been developed to address the adequacy and representativeness of the sampling and testing effort.

The overall approach of the statistical sampling and testing plan is:

1. Determine the number and types of geotechnical samples and the associated geotechnical parameters that will be considered in the disposal facility design.

2. Identify the end use of each engineering parameter.

3. Determine and summarize the valid data from existing geotechnical testing.

4. Compute sample means, standard deviation, and coefficients of variation.

5. Compute the number of samples and tests required for a desirable confidence level and a predefined confidence interval for each parameter and material type.

6. Determine the adequacy and representativeness of the collected data.

The approach presented by EPA (1976, 1982) and Barth and Mason will be used to calculate the number of required samples and tests. A confidence level of 90% will be used. If the existing number of valid data points is less than that for meeting the minimum criterion in Step 5, additional sampling and testing will be performed to meet the requirements.

Material Types and Engineering Parameters

The foundation materials of interest in the disposal facility design consist of:

Ferrelview Clay
Clay Till
Basal Till

Material of interest will also include the residuum (weathered rock/residual soil) if sufficient thickness is encountered. Other overburden material, with the exception of loess, is not expected to be present but will be tested if encountered. Loess will be excavated and spoiled when encountered. Bedrock is not included in the above list since its quantitative engineering properties are not required for design.

The bedrock will be described and classified during drilling. Rock data that might affect disposal facility design (e.g. RQD and percent of core recovery) will be presented in the drill logs. Also, the geophysical exploration will provide information on the integrity of the bedrock foundation and possibly the presence of solution features and fractures. Laboratory tests of bedrock cores are therefore not planned as part of the characterization program.

<u>Data From Previous Studies</u>

The previous studies on geotechnical sampling and testing are documented in the following reports:

- U.S. Army Corps of Engineers Report (1955)
- Henry M. Reitz (1964)
- Bechtel National, Inc. (1984) (laboratory test by McClelland Engineers)
- Bechtel National, Inc. (1987)

The reports contain laboratory test data for the foundation materials in the Weldon Spring chemical plant and raffinate pits sites.

Table 1-6 summarizes the quantity and types of valid geotechnical test data contained in these reports for the three major soil types in the disposal facility area including Ferrelview Clay, Clay Till, and Basal Till. The table shows that most of the previous tests were performed on samples of Ferrelview Clay and Clay Till. There is a lack of comparable data for the Basal Till, and insufficient analyses for strength, consolidation, and

TABLE 1-6

SUMMARY OF VALID GEOTECHNICAL TEST DATA

FROM PREVIOUS STUDIES

Ferrelview Clay
No. of Tests

Tests	COE	HMR	BNI (1984)	BNI (1987)	TOTAL
Dry unit weight	-	-	12	7	19
Moisture content	-	-	15	7	22
Specific gravity	-	-	4	11	15
Atterberg limits	-	-	5	8	13
Capillary moisture	-	-	-	-	-
Gradation	-	-	5	10	15
Triaxial shear strength (CD)	-	-	1	-	1
Triaxial shear strength (CU)	-	-	1	-	1
Permeability	-	-	-	-	-
Consolidation	-	-	-	-	-
Compaction	1	2	-	-	3

TABLE 1-6 (continued)

Clay Till
No. of Tests

Tests	COE	HMR	BNI (1984)	BNI (1987)	TOTAL
Dry unit weight	-	-	5	14	19
Moisture content	-	-	7	15	22
Specific gravity	-	-	2	17	19
Atterberg limits	-	-	2	16	18
Capillary moisture	-	-	-	-	-
Gradation	-	-	2	18	20
Triaxial shear strength	-	-	-	-	-
Permeability	-	-	-	-	-
Consolidation	-	-	-	-	-
Compaction	-	-	-	-	-

Table 1-6 (continued)

Basal Till
No. of Tests

Tests	COE	HMR	BNI (1984)	BNI (1987)	TOTAL
Dry unit weight	-	-	-	5	5
Moisture content	-	-	-	3	3
Specific gravity	-	-	-	1	1
Atterberg limits	-	-	-	5	5
Capillary moisture	-	-	-	-	-
Gradation	-	-	-	6	6
Triaxial shear strength	-	-	-	-	-
Permeability	-	-	-	-	-
Consolidation	-	-	-	-	-
Compaction	-	-	-	-	-

permeability parameters for all soil and rock materials. Each valid test identified in Table 1-6 is documented in Appendix A. Documentation includes laboratory test, soil type, boring number, sample number, and test results.

Appropriate Number of Samples and Tests

As discussed previously, the appropriate number of samples and tests for achieving data sufficiency and representativeness can be determined using a statistical approach. Assuming that an engineering parameter is normally distributed, the number of samples and tests required to maintain a confidence level for that parameter to lie within a certain confidence interval can be computed. Using this approach, five tests are required for each engineering parameter of each soil type. However, as described in the following paragraph the number of tests performed will generally exceed the minimum required number calculated statistically. Standard engineering practices and professional judgement will be applied in selecting samples for testing.

Data Sufficiency

The sufficiency of the existing geotechnical test data can be evaluated based on the number of tests required as determined above. The difference between the number of existing valid test results (determined as described in Section 1.3.2) and the required number of results (5) is the number of tests that should required number of results (5) is the number of tests that should be carried out in the testing program shown in Table 1-7. The quantities presented in Table 1-7 are the minimum that should be performed. Most physical and index property tests are relatively quick and inexpensive. These tests should be performed both for additional quality assurance checks and for obtaining basic data required for strength, compressibility, consolidation, and permeability. The index properties are frequently used in empirical correlations for estimating strengths, compression indices, preconsolidation pressures, and permeability. These estimates can provide another check on the reliability of the values of these parameters obtained by direct testing methods.

1.4.3.3 Geophysical Surveys

The objectives of the previous investigations were different from those contemplated for the disposal facility area. Previous studies were performed primarily to determine the depth to bedrock and the characteristics of the overburden. The proposed survey is designed to both define the thickness and characteristics of the overburden and determine limestone bedrock parameters. The degree of fracturing in the bedrock and the presence of voids or other solution features that may affect the disposal facility foundation are of particular interest.

TABLE 1-7

Minimum Number of Laboratory Tests Required on Foundation Materials

Tests	No. of Tests Required Ferrelview Clay	Clay Till	Basal Till
Dry unit weight	0	0	0
Moisture content	0	0	2
Specific gravity	0	0	4
Atterberg limits	0	0	0
Capillary moisture	5	5	5
Gradation	0	0	0
Triaxial shear strength (undrained-consolidated)	4	5	5
Triaxial shear strength (undrained-unconsolidated)	4	5	5
Permeability	5	5	5
Consolidation	5	5	5
Compaction	2	5	0 [a]

(a) Basal Till soils are not expected to require compaction

The previous geophysical surveys were located primarily outside the present area of interest. Although geophysical data acquired in the raffinate pits are valuable in understanding the general site characteristics, current program objectives require specific information on the subsurface within the boundaries of the proposed disposal facility.

Only two seismic refraction lines from previous investigations are located within the proposed disposal facility area (Figures 1-5 and 1-11). The north-south line passing east of raffinate pits 1 and 2 is relevant because it extends along the western boundary of the disposal facility. Seismic data obtained along this line will be useful in characterizing the subsurface. The east-west seismic profile extends only 500 feet into the disposal facility area and consequently only the eastern 500 feet of the profile is relevant.

Three EM survey lines by Detection Sciences, Inc. (1987) are located within the study area. The resulting terrain conductivity contour map (Figure 1-6) covers only the northern and eastern portion of the disposal cell. These data will be useful once additional EM surveys are performed within the central area of the proposed disposal cell.

The geophysical testing program proposed for the disposal cell area is discussed in Section 2.2. Methods of investigation include various geophysical techniques, correlation with previously acquired data, and ground-truth information provided by boreholes.

The existence of borehole logs and additional drilling will assist in the geophysical interpretation. Boreholes corroborate geophysical results and provide non-interpretive, ground-truth information used to derive more accurate interpretations.

1.4.4 Data Requirements

To site a disposal facility, an area must be screened to show that certain engineering requirements are met. These requirements are that the foundation of the disposal facility:

- Has sufficient strength to withstand horizontal and vertical forces induced by the disposal facility
- Maintains integrity for the design life of the disposal facility

To meet these criteria, soil samples must be collected and tested. Standard engineering models are then developed using the collected data. The model results will demonstrate whether or not the selected site is stable under design loads.

1.4.5 Data Collection Methods

The geotechnical and geophysical testing will use standard methods. The sampling and testing procedures are defined in the following sections.

1.4.5.1 Geotechnical Drilling and Sampling

Geotechnical samples can be either disturbed or undisturbed. Completely undisturbed soil samples are impossible to obtain, and the quality of an undisturbed sample is related to how much disturbance the sample was subjected to during sampling procedures. Disturbed samples are collected with samplers which significantly alter the structure of the in-situ soil during sampling procedures.

Disturbed samples are generally obtained using some type of split-spoon sampler. Because these samplers are usually hammer driven, vibration affects the soil within the sampler. Also, the driving shoe at the tip of the sampler has a relatively large volume displacement which disturbs the soil as it enters the sampler (U.S. EPA, 1987; U.S. Dept. of the Navy, 1982). For these reasons, disturbed sampling techniques cannot be used in obtaining soil samples for permeability, consolidation, or shear strength testing as these tests require samples with a minimum of disturbance.

Disturbed soil samples can be used for physical property and index testing such as gradation, compaction, or Atterberg limits. In addition, the standard penetration test (SPT) has been correlated with geotechnical properties such as relative density and undrained shear strength (Bowles, 1982; Lambe and Whitman, 1969; Mitchell, 1976; Terzaghi and Peck, 1967). Therefore, disturbed sampling is most useful when SPT equipment and procedures are used.

Undisturbed borehole samples are retrieved using thin-wall seamless brass or steel tubing pushed into the soil under hydraulic or pneumatic pressure. Some disturbance occurs along the outside of the sample due to friction with the inside wall of the tube; however, this disturbed area is usually trimmed off prior to laboratory testing.

In general, as the diameter of the tube increases, the quality of the soil samples increases since wall friction tends to disturb the same amount of soil regardless of the tube diameter. However, sampling costs escalate rapidly as larger tubes are used so that a compromise must be reached between sampling and testing requirements. An additional constraint is that the sampler must fit within the hollow inner stem of the augers. Three inch diameter tube samples are most common and provide adequate samples for strength, permeability, and consolidation testing of nominally undisturbed soils.

Boring logs are required to provide a record of the soil and rock types encountered during drilling. Logs also show where samples were taken within the borehole and provide sample identification and sampling method documentation.

1.4.5.2 Geotechnical Lab Testing

The following standards will be used when performing geotechnical laboratory tests:

- American Society of Testing and Materials
- Army Corps of Engineers

Specific standard methods which apply to individual laboratory tests are given in Table 3.1.

1.4.5.3 Geophysical Surveys

Various geophysical methods may be applied to meet current objectives. Data is generally obtained using signals from electronic sensors recorded in the field on a data logger and later transferred to a computer for storage and processing. Although a variety of techniques are used to obtain data by any individual method, the basic geophysical principles are followed. These techniques vary among companies involved in geophysical studies and are too numerous and complex to describe. In electrical resistivity (ER) surveys, for example, the electrode configuration may be Wenner, Schlumberger, modified Schlumberger, monopole, dipole-dipole, or modifications of these with the first two configurations the most commonly used. Seismic refraction and reflection lines may vary in length of spread, overlap, geophone separation, energy applied, location of shot points, and minor modifications of arrays.

There are also variations in techniques applicable to electromagnetic (EM), induced polorization (IP), and self potential (SP) surveys. Microgravity and magnetometry surveys are less complex with the separation between stations and type of instrument being the basic variations. The applicability and objective of each geophysical method proposed at WSS is further discussed in Section 2.2.

SECTION 2

PROPOSED SCOPE OF WORK

2.0 PROPOSED SCOPE OF WORK

The proposed geotechnical and geophysical work tasks are necessary to demonstrate that radioactive and hazardous wastes can be safely encapsulated at the Weldon Spring Site. The combined geotechnical and geophysical studies will characterize the soil and bedrock horizons beneath the proposed disposal facility site and provide engineering parameters for design.

The "Contractor" referred to in the following sections is the Project Management Contractor responsible for overseeing the work tasks. The "Subcontractor" is the party actually performing the specific task.

2.1 Geotechnical Drilling

2.1.1 Purpose and Scope

The drilling program will be used to obtain samples required for design of the disposal facility and to obtain direct visual information on soil and rock parameters and thickness of overburden. Twelve boreholes will be drilled beneath geophysical survey lines and six additional boreholes will be placed within the disposal facility area to provide additional soil and bedrock data away from the geophysical survey lines.

Drill holes provide noninterpretive, ground-truth information on soil and bedrock conditions. The 18 boreholes will be used to correlate geophysical measurements to subsurface conditions. Laboratory tests of samples will be performed to obtain geotechnical design data (Section 3.1.2). Additional borings into the bedrock may later be required if geophysical data reveals solution features.

2.1.2 Drilling Locations

Approximate borehole locations are shown on Figure 2-1 on a tentative geophysical survey grid that encompasses the proposed disposal facility area. Most of the borings will be located within the chemical plant area and thus may require coring through or breaking concrete foundations to reach overburden soils.

Boreholes will generally be 50 to 70 feet deep. A minimum of two boreholes will be drilled to approximately 200 feet below the ground surface. These deep holes will be geophysically logged. All boreholes will penetrate at least 20 feet into competent bedrock. The depth and location of all boreholes will be determined by the Contractor's technical representatives including geophysicist, geologist, and engineer.

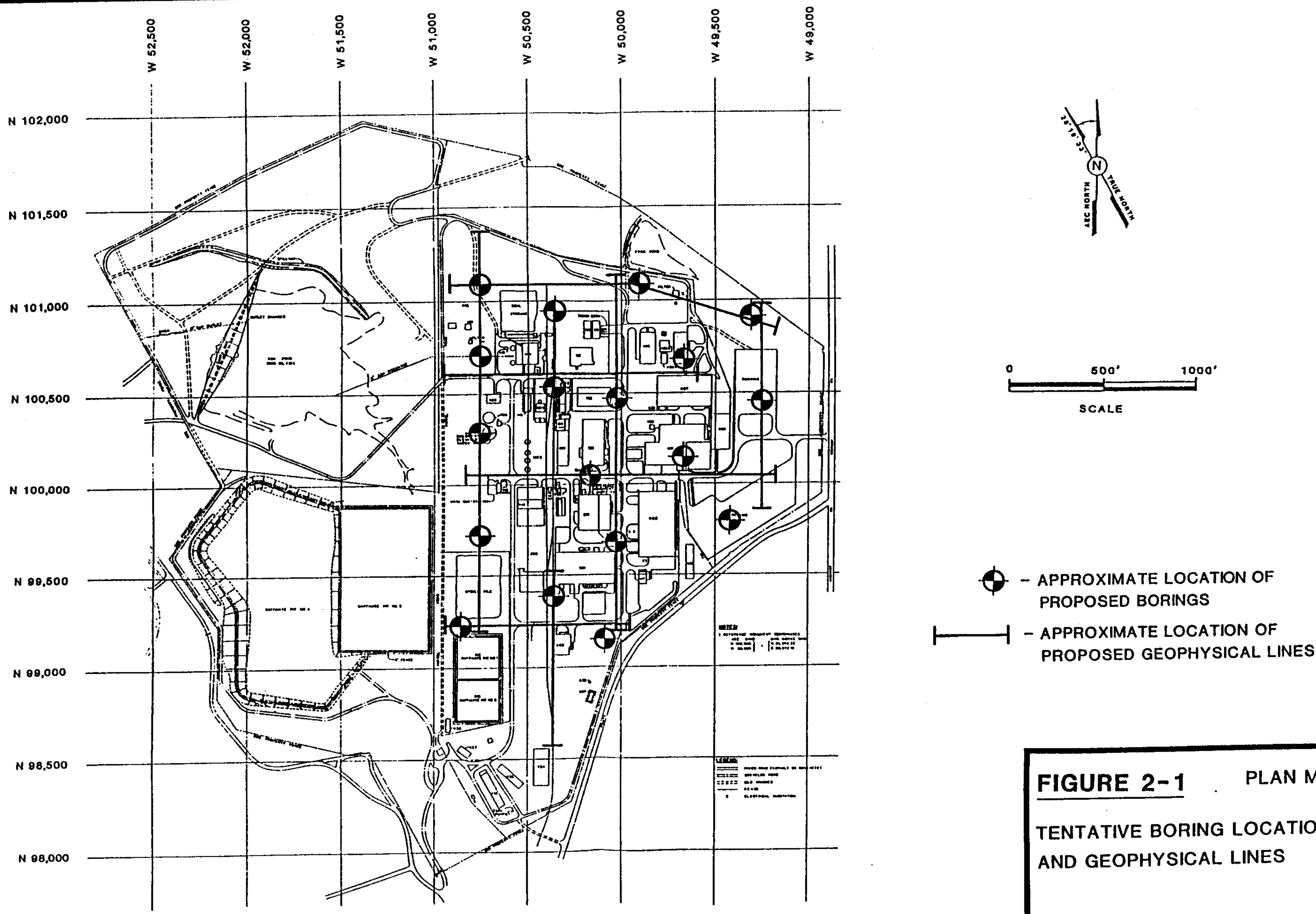


FIGURE 2-1 PLAN MAP

TENTATIVE BORING LOCATIONS AND GEOPHYSICAL LINES

Samples in the overburden will be collected at 2 1/2 foot intervals or continuously as determined by the field geologist. After a hole is advanced five feet below the ground surface, at least one undisturbed sample will be taken every five feet or at every change of material type until refusal.

Disturbed split-spoon samples will be collected between undisturbed samples. Rock samples will be obtained by coring below auger or sampler refusal.

2.1.3 Drilling Equipment and Methods

Standard drilling equipment will be used. The equipment will be capable of undisturbed and disturbed sampling above and below the groundwater table. Drilling equipment will be sufficient for coring and recovering rock core to a depth of 300 feet. The drilling Subcontractor will advance an 8-inch or 10-inch OD hollow-stem auger to refusal depth, and a 3-inch OD NQ wireline core barrel below auger refusal.

Undisturbed soil samples will be collected with new and previously cleaned 30-inch or 36-inch Shelby tubes (3-inch OD) pushed with smooth hydraulic or pneumatic pressure to the full usable length. Usable length is defined as 24 inches for a 30-inch long tube and 30 inches for a 36-inch long tube. The

Contractor may redefine usable length if sample recovery is inadequate or sample disturbance is too great.

The loaded Shelby tube shall be detached from the sampler head and then capped and wax-sealed upon removal from the borehole. After capping and sealing, Shelby tubes will be stored vertically in an environment protected from temperature extremes. Sampling techniques and equipment shall be in accordance with ASTM D1587 (Shelby Tube Sampling).

Disturbed soil samples will be recovered from clean and uncontaminated split-spoon samplers. Split-spoon soil samples will be sealed in airtight 8-ounce (or larger) glass jars and stored in a protected environment. Techniques and equipment used for split-spoon sampling shall be in accordance with ASTM D1586 (Standard Penetration Test).

Rock cores will be obtained using clean and uncontaminated 3-inch OD NQ wireline core barrels. Recovered cores will be placed in standard core boxes. Boxes will be labelled, and stored in a protected dry location to prevent mishandling and damage to the rock samples. Rock coring shall employ techniques and equipment as called for in ASTM D2113-83.

Coring shall be performed through the hollow stem of the auger. If this method proves to be unsatisfactory for any reason, a 6-inch diameter casing (schedule 40 PVC pipe) will be installed to the depth of auger refusal and grouted in place before coring operations begin. The PVC casing will have flush threaded joints. No adhesives or solvents shall be used to cement the pipe lengths together. The borehole will be reamed to a diameter of at least 10 inches prior to casing installation to create sufficient annular space for grouting the casing into the borehole. A cement-bentonite grout mix will be used and will completely fill the annular space between the outside of the conductor casing and the natural soils of the open borehole. Grout will be tremmied from the bottom of the hole. The grout mix and the curing time will follow the Manual of Water Well Construction Practices (U.S. EPA, 1975). The casing will prevent potential leakage and cross-contamination between overburden soils and the limestone bedrock. All boreholes will be plugged after sampling has been completed and in accordance with established WSSRAP procedures.

2.1.4 Drilling and Sampling Procedures

Drilling and sampling will be performed in accordance with accepted procedures as discussed in the U.S. EPA RCRA Technical Enforcement Guidance Document (U.S. EPA, 1986). Standard operating procedures (SOPs) have been developed for WSSRAP based on EPA guidance. A supervising geologist will be present to document all drilling and sampling activities. The geologist will perform pocket penetrometer or vane shear testing on all cohesive soil samples immediately after the sample is retrieved.

Results will be recorded on the core logs. Samples will be handled, tested, and shipped in accordance with approved WSS procedures for potentially contaminated materials.

2.1.5 Decontamination

All sampling equipment, augers, drill rods, drill bits, and other equipment which has been in contact with the site soils or rock shall be decontaminated by high pressure hot water or steam before each borehole is drilled. The entire drilling rig will be decontaminated upon arrival on-site and upon completion of drilling activities. Interior portions of equipment such as pumps and hoses which are not accessible for cleaning with a pressure or steam cleaner shall be thoroughly cleaned and flushed with potable water. Decontamination will be performed at the established site decontamination pad. Split-spoon samplers shall be washed with a dispersant (such as Calgon or tri-sodium phosphate) and water, rinsed with potable water, rinsed with de-ionized water, and reassembled prior to further sampling. Solid waste from the drilling program shall be placed in barrels. The contents of each barrel will be identified. The barrels will be stored in a secure area on site.

2.2 Geophysical Surveys

2.2.1 Purpose

The primary emphasis of the geophysical program will be to try to determine if solution features are present in the bedrock below the proposed disposal facility area. These features could adversely affect the integrity of a disposal facility. The geophysical survey will also attempt to obtain other parameters that might impact the design or integrity of the disposal facility. Characteristics to be detected and delineated include, but are not limited to:

- Bedrock channel, cavity, joint, and fracture distribution
- Overburden types, thicknesses, extents, and characteristics
- Depth to top of bedrock
- Bedrock layer condition and extent
- Depth to top of saturated overburden
- Perched water tables
- Overburden and bedrock velocities and densities

2.2.2 Survey Layout

The proposed disposal facility site is located on 75 acres and includes portions of the chemical plant and raffinate pit area. Numerous buildings, concrete paving, buried pipes and other hindrances must be considered when planning the layout of geophysical survey lines. The proposed area will be crossed by north-south and east-west survey lines varying in length from 500 to 2500 feet. Approximate geophysical survey line locations are shown on Figure 2-1. These locations are only tentative and precise locations will have to be determined based on careful consideration of the many obstructions and sources of interference on the site. The location of the lines will be determined by the Subcontractor in consultation with the Contractor's geophysicist. Required depth of investigation is approximately 200 feet below top of bedrock. Both long and short survey lines will be used to investigate deep and shallow conditions/layers respectively.

Elevation and position of survey lines and stations will generally be located to an accuracy of 0.1 feet. Higher precision may be required for some surveys. Precise elevations and required positions will be determined by a licensed surveyor.

2.2.3 Geophysical Methods

The following geophysical methods are potentially applicable in this study:

- o Seismic refraction
- o Seismic reflection
- o DC electrical resistivity (ER)
- o Electromagnetic induction (EM)
- o Induced polarization (IP)
- o Self potential (SP)
- o Microgravity
- o Magnetometry

Seismics, ER, and EM are the primary methods for the current program. The accuracy of geophysical interpretations will be increased by combining and correlating data from more than one method. The primary methods will be employed for data acquisition; secondary methods may be used to support the data obtained. A description of how these methods and results address the program objectives follows.

Seismic refraction surveys yield overburden and bedrock seismic velocities. Velocities are then used to identify the top and general condition of bedrock, thickness and general consistency of overburden materials, and location of the water table in overburden. When correlated with other geophysical methods, seismic refraction surveys could identify possible anomalous areas where solution features may be present.

Seismic reflection surveys also yield data on soil and bedrock seismic velocities. This information shows variations within the bedrock horizons. Deep penetration to 200 feet below top of bedrock may be possible through high resolution survey techniques, but shallow and irregular bedrock surfaces may disperse the reflected waves. This method may therefore be used as a secondary technique to complement the refraction surveys.

DC electrical resistivity (ER) surveys detect resistivity contrasts in subsurface materials. ER can identify overburden and bedrock layers, lateral variations in composition, and hidden lower density layers not detected by seismic methods. ER may also detect the overburden/bedrock contact and large subsurface fracture zones, cavities, or channels. This technique complements seismic methods and correlates with the electromagnetic induction data to derive more accurate interpretations or locations of fractured or cavernous areas. Both lateral profiling and vertical sounding surveys are applicable to the present investigation.

Electromagnetic induction (EM) survey data will be integrated with the ER surveys to locate anomalous areas that may contain fractures, voids, or cavities. Various exploration depths up to

250 feet may be investigated with this technique using vertical soundings as well as lateral profiling. The combination of EM and ER survey data with borehole information results in a better understanding of specific subsurface features.

Induced polarization (IP) surveys detect polarization phenomena caused by water-borne ions in clays that fill voids primarily in the overburden and above the water table. If the polarizations can be differentiated, they may identify anomalous subsurface features such as cavities. The IP survey is a secondary method that provides additional information to corroborate EM and ER data.

Self potential (SP) surveys measure the natural electric potentials in the subsurface caused by electrochemical activity such as a contaminant plume interaction with groundwater. This method can detect "streaming potentials" caused by fluid movement through fractures, joints, or cavities in the shallow subsurface.

Microgravity surveys detect density contrasts in the subsurface such as large solution features within the bedrock. With appropriate computer modeling programs, the density contrasts are identified and interpreted. To compensate for the inadequate depth control, other geophysical results and drilling are used to enhance microgravity.

Magnetic surveys are not applicable to current program objectives at WSS. Their only use would be to identify magnetic anomalies caused by buried pipes, structures or other metallic debris (cultural interference) which would impact other survey measurements.

2.2.4 Survey Techniques

The geophysical methods described in the previous section employ a variety of techniques to obtain data. Although the general principle of each method is described in the literature, the data may be obtained and processed by a variety of procedures. Differing methodologies may all be valid. Subcontractors rely on a particular combination of techniques, corresponding reduction procedures, computer programs and experience. The selection of techniques is left to the Subcontractor's discretion subject to review and concurrence by the Contractor's technical staff. Selected techniques must use proven methodologies and geophysical principles and be responsive to the primary objective of locating solution features.

SECTION 3

ANALYTICAL REQUIREMENTS

3.0 ANALYTICAL REQUIREMENTS

3.1 Geotechnical Laboratory Testing

3.1.1 Site Soils

Geotechnical laboratory testing is necessary to provide valid and sufficient data for each soil type within the Weldon Spring Site. Section 1.4.3.2 describes the statistical evaluation used to determine the minimum number of valid test results necessary to achieve data sufficiency.

Site soils relevant to design of the disposal facility are generally divided into three types. In order of increasing depth below ground surface they are:

- Ferrelview Clay
- Clay Till
- Basal Till

In addition, the residuum (weathered rock/residual soil) will be included for testing if sufficient thickness is encountered and if good quality representative samples can be obtained.

3.1.2 Laboratory Tests

The proposed laboratory testing program will be combined with results determined to be valid from the previous investigations to provide complete geotechnical design data. Assigning specific soil samples to each laboratory test will take place after the boring logs have been thoroughly reviewed and analyzed.

Testing will be performed in different phases so that representative samples can be selected for the more sophisticated tests such as shear strength and permeability. Geotechnical laboratory tests suggested for the proposed drilling and sampling program described in Section 2.1 are shown in Table 3-1 and are followed by a brief test description. For some of the detailed tests required for data adequacy such as triaxial shear strength, additional basic tests such as moisture content are recommended as a check on data consistency and reliability.

Moisture content, a physical soil property, is the ratio of the weight of the free water within the soil voids to the weight of the soil solids expressed as a percentage. The results of this test are used to help define soil horizons and to determine volume-weight relationships of the in-situ soils (U.S. EPA, 1983; U.S. Dept. of the Navy, 1982). When used with the Atterberg limits, moisture content can indicate whether a soil is preconsolidated. One moisture content test will be run on each

Table 3-1

SUGGESTED MINIMUM
NUMBER OF GEOTECHNICAL
LABORATORY TESTS

LABORATORY TEST	FERRELVIEW CLAY	CLAY TILL	BASAL TILL
Moisture Content (ASTM D2216)	18	18	18
Dry Unit Weight	18	18	1
Specific Gravity (ASTM D854)	3	3	5
Capillary Moisture (ASTM D3152 & ASTM D2325)	5	5	5
Gradation (ASTM D422)	5	5	5
Atterberg Limits (ASTM D4318)	12	12	12
Triaxial Shear Strength: Consolidated Undrained (CU), pore-pressure measurements, 3-point test (EM-1110-2-1906)	3[a]	3[a]	3[a]
Unconsolidated Undrained UU (EM-1110-2-1906)	5	5	5
Falling Head Permeability (EM-1110-2-1906)	5	5	5
Consolidation (ASTM D2435)	5	5	5
Compaction (ASTM D698)	2	5	0

(a) Each "test" consists of one (1) specimen subjected to three (3) CU test cycles, with increasing confining (consolidation) pressures, in order to obtain three (3) data points for each "test" performed.

of the triaxial shear strength (CU and UU), permeability, and consolidation test soil samples.

Dry unit weight is another physical property of the soil, and measures the weight of the soil solids within a given volume. This test must be run on undisturbed samples, and helps to define soil horizons and determine volume-weight relationships of the soils (U.S. EPA, 1983; U.S. Dept. of the Navy, 1982). As with moisture content, one dry unit weight test will be performed on each of the triaxial shear strength (CU and UU), permeability, and consolidation soil samples.

Specific gravity measures the ratio between the unit weight of soil solids and the unit weight of water. The primary uses of the soil specific gravity are in determining volume-weight relationships and in helping to classify soils and soil types (U.S. EPA, 1983; U.S. Dept. of the Navy, 1982). Because of existing test data, only three tests will be performed on Ferrelview Clay and Clay Till samples. Five tests will be run on the Basal Till.

Capillary moisture measures the moisture content of a soil subjected to an external suction pressure. Typically, suction values ranging from -0.1 bars to -15 bars are used. Capillary moisture values are used to determine long-term moisture contents for radon attenuation studies and also for correlating unsaturated hydraulic conductivities with soil saturation

(Mitchell, 1976). Five capillary moisture tests will be run on each soil type.

Gradation tests are used to measure the relative percentages of gravel, sand, silt, and clay-size portions of a soil. Test results are used to help classify soils and to aid in defining soil horizons. Five additional gradation tests are specified for each soil type in this investigation.

Atterberg limits, in the form of plastic and liquid limits, are used to classify and characterize fine-grained soils. The plastic limit is defined as the moisture content at which a soil just begins to exhibit plastic behavior, and the liquid limit is defined as the moisture content at which a soil first begins to flow. These limits are highly correlated with shear strength, consolidation, and shrink/swell characteristics of fine-grained soils (Bowles, 1982; Lambe and Whitman, 1969; Mitchell, 1976; Terzaghi and Peck, 1967; U.S. EPA, 1975; Wroth, 1984). Three Atterberg limit tests will be performed for each of the following: triaxial shear strength (CU and UU), permeability, and consolidation for a total of twelve Atterberg limit tests per soil type.

Triaxial shear strength tests determine soil shearing strength under varying drainage and loading conditions.
Consolidated-undrained (CU) tests with pore-pressure measurements provide both effective and total strength parameters for a

laboratory consolidated soil sample. Unconsolidated-undrained (UU) tests measure the undrained shear strength of soil samples which have not undergone laboratory consolidation. In general, effective strength applies to long-term or drained loading conditions, while total strength approximates actual soil strength during short-term or undrained loading conditions (Lambe and Whitman, 1969; Wroth, 1984). The undrained shear strength represents a more accurate soil strength during short-term undrained loading conditions. Three 3-point CU tests with pore-pressure measurements and five UU tests will be performed on each soil type.

Falling head permeability tests measure the flow rate of water through a given soil sample under a decreasing hydraulic gradient. Test results are given in terms of coefficients of permeability which are then used to classify the relative soil permeability. Five falling head tests will be run on undisturbed samples of each soil type. Field permeability tests may be performed if the soil encountered is below the groundwater table.

One-dimensional consolidation tests analyze time-dependent settlement behavior of fine-grained soils. Total settlement, secondary settlement, and time rates of settlement are calculated from test results. In addition, maximum past pressures and overconsolidation rates can be determined (Bowles, 1982; Lambe and Whitman, 1969; Terzaghi and Peck, 1967; Wroth, 1984). Test data from these consolidation tests will be correlated with undrained shear strength (Wroth, 1984). Five consolidation tests will be run on each soil type.

Compaction tests determine the maximum dry density and optimum water content for a soil compacted at a specified energy level. These tests are used to determine the required compactive effort and methods of compaction. Two additional compaction tests will supplement existing data for the Ferrelview Clay. Five tests will be run on the Clay Till. The Basal Till will not be compacted during construction and thus will not be tested.

3.2 Geophysical Surveys

3.2.1 Data Reduction Methods

Data reduction translates the raw data into useful results and consists of a sequential process consisting of data retrieval, input, calculation, and output. Computer programs enhance and simplify geophysical data reduction by eliminating tedious and lengthy calculations of manual data processing. Preliminary data reduction will be done as field measurements are collected. Survey techniques can be modified and instruments can be adjusted to optimize data acquisition methods and data reliability.

Because of variable subsurface characteristics including numerous subsurface layers, irregular bedrock surface, saturated soils, perched water tables, and the water table in the bedrock, computer data reduction procedures at WSS may require modification by manual data reduction methods. Some manual data reduction may also be required to verify computer results. Reduction processes are described in numerous geophysical publications (Breiner, 1973; Keller and Frischnecht, 1960; Telford, 1976). References and computer codes will be documented by the Subcontractor once the specific geophysical techniques are clearly identified. Independent verification of reduction methods by multiple checks, cross checks (with other results), and spot checks, especially of lengthy calculations, will be performed.

3.2.2 Data Analysis

Results of the data reduction process are used to derive subsurface interpretations. This process includes:

- Correlating data with parameters documented in the literature
- Correlating data with ground-truth information from boreholes
- Correlating data with a stored reference data base included in the computer codes
- Independent analysis of results and interpretations
- Verifying compatibility of results by correlating data obtained from different geophysical methods

The objective of the analyses is subsurface characterization. This is generally shown by means of pseudo-sections along the geophysical survey lines depicting the subsurface configuration, location of water tables, anomalous zones, and values of the soil and rock properties (e.g. resistivity or seismic velocity). Preliminary interpretations are drawn from the original data. Subsequent modifications or additions are based on further detailed correlations, additional ground-truth information, or refinements to computer models. The survey results will be presented as tables, cross-sections, and contour maps.

3.2.3 Models

Geophysical models of the WSS would be generally confined to microgravity surveys, if performed. The other survey methods yield results that directly portray the subsurface pseudo-sections. Microgravity survey models compare observed anomalies with conceptual density variations in the subsurface.

SECTION 4

QUALITY ASSURANCE

4.0 QUALITY ASSURANCE

Geotechnical drilling and sampling, geotechnical lab analysis, and geophysical surveys will be designed, performed and reviewed in accordance with the following quality assurance (QA) procedures. The QA plan includes all applicable WSSRAP procedures established in the Weldon Spring Quality Assurance Program Plan (QAPP) in accordance with EPA guidelines. The following QA requirements provide assurance that methods and techniques used to collect, analyze, and report data shall produce scientifically sound results consistent with the program objectives. Work will be carried out in accordance with WSSRAP Engineering Procedures (ENPs) and Standard Operating Procedures (SOPs). Forms required for the Geophysical/Geotechnical programs include:

- Chain of custody forms (Appendix I)
- Sample seals and tags
- Field data sheets

The required QA elements are generally described in the QAPP and in the relevant SOPs and ENPs. Task-specific aspects of the elements directly applicable to the Geophysical/Geotechnical Sampling Plan are presented in this document.

4.1 Geotechnical Drilling and Sampling

Quality assurance during drilling and sampling operations will consist of surveillance and audits of the drilling Subcontractor. Drilling and sampling procedures will be inspected. Samples will be stored in containers that will prevent sample contamination or cross-contamination.

All drilling and sampling activities shall be continuously inspected by qualified, experienced personnel. A PMC geologist or soils engineer with experience in geotechnical drilling, sampling, rock coring, and core recovery procedures will log each borehole.

4.2 Geotechnical Lab Analysis

All soil samples and rock cores will be labeled immediately after removal from the sampler. Labeling will correspond with identification provided on the borehole logs for each sample taken. All soil samples and rock cores will be stored in an environment safe from mishandling or temperature extremes.

Sample disturbance will be minimized during transport to the testing facility. Correlating sample identification to assigned laboratory tests will be verified at the laboratory upon receipt of the sample. Thorough sample tracking and documentation will be initiated and maintained throughout the testing program.

Laboratory test results will be cross-checked and approved by different personnel before being sent from the laboratory. Adherence to proper ASTM and COE standards will be verified by the Contractor prior to the start of laboratory testing.

4.3 Geophysical Surveys

Quality assurance during geophysical testing will consist of:

- Written procedures and work instructions defining the methods and sequence for performing the tests

- Approved written procedures and work instructions issued to the appropriate personnel prior to the commencement of the work and used during the performance of the tests

- Test performance by qualified personnel

- The presence of at least two persons (Subcontractor and Contractor technical representatives) for all geophysical work

- Mutual on-site verification by the Subcontractor and Contractor representatives of data acquisition, data storage, documentation of inconsistencies, problem resolution, and adherence to all Contractor and DOE guidelines and QA/QC procedures

- Recording test results by the personnel performing the tests

- Photographing field procedures and survey locations

- Auditing all elements of the geophysical investigation and taking corrective action as required

SECTION 5

DATA DOCUMENTATION

Appendix D

Specification WP028, Geotechnical Investigation

5.0 DATA DOCUMENTATION

All field activities performed by WSSRAP staff and subcontractors will be thoroughly documented by a combination of chronological field notes encompassing all field activities, photographs of field activities, and data forms for specific sampling activities and field measurements. During the course of the geotechnical and geophysical sampling and testing, a qualified field geologist, geophysicist, or engineer will record daily activities in a permanently bound, waterproof, and paginated notebook. Entries in this notebook shall include:

- Date
- Weather conditions
- All on-site personnel involved
- Chronological record of the day's activities (a description of the activity and the time will be included)
- Any measurements or other information not recorded on designated field forms

5.1 Geotechnical Samples

5.1.1 Sample Transfer/Chain-of-Custody Records

The presence of contaminated soils requires careful handling of samples and detailed documentation. Since the extent of subsurface contamination has not been completely delineated, all samples taken within the boundary of WSS will be considered as potentially contaminated and treated accordingly. The principal component of the quality control procedures lies in the accuracy of documentation and chain-of-custody records. Procedural requirements are:

- Strict adherence to the proposed sampling techniques as described in ASTM procedure
- Prepared labels showing project, hole location, sample identification number, date, and type of sampler
- Standardized field tracking report forms to establish sample custody in the field
- Documentation of preservation methods, if required

5.1.2 Test Records

Appropriate forms for reporting raw data and test results will be used. These forms will address all pertinent factors. In addition to the standard information required, these forms will also include the continuation of chain-of-custody by showing the hole and sample number, sample type, date, and name of the sampler. The form will also include a section where the reviewer will initial and date the form after the data and/or results have been checked. All tables and headings will be clearly identified and the appropriate units will be shown.

5.1.3 Borehole Logs

Borehole logs will be kept on-site and updated as drilling progresses. Information contained in these logs will provide an accurate characterization of the soil/rock encountered, drilling conditions, well completion (if appropriate), and any other related data pertinent to understanding borehole conditions. These logs will be prepared by a qualified geologist and reviewed for accuracy by the Contractor. The following data will be included on each borehole log (additional information may be required):

- Hole identification
- Hole location (coordinates and elevation)
- Drilling method(s) and equipment
- Drilling contractor, driller, and logger's names
- Date of drilling commencement and completion
- Total borehole depth
- Depth to water table and bedrock
- Hole diameter
- Casing diameters and quantities
- Type of casing and method of installation
- Grouted interval
- Accurate advance penetration control
- Lithologic description of materials and soil classification
- Sample numbers, depth of sample, and sample interval

- Length of sample recovered
- Description of sampling method; number of blows for Standard Penetration Tests (SPTs)
- Drilling rate and any unusual drilling problems, especially any drop of drill rods or rapid penetration
- Description of completion operations

For core logs, the appropriate information listed above will be recorded in addition to the following:

- Core length
- Coring rate
- Fluid gain or loss
- Core logs
- Percentage of recovery
- Discontinuities
- Rock quality designation
- Rock classification and lithology

5.1.4 Photographs

Photographs will be taken of soil samples prior to placement in storage containers. Opened split-spoon samples will be photographed using an adequate scale and label depicting the sampled interval, hole number, date and soil type. Rock samples may be photographed in the core boxes and must depict similar information as the soil samples. Additional photographs of important sections of samples or drilling processes may be taken if these are relevant to the accurate documentation of the drilling/logging operation. Upon completion of the investigations, the photographs will be labeled and compiled to provide clear documentation.

5.1.5 Calculations

All calculations required for the geotechnical sampling program will follow standard quality control procedures of verification by independent checking. The reviewer will place his/her initials and date on each calculation page after appropriate verification of calculations, assumptions, data, and results. Any corrections or additions will be written without erasing or eliminating previous figures and initialed by the reviewer.

5.2 Geophysical Surveys

5.2.1 Test Records

Data record labeling shall show date, time, survey type, methodology, equipment operator, length and number of the survey lines, coordinates, instrument settings, orientation, spacings (if required), and any other inferred or required information that impacts data acquisition.

5.2.2 Equipment Calibration

All geophysical equipment will be calibrated to the manufacturer's specifications prior to commencement of any field activities and again after testing is completed. For systems with internal calibration, calibration will be performed daily prior to the start of work. Accurate documentation of all calibration will be maintained. All specifications for calibration shall be traceable to nationally recognized standards. Should no nationally recognized standards exist, the basis for calibration shall be documented.

5.2.3 Assumption Documentation

Geophysical data acquisition, reduction and interpretation generally follow standard physical and mathematical principles documented in the literature (Breiner, 1973; Keller and Frischnecht, 1966; Telford, 1976). However, certain assumptions are usually required for the data reduction process. For example, in seismic refraction investigations assumptions are required for the number of subsurface layers present and the homogeneity of the individual layers. Similar assumptions may apply to the other geophysical methods.

There also may be basic assumptions inherent in the data reduction methods themselves. For example, seismic refraction interpretation assumes that seismic velocity increases with depth. The interpretation of other geophysical parameters may also be based on similar types of assumptions. The validity of these assumptions can be verified by correlating interpretations obtained from the various geophysical methods as well as utilizing ground-truth information from boreholes. The data reduction and analysis procedures (Section 5.2.4 and 5.2.5) will document assumptions made in the interpretation process.

5.2.4 Computer Runs

Various computer programs will be used during the data reduction procedure. The number of computer runs will be determined once the quality and quantity of data is evaluated. Computer programs will be verified and documented prior to reducing the data.

5.2.5 Data Reduction and Analysis

Proper documentation (labeling and filing) of data will be maintained throughout the reduction process. This involves clear identification of field data and final product as well as all assumptions made in the data reduction and analysis process.

All independent checks will be documented. Inconsistencies in both raw data and final results will be documented. These include inconsistencies noted in correlations of data with previous results, correlations of data among the various geophysical methods, correlations with borehole information, and apparent inconsistencies in the data itself.

5.3 Daily Logs

The events of the day shall be maintained in a daily log by the subcontractors. These logs will include, but not be limited to, the activities performed, locations where the activity was performed, the time, the weather conditions, problems encountered and actions taken to solve them, personnel working on-site, and equipment used. These logs will become part of the permanent project record.

SECTION 6

REFERENCES

6.0 REFERENCES

1. Barth, D.S. and B.J. Mason, 1984, Soil Sampling Quality Assurance User's Guide. EPA-600/4-84-043, U.S. EPA, Las Vegas, NV.

2. Bechtel National, Inc., November 1984, Geologic Report, Weldon Spring Raffinate Pits Site, Weldon Spring, MO. DOE/OR/20722-6, U.S. Department of Energy, ORO, Oak Ridge, TN.

3. Bechtel National, Inc., July 1987, Hydrogeological Characterization Report for Weldon Spring Chemical Plant, Weldon Spring, MO. DOE/OR/20722-137, U.S. Department of Energy, ORO, Oak Ridge, TN.

4. Bowles, Joseph E., 1982, Foundation Analysis and Design. 3rd Ed., McGraw-Hill, Inc., NY.

5. Breiner, S., 1973, Applications Manual for Portable Magnetometers. Geometrics, Sunnyvale, CA.

6. Detection Sciences, Inc., 1986, "Seismic Refraction Survey - Weldon Spring Chemical Plant - Weldon Spring, Missouri" and "Appendix E - Electromagnetic Terrain Conductivity Survey of the Weldon Spring Chemical Plant Grounds" in Hydrogeological Characterization Report for Weldon Spring

Chemical Plant - Weldon Spring, Missouri by Bechtel National, Inc., July 1987, DOE/OR/20722-137.

7. Keller, G.V. and Frischnecht, 1966, Electrical Methods in Geophysical Prospecting, Pergamon Press, NY.

8. Lambe, T. William and Robert V. Whitman, 1969, Soil Mechanics. John Wiley & Sons, Inc., NY.

9. McClelland Engineers, July 1983, Laboratory Testing of Soils, Weldon Spring Storage Site, Weldon Spring, MO.

10. Mitchell, James K., 1976, Fundamentals of Soil Behavior. John Wiley & Sons, Inc., NY.

11. Henry M. Reitz, Consulting Engineers, January 1964, Design Memorandum for 12M Cu. Ft. Raffinate Pit, Atomic Energy Commission Plant, Weldon Spring, MO.

12. Telford, W.M. et.al., 1976, Applied Geophysics. Cambridge University Press, Cambridge, London, England.

13. Terzaghi, Karl and Ralph B. Peck, 1967, Soil Mechanics in Engineering Practice. 2nd. Ed., John Wiley & Sons, Inc. NY.

14. U.S. Army Corps of Engineers, Office of the District Engineer, St. Louis District, February 1955, Report of Foundation Investigation, United States Atomic Energy Commission, Weldon Spring, MO.

15. U.S. Environmental Protection Agency, 1983, Lining of Waste Impoundment and Disposal Facilities. EPA Doc. No. SW-870. Municipal Environmental Research Laboratory, U.S. EPA, Cincinnati, OH.

16. U.S. Environmental Protection Agency, 1975, Manual of Water Well Construction Practices. EPA-570/9-75-001. Office of Water Supply, U.S. EPA, Washington, DC.

17. U.S. Environmental Protection Agency, 1976, Quality Assurance Handbook for Air Pollution Measurement Systems. EPA-600/9-76-005. Environmental Monitoring and Support Laboratory, U.S. EPA, Research Triangle Park, NC.

18. U.S. Environmental Protection Agency, 1982, Test Methods for Evaluating Solid Waste, Physical/Chemical Methods. EPA Doc. No. SW-846. Office of Solid Waste and Emergency Response, U.S. EPA, Washington, DC.

19. U.S. Environmental Protection Agency, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document. EPA Doc. OSWER-9950.1. Office of Solid Waste and Emergency Response, U.S. EPA, Washington, DC.

20. U.S. Environmental Protection Agency, 1987, A Compendium of Superfund Field Operations Methods: Vols. 1 & 2 (Pre-print). EPA/540/P-87/001a. U.S. EPA, Washington, DC.

21. U.S. Department of the Navy. Naval Facilities Engineering Command, 1982, Soil Mechanics, NAVFAC DM-7.1.

22. Weston Geophysical Corp., 1983, "Geophysical Measurements - U.S. Department of Energy Raffinate Pit Site Weldon Spring, Missouri", and "Geophysical Survey--Vicinity of Raffinate Pits 3 & 4," in Geologic Report, Weldon Spring Raffinate Pit Site, Weldon Spring, Missouri by Bechtel National, Inc., November 1984, DOE/OR/20722-6.

23. Wroth, C.P., 1984, "The Interpretation of In Situ Soil Tests," Geotechique, 34 No. 4, Institution of Civil Engineers, London, U.K., pp. 449-489.

Appendix A

Summary of Valid Data From Previous Investigations

ENGINEERS
AND
CONSTRUCTORS

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT
ROUTE 2, HIGHWAY 94 SOUTH
ST. CHARLES, MISSOURI 63303
PHONE: (314) 441-8086

PROC-87-SM-318

August 14, 1987

ATTENTION: All Prospective Proposers

ADDENDUM NO. 01

TO

REQUEST FOR PROPOSAL NO. RFP-3589-WP028

GEOPHYSICAL INVESTIGATION

This Addendum No. 01 is issued in accordance with the Request For Proposal documents. Exact copies of this addendum have been sent to all subcontractors on the "Prospective Proposer's List".

The following modifications and/or clarifications are hereby incorporated into RFP-3589-WP028:

I. Delete in its entirety Specifications WP028, dated June 10, 1987. In its place incorporate Specifications WP028, dated August 7, 1987. The revised Specification WP028, dated August 7, 1987 reflects minor changes to Specification WP028, dated June 10, 1987. Revised sections of the Specification indicated by a vertical line in the right margin.

II. Delete in its entirety Technical Instructions to Proposers 3589-SC-WP028 dated July 7, 1987. In its place incorporate Technical Instructions to Proposers 3589-SC-WP028, dated August 7, 1987.

III. Attachment No. 1, enclosed herewith, provides additional information on the hydrogeological characteristics of the Weldon Spring Chemical Plant.

RfpAdNo1.txt

CORPS OF ENGINEERS (1955)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Compaction	Ferrelview Clay	DH-8	composite	max.=110.0 pcf Wopt=16.2%

HENRY M. REITZ (1964)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Atterberg Limits	Ferrelview Clay	TH-2	N/A (5'-6')	LL=50, PI=32
		TH-2	N/A (8.5'-9.5')	LL=59, PI=41
Compaction	Ferrelview Clay	TH-2	N/A (5'-6')	max=105.2 pcf, Wopt=17.5%
		TH-2	N/A (8.5'-9.5')	max=101.4 pcf, Wopt=18.5%

BECHTEL NATIONAL, INC. (1984)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Moisture Content	Ferrelview Clay	B-12	12	19.8%
		B-12	12	22.6
		B-13	5	21.2
		B-13	6	28.5
		B-13	7	22.8
		B-13	7	26.2
		B-13	8	23.9
		B-13	8	19.7
		B-13	8	24.0
		B-13	10	23.2
		B-13	11	24.1
		B-13	11	24.2
		B-15	9	27.4
		B-15	9	21.5
		B-15	10	21.6
	Clay Till	B-12	13	19.5%
		B-12	13	20.0
		B-12	13	21.8
		B-12	14	17.1
		B-12	14	18.7
		B-12	15	14.6
Dry Unit Weight	Ferrelview Clay	B-12	12	102.1 pcf
		B-12	12	101.1
		B-13	5	103.6
		B-13	6	91.9
		B-13	7	100.2
		B-13	7	98.3
		B-13	8	106.2
		B-13	8	99.9
		B-13	10	100.2
		B-13	11	100.4
		B-15	9	104.5
		B-15	10	96.0
	Clay Till	B-12	13	104.8 pcf
		B-12	13	103.7
		B-12	14	109.9
		B-12	14	100.6
		B-12	15	118.2

BECHTEL NATIONAL, INC. (1984)

(continued)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Specific Gravity	Ferrelview Clay	B-12	11	2.72
		B-13	8	2.81
		B-13	11	2.69
		B-15	9	2.71
	Clay Till	B-12	13	2.72
		B-12	15	2.75
Gradation	Ferrelview Clay	B-12	11	N/A
		B-13	5	N/A
		B-13	8	N/A
		B-13	11	N/A
		B-15	9	N/A
	Clay Till	B-12	13	N/A
		B-12	15	N/A
Atterberg Limits	Ferrelview Clay	B-12	11	LL=32, PI=13
		B-13	5	LL=42, PI=16
		B-13	8	LL=38, PI=22
		B-13	11	LL=66, PI=45
		B-15	9	LL=52, PI=29
	Clay Till	B-12	13	LL=56, PI=35
		B-12	15	LL=41, PI=24
Triaxial Shear Strength	Ferrelview Clay	B-15	9	C'=500 psf, Ø=29°
Triaxial Shear Strength (CU)	Ferrelview Clay	B-15	7 & 8	C'=300 psf, Ø=30° (C+Ø not plotted)

BECHTEL NATIONAL, INC. (1987)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Moisture Content	Ferrelview Clay	G-8	3	24.5%
		G-9	2	24.6
		GMW-3	ST-1	24.7
		GMW-7	ST-1	24.6
		GMW-12	ST-1	25.7
		GMW-13	ST-1	23.8
		GMW-15	ST-1	24.9
	Clay Till	G-5	ST-1	22.9%
		G-6	3	18.0
		G-8	6	16.9
		G-9	5	18.7
		G-19	2	16.9
		G-20	2	23.5
		G-21	ST-1	14.2
		GMW-4	ST-1	19.7
		GMW-5	ST-1	18.7
		GMW-6	ST-1	18.6
		GMW-8	ST-1	15.7
		GMW-10	ST-1	17.2
		GMW-11	ST-1	23.3
		GMW-14	ST-1	23.3
		GMW-18	ST-1	21.7
	Basal Till	GMW-1	ST-1	23.0%
		GMW-2	ST-1	23.1
		GMW-9	ST-1	16.5
Dry Unit Weight	Ferrelview Clay	G-8	3	115.1 pcf
		G-9	2	103.5
		GMW-3	ST-1	101.7
		GMW-7	ST-1	108.0
		GMW-13	ST-1	109.9
		GMW-15	ST-1	98.8
		GMW-17/G-10	SS-2	107.9
	Clay Till	G-5	ST-1	105.4 pcf
		G-6	3	110.6
		G-8	6	103.9
		G-9	5	107.3
		G-19	2	107.9
		G-20	2	96.7
		GMW-4	ST-1	102.9
		GMW-5	ST-1	113.4
		GMW-6	ST-1	104.7
		GMW-8	ST-1	100.3

BECHTEL NATIONAL, INC. (1987)
(continued)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Dry Unit Weight (continued)	Clay Till	GMW-10	ST-1	104.6
		GMW-11	ST-1	105.5
		GMW-14	ST-1	98.2
		GMW-18	ST-1	105.2
	Basal Till	G-15	7	104.8 pcf
		G-21	SS-5	99.4
		GMW-1	ST-1	86.5
		GMW-7	SS-9	103.6
		GMW-9	ST-1	104.8
Specific Gravity	Ferrelview Clay	G-8	3	2.53
		G-9	2	2.63
		G-14	1	2.45
		G-16	1	2.62
		GMW-3	SS-2	2.56
		GMW-3	ST-1	2.62
		GMW-7	ST-1	2.64
		GMW-12	ST-1	2.59
		GMW-13	ST-1	2.66
		GMW-15	ST-1	2.67
		GMW-18	SS-2	2.67
	Clay Till	G-5	ST-1	2.43
		G-6	1	2.67
		G-6	3	2.65
		G-8	6	2.61
		G-9	5	2.60
		G-19	2	2.68
		G-20	2	2.67
		G-21	ST-1	2.64
		GMW-4	ST-1	2.46
		GMW-5	ST-1	2.62
		GMW-6	ST-1	2.66
		GMW-11	ST-1	2.55
		GMW-13	SS-4	2.68
		GMW-14	ST-1	2.68
		GMW-15	SS-6	2.68
		GMW-17/G-10	SS-4	2.62
		GMW-18	ST-1	2.55
	Basal Till	GMW-1	ST-1	2.45

BECHTEL NATIONAL, INC. (1987)
(continued)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Gradation	Ferrelview Clay	G-8	1	N/A
		G-8	3	N/A
		G-9	2	N/A
		GMW-3	SS-2	N/A
		GMW-3	ST-1	N/A
		GMW-7	ST-1	N/A
		GMW-12	ST-1	N/A
		GMW-13	ST-1	N/A
		GMW-15	ST-1	N/A
		GMW-18	SS-1	N/A
	Clay Till	G-5	ST-1	N/A
		G-5	SS-3	N/A
		G-6	3	N/A
		G-8	6	N/A
		G-9	5	N/A
		G-19	2	N/A
		G-20	2	N/A
		G-21	ST-1	N/A
		GMW-4	ST-1	N/A
		GMW-4	SS-4	N/A
		GMW-5	ST-1	N/A
		GMW-6	ST-1	N/A
		GMW-7	SS-6	N/A
		GMW-8	ST-1	N/A
		GMW-10	ST-1	N/A
		GMW-11	ST-1	N/A
		GMW-14	ST-1	N/A
		GMW-18	ST-1	N/A
	Basal Till	G-15	7	N/A
		G-21	SS-5	N/A
		GMW-1	ST-1	N/A
		GMW-2	ST-1	N/A
		GMW-7	SS-9	N/A
		GMW-9	ST-1	N/A

BECHTEL NATIONAL, INC. (1987)
(continued)

Laboratory Test	Soil Type	Borehole No.	Sample No.	Test Results
Atterberg Limits	Ferrelview Clay	G-8	3	LL=49, PI=33
		G-9	2	LL=40, PI=23
		G-21	SS-2	LL=63, PI=43
		GMW-3	SS-2	LL=55, PI=41
		GMW-7	ST-1	LL=55, PI=37
		GMW-12	ST-1	LL=50, PI=32
		GMW-13	ST-1	LL=45, PI=28
		GMW-15	ST-1	LL=61, PI=44
	Clay Till	G-5	ST-1	LL=53, PI=36
		G-6	3	LL=46, PI=29
		G-8	6	LL=47, PI=31
		G-9	5	LL=50, PI=34
		G-19	2	LL=41, PI=27
		G-20	2	LL=62, PI=43
		G-21	ST-1	LL=42, PI=29
		GMW-3	SS-4	LL=81, PI=56
		GMW-4	ST-1	LL=48, PI=33
		GMW-5	ST-1	LL=44, PI=29
		GMW-6	ST-1	LL=42, PI=28
		GMW-8	ST-1	LL=44, PI=28
		GMW-10	ST-1	LL=39, PI=23
		GMW-11	ST-1	LL=58, PI=44
		GMW-14	ST-1	LL=53, PI=39
		GMW-18	ST-1	LL=44, PI=39
	Basal Till	G-21	SS-5	LL=35, PI=19
		GMW-1	ST-1	LL=66, PI=43
		GMW-2	ST-1	LL=35, PI=16
		GMW-5	SS-5	LL=31, PI=14
		GMW-9	ST-1	LL=41, PI=26

Appendix B

Specifications WP024-01 and WP024-02, Geotechnical Drilling and Sampling Characterization

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

SPECIFICATIONS WP024-01

SUBCONTRACT NO. 3589-SC-WP024

GEOTECHNICAL DRILLING AND SAMPLING CHARACTERIZATION

MK-FERGUSON COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT

ST. CHARLES, MISSOURI

06/10/87

SPECIFICATION 3589-SC-WP024
SECTION NO. 01
WELDON SPRING SITE

GEOTECHNICAL DRILLING AND SAMPLING CHARACTERIZATION PROJECT

1.0 SCOPE AND OBJECTIVES

The purpose of the work is to determine the geotechnical characteristics of the soils by drilling and standard soils sampling.

This project is conducted by MK-Ferguson company (MK-F), to collect soils data at Weldon Spring Site Remedial Action Project.

2.0 LOCATION

The site is in St. Charles County, Missouri approximately 30 miles west of St. Louis, Missouri, as shown on Figures 1 and 2.

3.0 PROJECT SUPERVISION

All technical activities shall be under the supervision of the MK-Ferguson Co. (MK-F) Construction Engineer (CE). No work shall commence without the Contractor's approval.

4.0 DRILLING AND SAMPLING

4.1 General

Drilling for this subcontract is subject to the specification clauses contained in Section No. 02 of this Subcontract.

4.2 Site Conditions

4.2.1 Surface

The surface conditions on the site and in the area immediately west of the building area is relatively flat and vegetated with grasses. These areas are readily accessible by existing, improved dirt roads and paved roads and thus access problems should be minimal in the area. However, there may be areas of soft soils which will require working pads (see Section No. 02, Paragraph 6.0). Every effort will be made by MK-F to avoid drilling in locations with poor access.

4.2.2 Subsurface

Based on the best available information for the project area, the natural soils consist of 30 to 50 feet of silts and clays which overlie limestone bedrock.

4.3 Hole Location and Depths

This project is exploratory in nature. Test pit and boring locations may be anywhere within the area shown in Figure 2 of Section 02, other than areas covered by structures or paving. A total of ten (10) borings shall be drilled to an approximate depth of 50 feet (50') but shall not penetrate competent bedrock.

4.4 Sampling

Borings shall be advanced with conventional geotechnical exploratory equipment as outlined in Section No. 02. Soil sampling shall be continuous as outlined in Section No. 02.

The Sampling intervals in the overburden will be at two and one half feet (2-1/2') on center and then every five feet (5') on center past a depth of forty feet (40'). Sampling shall consist of Standard Penetration Tests (SPT), and at the discretion of the Contractor, Shelby tube or Ring Lined Split Barrel samples will be substituted for SPT sampling at certain sample intervals.

4.5 Test Pits

The Subcontractor shall supply a track or tractor mounted backhoe with a two foot (2') wide bucket capable of excavating to depths of twelve feet (12'). During the excavation of the test pits, the subcontractor shall segregate the top one foot (1') of topsoil from other excavated soils while minimizing the area of disturbance. The Subcontractor shall carefully replace excavated soils following completion of sampling in the test pits and replace the topsoil as the topmost layer of the backfill.

4.6 Soils Logging and Supervision

Soils logging, sampling, and drilling monitoring will be performed by the Contractor.

4.7 Health Physics

The Contractor shall provide industrial hygiene and/or health physics support, as appropriate, during all field operations in areas of radiological and/or chemical contamination.

The Subcontractor shall comply with all applicable Federal, State, and local health and safety regulations and requirements, including, but not limited to, those established pursuant to the Occupational Safety and Health Act (OSHA) and the WSSRA Project Safety and Health Plan.

4.8 Quality Assurance

The Contractor shall direct all fieldwork. Periodic Quality Assurance Surveillance will be performed by the Contractor to verify compliance with specification requirements.

4.9 Permits

The Subcontractor shall abide by the requirements contained in any required permits, letters of authorization, and environmental laws which are applicable to the data collection project. Copies of the applicable documents shall be transmitted to the Subcontractor by the Contractor prior to the start of fieldwork.

4.10 Site Restoration

The Subcontractor shall reclaim areas disturbed by drilling and test pitting activities performed under this subcontract.

4.10.1 All disturbed areas shall be recontoured to approximate original contours.

4.10.2 The Subcontractor shall purchase an appropriate seed mixture, spread this seed mixture over the disturbed areas, and lightly rake the seed into the surface.

SPECIFICATION 3589-SC-WP024

SECTION NO. 02

SCOPE OF WORK

WELDON SPRING SITE
GEOTECHNICAL DRILLING SPECIFICATIONS

TABLE OF CONTENTS

Specification Section		Page
1.0	DRILL RIG EQUIPMENT AND CAPABILITIES	6
2.0	SOIL SAMPLING STANDARDS, METHODS AND MATERIALS	6
2.1	Standards	6
2.2	Methods	6
2.2.1	Standard Penetration Tests (SPT)	6
2.2.2	Shelby Tube Samples	7
2.2.3	Ring Lined Split Barrel	7
2.3	Sample Handling	7
2.4	Materials	8
2.4.1	Subcontractor Furnished Material	8
3.0	DRILLING FLUIDS AND ADDITIVES	9
4.0	INSTALLATION OF PIEZOMETERS	9
5.0	WORKING PADS	9
6.0	FIELD DOCUMENTATION	10
7.0	DECONTAMINATION EQUIPMENT AND PROCEDURES	10
8.0	PERMITS	10
9.0	LEGAL ACCESS	10

SPECIFICATION 3589-SC-WP024
SECTION NO. 2

GEOTECHNICAL DRILLING SPECIFICATIONS

1.0 DRILL RIG EQUIPMENT AND CAPABILITIES

A drilling rig used for soil sampling shall be capable of drilling in clayey or granular soil, above or below the water table. It shall be able to conduct standard penetration tests (SPT) and push Shelby tubes. A hollow stem auger rig equipped for rotary/mud drilling satisfies the requirements of this Specification. Any change in the proposed drilling rig capabilities or other equipment must be approved in writing by the Contractor.

The Subcontractor must supply the three inch (3") outside diameter (O.D.), two and one half inch (2-1/2") inside diameter (I.D.), and twenty-four inch (24") long tube, ring lined split barrel samplers. This sampler shall be designed to accepting a 2.5" O.D. by 6" long brass tube having a 0.042 wall thickness.

2.0 SOIL SAMPLING STANDARDS, METHODS AND MATERIALS

2.1 Standards

The subcontractor's equipment must be capable of performing soil sampling using all sampling techniques and equipment in accordance with the latest American Society for Testing and Materials (ASTM) Standard. Copies of these standards are available from MK-F upon request. These include:

- ASTM D1586 - Standard Penetration Test (SPT).
- ASTM D1587 - Shelby tube sampling.
- ASTM D3550 - Ring-lined barrel sampling.

2.2 Methods

2.2.1 Standard Penetration Tests (SPT)

These tests shall be performed according to the ASTM D1586 method. The recovered SPT samples shall be sealed in airtight "olive sized" (8 ounce or larger) plastic jars, immediately on removal from the drill hole.

2.2.2 Shelby Tube Samples

Samples shall be obtained by pushing a new three (3") inch O.D. x thirty-six (36") inch long Shelby tube beneath the lead hollow-stem auger, into undisturbed ground, to its usable length or to a point of refusal. A constant smooth hydraulic pressure shall be applied as necessary to penetrate the material being sampled. Upon removal from the hole, the loaded Shelby tube shall be removed from sampler head and sealed with wax and end caps or as directed by the Contractor.

2.2.3 Ring Lined Split Barrel Samples

Samplers shall be pushed in the manner similar to that used in Shelby tube sampling, where possible. Immediately upon removal from the hole, the split barrel samplers shall be capped and taped. All brass tubes for each sample shall be retained in this manner.

2.3 Sample Handling

The Subcontractor shall place all contained samples (Shelby Tubes), neatly and carefully, in the immediate vicinity of the drill site, as directed by the Contractor. The Contractor will be responsible for labeling and shipping all samples. The Subcontractor shall assist the Contractor in handling and opening split spoons and hand samples to the Contractor for packaging and labeling.

2.4 Materials

2.4.1 Subcontractor Furnished Material

The following items will be provided by the Subcontractor for the Weldon Spring Site drilling and sampling program.

Item	Quantity	Description
1	160	Plastic jars for SPT samples, 8 ounces or larger, olive size.
2	25	Shelby tubes, three inch (3") outside diameter (O.D.) by thirty-six inches (36") long, with wax and end caps.
3	140	Brass tubes (liner), two and one half (2 1/2") inches O.D. by six (6") inches long, 0.042" wall thickness, with caps, tape and storage boxes.
4	230'	PVC, two inch (2") Schedule 40, flush-jointed, threaded, slotted 0.010" screen.
5	50'	PVC, two inch (2"), Schedule 40, flush-jointed, threaded riser
6	6	PVC slip caps
7	6	PVC Bottom plugs for piezometers
8	1000 lbs.	Bentonite pellets, 1/4" to 1/2" diameter, minimum 90% montmorillonite.
9	6	Filter pack, clean coarse silica sand. (20 to 40 mesh)

3.0 DRILLING FLUIDS AND ADDITIVES

All drilling fluids and additives must be approved by the Contractor prior to their use. Where the potential exists for drilling fluids and/or additives to contaminate existing surface or ground water, such fluids/additives shall be contained at each drill site and disposed of as directed by the Contractor.

4.0 INSTALLATION OF PIEZOMETERS

The Subcontractor shall, upon reaching bedrock, install a two inch (2") diameter piezometer according to the following specifications.

The hole shall be backfilled with bentonite pellets - 1/4 to 1/2 inch diameter having a minimum purity of 90% montmorillonite as specified by the American Colloid Company or equivalent from the top of competent bedrock to five feet (5') above the bottom of the glacial till. These pellets shall be placed through the augers in five foot (5') lifts (maximum) and hydrated with Contractor approved water.

After the final lift of bentonite pellets has hydrated, the Subcontractor shall install a 2 inch (2") inside diameter piezometer. This piezometer shall be constructed of 2 inch (2") Schedule 40 PVC, flush-threaded, factory slotted (0.010") screen and riser. The screen shall extend from the top of the bentonite plug to within five feet (5') of the surface. All screen and riser shall be placed through the augers. After the screen and riser are in place, the Subcontractor shall install a sand pack as the augers are removed. This sand pack shall extend from the bottom of the screen to one foot (1') above the top of the screen. The filter pack shall consist of a clean coarse silica sand (WB-40 or equivalent). After the filter pack is in place, the remainder of the annular space shall be sealed using the previously specified bentonite pellets. The riser pipe shall extend between 2 and 3 feet above the grade and be covered with a PVC slip cap.

5.0 WORKING PADS

It is anticipated that the surface soils may be soft in certain areas. In these areas, working pads shall be supplied and constructed by the Subcontractor from portable loading mats. The dimensions of the pads shall be limited to those required to support the drill rig and provide working space in order to limit displacement of soft soils.

6.0 FIELD DOCUMENTATION

The CE shall maintain a "Daily Field Activity Report" (a sample copy is attached to Section 02 as Figure 3) detailing billable drilling work. The Subcontractor is required to initial this report on a daily basis and note any differences that cannot be resolved. Any differences shall be documented for future reviews and resolution between the Subcontract Administrator and Subcontractor.

7.0 DECONTAMINATION EQUIPMENT AND PROCEDURES

Augers and downhole tools shall be thoroughly washed/cleaned before moving to a new hole or demobilizing from the site by the Subcontractor. These augers and tools will then be inspected by MK-F personnel before being returned to service or demobilization by the Subcontractor. MK-F shall be responsible for furnishing all potable water and cleaning equipment to decontaminate drilling equipment. Any necessary decontamination work shall be performed at the stipulated standby time (hourly rate).

8.0 PERMITS

The Subcontractor shall abide by the requirements contained in any required permits, letters of authorization, and environmental laws which are applicable to the data collection project.

9.0 LEGAL ACCESS

The Contractor will be responsible for and provide legal access Agreements and permits (if applicable) for the drilling locations. It will be the Subcontractor's responsibility to comply with the terms of the access agreements and permits which the Contractor will provide to the Subcontractor prior to commencement of work.

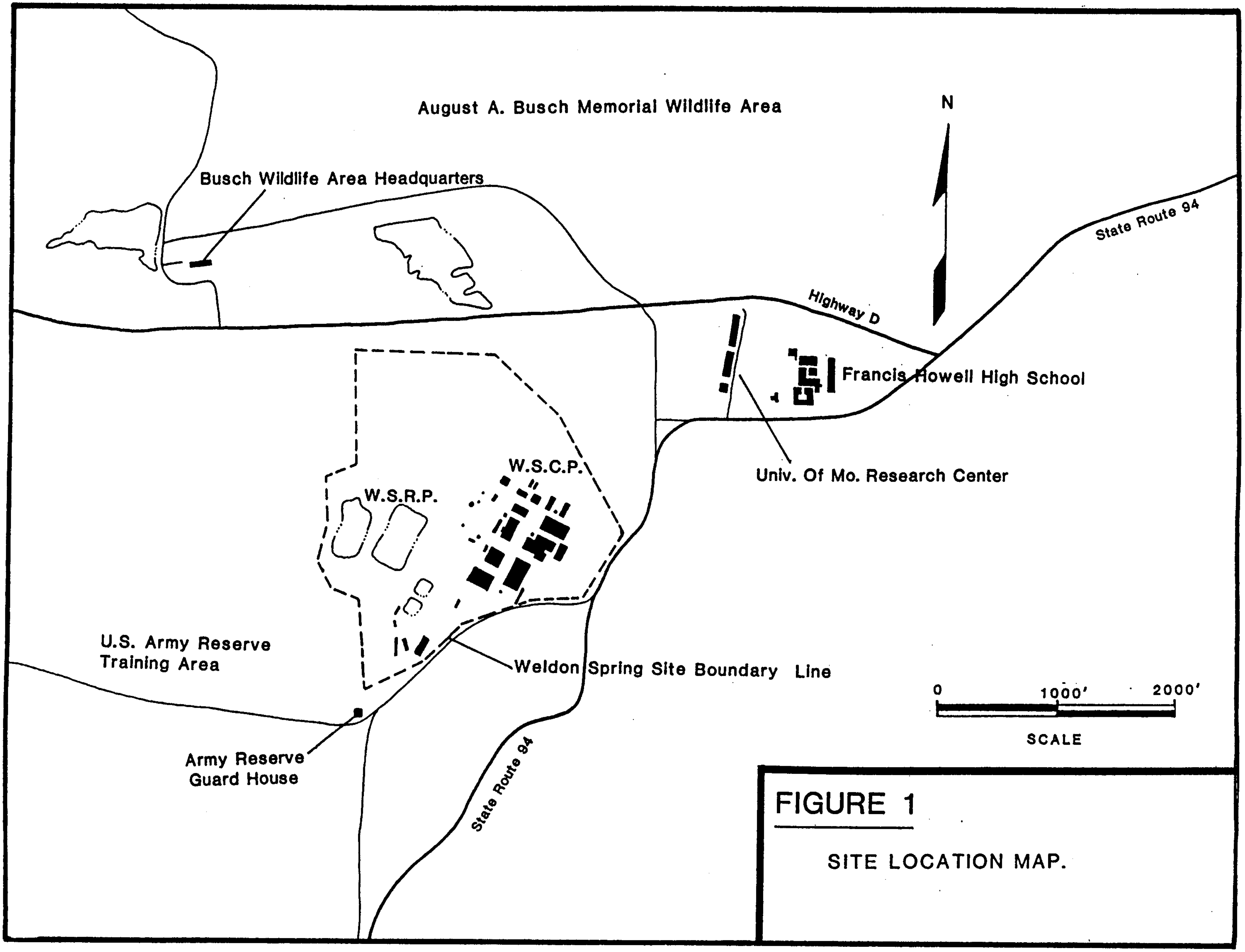


FIGURE 1

SITE LOCATION MAP.

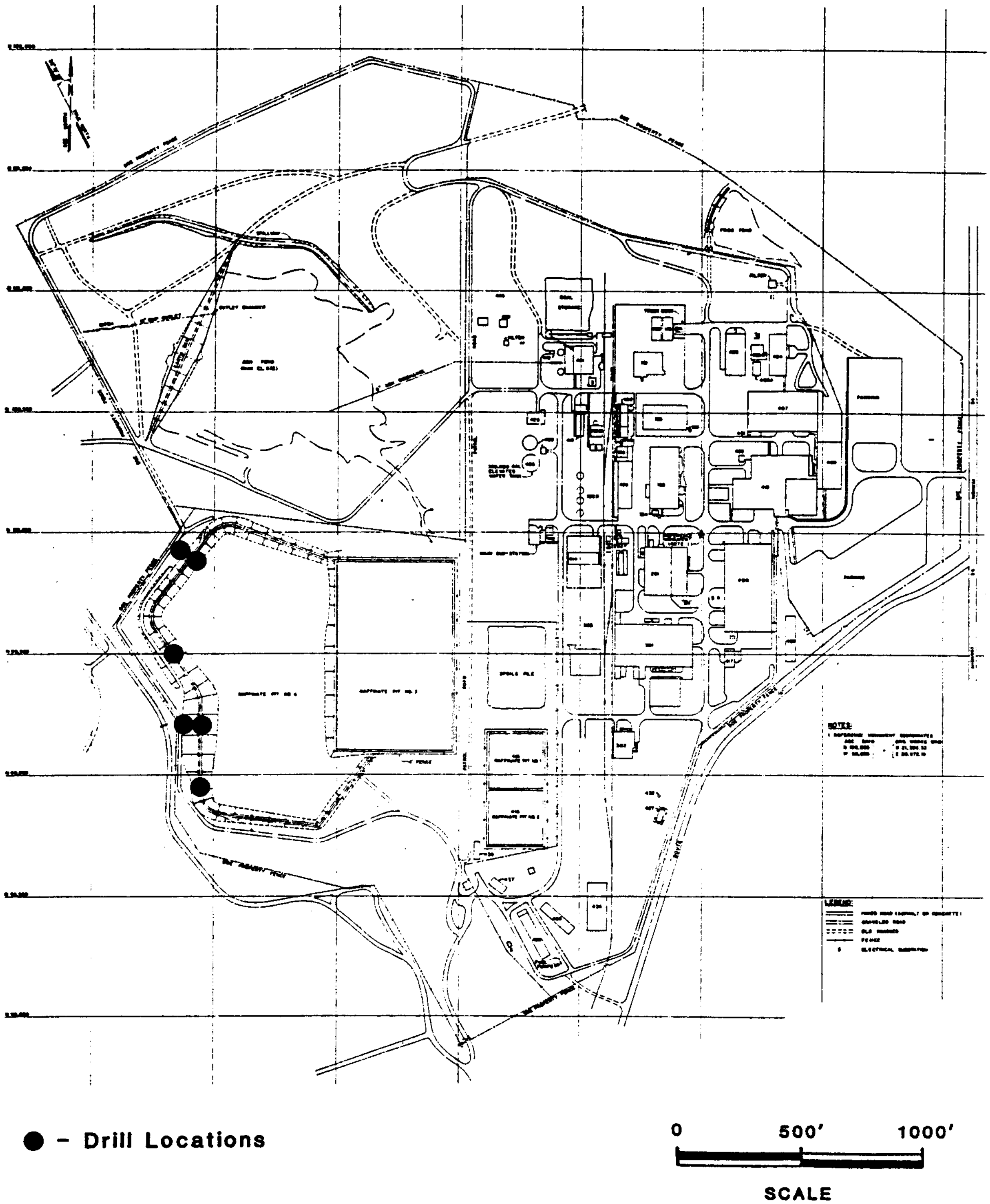


Figure 2

Geotechnical Sample Locations

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

DAILY FIELD ACTIVITY REPORT

SITE NAME : ____________ CONTRACT NO. : ____________ WEEK OF : ____________

F.T.R. : ________________________________ SUBCONTRACTOR : ____________

BILLABLE WORK	ITEM NO.	DATE / UNITS	MON.	TUES.	WED.	THUR.	FRI.	SAT.	SUN.	WEEKLY SUMMARY
F.T.R. INITIALS :										
SUBCONTRACTOR INITIALS :										

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

SPECIFICATIONS WP024-02

SUBCONTRACT NO. 3589-SC-WP024

GEOTECHNICAL DRILLING AND SAMPLING OF PIT 4 DIKE

MK-FERGUSON COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT

ST. CHARLES, MISSOURI

06/10/87

SPECIFICATION 3589-SC-WP024-02
SECTION NO. 01
WELDON SPRING SITE

GEOTECHNICAL DRILLING AND SAMPLING OF PIT 4 DIKE

1.0 SCOPE AND OBJECTIVES

The purpose of the work is to determine the geotechnical characteristics of the soils by drilling and standard soils sampling. Piezometer installation will provide a means to monitor the phreatic surface through the dike.

This project is conducted for MK-Ferguson Company (MK-F), to collect soils data at Weldon Spring Site Remedial Action Project.

2.0 LOCATION

The site is in St. Charles County, Missouri approximately 30 miles west of St. Louis, Missouri, as shown on Figures 1 and 2.

3.0 PROJECT SUPERVISION

All technical activities shall be under the supervision of the MK-Ferguson Co. (MK-F) Construction Engineer (CE). No work shall commence without the Contractor's approval.

4.0 DRILLING AND SAMPLING

4.1 General

Drilling for this subcontract is subject to the specification clauses contained in Section No. 02 of this Subcontract.

4.2 Site Conditions

4.2.1 Surface

The surface conditions on and at the toe of the dike of pit 4 varies from gravel packed to vegetated with grasses. The crest of the dike ranges in width from eight (8) to twenty feet (20'). The outer slope of the embankment is 2:1. The inner slope is fenced and the pit contains radiologically contaminated water. The area is readily accessible by improved dirt roads and paved roads and thus access problems should be minimal.

However, there may be areas of soft soils which will require working pads (see Section No. 02, Paragraph 6.0). Every effort will be made by MK-F to avoid drilling in locations with poor access.

4.2.2 Subsurface

Based on the best available information for the project area, the natural soils consist of 25 to 30 feet of silts and clays which overlie limestone bedrock. The dike rises approximately 25' above the surrounding terrain.

4.3 Hole Location and Depths

This project is exploratory in nature. Boring locations are shown in Figure 2 of Section 02. A total of six (6) borings shall be drilled; two (2) at the toe and four (4) on the crest of the dike, to an approximate depth of 30 to 60 feet but shall not penetrate competent bedrock.

4.4 Sampling

Borings shall be advanced with conventional geotechnical exploratory equipment as outlined in Section No. 02. Soil sampling shall be continuous as outlined in Section No. 02.

The Sampling intervals in the dike will be continuous and through the foundation soils at five feet (5') on center. Sampling shall consist of Standard Penetration Tests (SPT), and at the discretion of the Contractor, Shelby tube or Ring Lined Split Barrel samples will be substituted for SPT sampling at certain sample intervals.

4.5 Soils Logging and Supervision

Soils logging, sampling, and drilling monitoring be performed by the CE.

4.6 Health Physics

The Contractor shall provide industrial hygiene and/or health physics support, as appropriate, during all field operations in areas of radiological and/or chemical contamination.

The Subcontractor shall comply with all applicable Federal, State, and local health and safety regulations and requirements, including, but not limited to, those established pursuant to the Occupational Safety and Health Act (OSHA) and the WSSRA Project Safety and Health Plan.

4.7 Quality Assurance

The CE shall direct all fieldwork. Periodic Quality Assurance Surveillance will be performed by the Contractor to verify compliance with specification requirements.

4.8 Permits

The Subcontractor shall abide by the requirements contained in any required permits, letters of authorization, and environmental laws which are applicable to the data collection project. Copies of the applicable documents shall be transmitted to the Subcontractor by the Contractor prior to the start of fieldwork.

4.9 Site Restoration

The Subcontractor shall reclaim areas disturbed by drilling activities performed under this subcontract. All disturbed areas shall be recontoured to approximate original contours. Seeding is specified as follows.

4.9.1 All disturbed areas shall be recontoured to approximate original contours.

4.9.2 The Subcontractor shall purchase and apply an appropriate seed mixture, and rake into disturbed areas.

SPECIFICATION 3589-SC-WP024

SECTION NO. 02

SCOPE OF WORK

WELDON SPRING SITE
GEOTECHNICAL DRILLING SPECIFICATIONS

TABLE OF CONTENTS

Specification Section | Page

1.0 DRILL RIG EQUIPMENT AND CAPABILITIES 6

2.0 SOIL SAMPLING STANDARDS, METHODS AND MATERIALS 6
2.1 Standards 6
2.2 Methods 6
2.2.1 Standard Penetration Tests (SPT) 6
2.2.2 Shelby Tube Samples 7
2.2.3 Ring Lined Split Barrel 7
2.3 Sample Handling 7
2.4 Materials 8
2.4.1 Subcontractor Furnished Material 8

3.0 DRILLING FLUIDS AND ADDITIVES 9

4.0 INSTALLATION OF PIEZOMETERS............................. 9

5.0 WORKING PADS 9

6.0 FIELD DOCUMENTATION 10

7.0 DECONTAMINATION EQUIPMENT AND PROCEDURES 10

8.0 PERMITS 10

9.0 LEGAL ACCESS 10

GEOTECHNICAL DRILLING SPECIFICATIONS

1.0 DRILL RIG EQUIPMENT AND CAPABILITIES

A drilling rig used for soil sampling shall be capable of drilling in clayey or granular soil, above or below the water table. It shall be able to conduct standard penetration tests (SPT) and push Shelby tubes. A hollow stem auger rig equipped for rotary/mud drilling satisfies the requirements of this Specification. Any change in the proposed drilling rig capabilities or other equipment must be approved in writing by the Contractor.

The Subcontractor must supply the three inch (3") outside diameter (O.D.), two and one half inch (2-1/2") inside diameter (I.D.), and twenty-four inch (24") long tube, ring lined split barrel samplers. This sampler shall be designed to accepting a 2.5" O.D. by 6" long brass tube having a 0.042 wall thickness.

2.0 SOIL SAMPLING STANDARDS, METHODS AND MATERIALS

2.1 Standards

The subcontractor's equipment must be capable of performing soil sampling using all sampling techniques and equipment in accordance with the latest American Society for Testing and Materials (ASTM) Standard. Copies of these standards are available from MK-F upon request. These include:

- ASTM D1586 - Standard Penetration Test (SPT).
- ASTM D1587 - Shelby tube sampling.
- ASTM D3550 - Ring-lined barrel sampling.

2.2 Methods

2.2.1 Standard Penetration Tests (SPT)

These tests shall be performed according to the ASTM D1586 method. The recovered SPT samples shall be sealed in airtight "olive sized" (8 ounce or larger) plastic jars, immediately on removal from the drill hole.

2.2.2 Shelby Tube Samples

Samples shall be obtained by pushing a new three (3") inch O.D. x thirty-six (36") inch long Shelby tube beneath the lead hollow-stem auger, into undisturbed ground, to its usable length or to a point of refusal. A constant smooth hydraulic pressure shall be applied as necessary to penetrate the material being sampled. Upon removal from the hole, the loaded Shelby tube shall be removed from sampler head and sealed with wax and end caps or as directed by the Contractor.

2.2.3 Ring Lined Split Barrel Samples

Samplers shall be pushed in the manner similar to that used in Shelby tube sampling, where possible. Immediately upon removal from the hole, the split barrel samplers shall be capped and taped. All brass tubes for each sample shall be retained in this manner.

2.3 Sample Handling

The Subcontractor shall place all contained samples (Shelby Tubes), neatly and carefully, in the immediate vicinity of the drill site, as directed by the Contractor. The Contractor will be responsible for labeling and shipping all samples. The Subcontractor shall assist the Contractor in handling and opening split spoons and hand samples to the Contractor for packaging and labeling.

2.4 Materials

2.4.1 Subcontractor Furnished Material

The following items will be provided by the Subcontractor for the Weldon Spring Site drilling and sampling program.

Item	Quantity	Description
1	160	Plastic jars for SPT samples, 8 ounces or larger, olive size.
2	25	Shelby tubes, three inch (3") outside diameter (O.D.) by thirty-six inches (36") long, with wax and end caps.
3	140	Brass tubes (liner), two and one half (2 1/2") inches O.D. by six (6") inches long, 0.042" wall thickness, with caps, tape and storage boxes.
4	230'	PVC, two inch (2") Schedule 40, flush-jointed, threaded, slotted 0.010" screen.
5	50'	PVC, two inch (2"), Schedule 40, flush-jointed, threaded riser
6	6	PVC slip caps
7	6	PVC Bottom plugs for piezometers
8	1000 lbs.	Bentonite pellets, 1/4" to 1/2" diameter, minimum 90% montmorillonite.
9	6	Filter pack, clean coarse silica sand. (20 to 40 mesh)

3.0 DRILLING FLUIDS AND ADDITIVES

All drilling fluids and additives must be approved by the Contractor prior to their use. Where the potential exists for drilling fluids and/or additives to contaminate existing surface or ground water, such fluids/additives shall be contained at each drill site and disposed of as directed by the Contractor.

4.0 INSTALLATION OF PIEZOMETERS

The Subcontractor shall, upon reaching bedrock, install a two inch (2") diameter piezometer according to the following specifications.

The hole shall be backfilled with bentonite pellets - 1/4 to 1/2 inch diameter having a minimum purity of 90% montmorillonite as specified by the American Colloid Company or equivalent from the top of competent bedrock to five feet (5') above the bottom of the glacial till. These pellets shall be placed through the augers in five foot (5') lifts (maximum) and hydrated with Contractor approved water.

After the final lift of bentonite pellets has hydrated, the Subcontractor shall install a 2 inch (2") inside diameter piezometer. This piezometer shall be constructed of 2 inch (2") Schedule 40 PVC, flush-threaded, factory slotted (0.010") screen and riser. The screen shall extend from the top of the bentonite plug to within five feet (5') of the surface. All screen and riser shall be placed through the augers. After the screen and riser are in place, the Subcontractor shall install a sand pack as the augers are removed. This sand pack shall extend from the bottom of the screen to one foot (1') above the top of the screen. The filter pack shall consist of a clean coarse silica sand (WB-40 or equivalent). After the filter pack is in place, the remainder of the annular space shall be sealed using the previously specified bentonite pellets. The riser pipe shall extend between 2 and 3 feet above the grade and be covered with a PVC slip cap.

5.0 WORKING PADS

It is anticipated that the surface soils may be soft in certain areas. In these areas, working pads shall be supplied and constructed by the Subcontractor from portable loading mats. The dimensions of the pads shall be limited to those required to support the drill rig and provide working space in order to limit displacement of soft soils.

6.0 FIELD DOCUMENTATION

The CE shall maintain a "Daily Field Activity Report" (a sample copy is attached to Section 02 as Figure 3) detailing billable drilling work. The Subcontractor is required to initial this report on a daily basis and note any differences that cannot be resolved. Any differences shall be documented for future reviews and resolution between the Subcontract Administrator and Subcontractor.

7.0 DECONTAMINATION EQUIPMENT AND PROCEDURES

Augers and downhole tools shall be thoroughly washed/cleaned before moving to a new hole or demobilizing from the site by the Subcontractor. These augers and tools will then be inspected by MK-F personnel before being returned to service or demobilization by the Subcontractor. MK-F shall be responsible for furnishing all potable water and cleaning equipment to decontaminate drilling equipment. Any necessary decontamination work shall be performed at the stipulated standby time (hourly rate).

8.0 PERMITS

The Subcontractor shall abide by the requirements contained in any required permits, letters of authorization, and environmental laws which are applicable to the data collection project.

9.0 LEGAL ACCESS

The Contractor will be responsible for and provide legal access Agreements and permits (if applicable) for the drilling locations. It will be the Subcontractor's responsibility to comply with the terms of the access agreements and permits which the Contractor will provide to the Subcontractor prior to commencement of work.

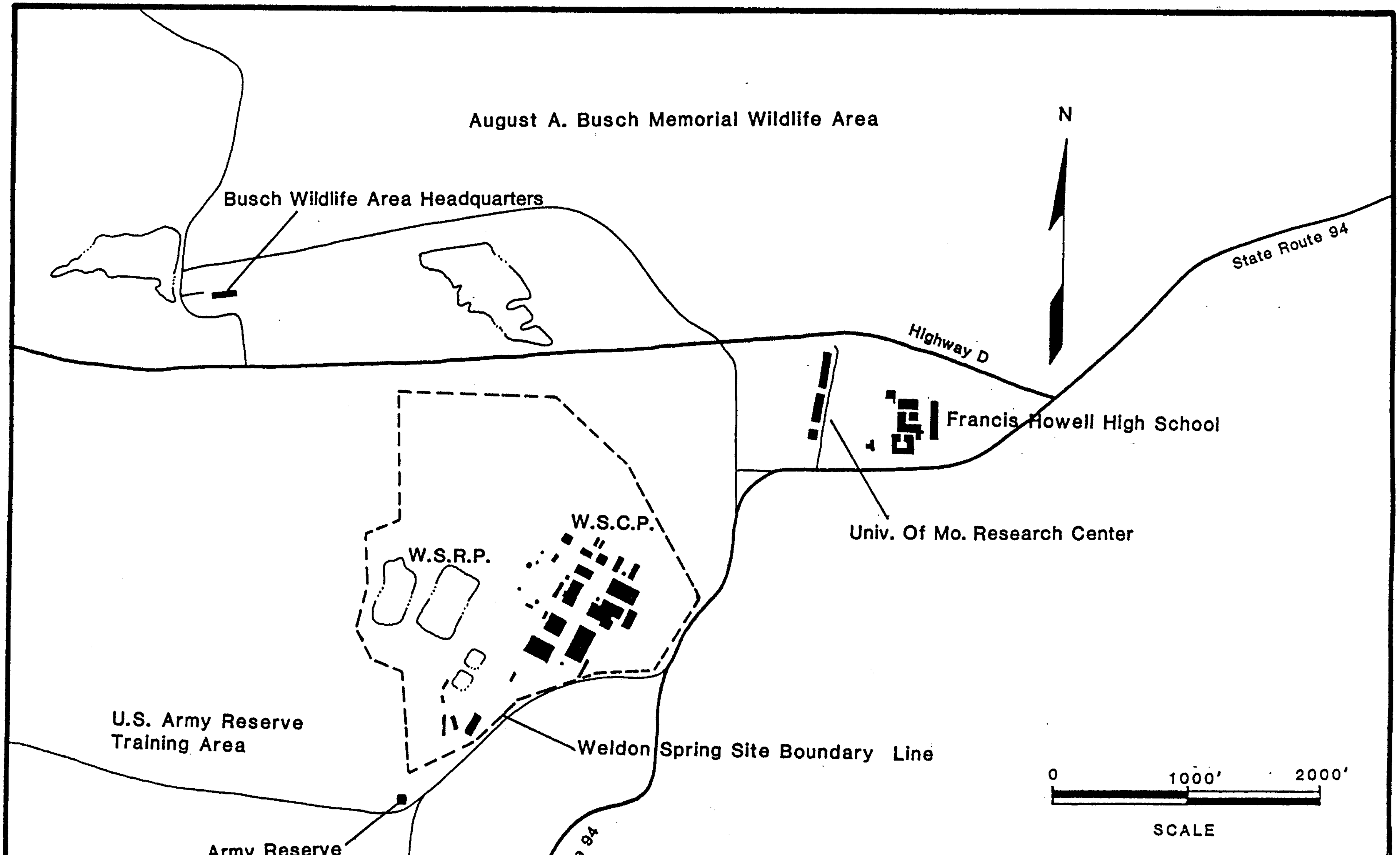


FIGURE 1

SITE LOCATION MAP.

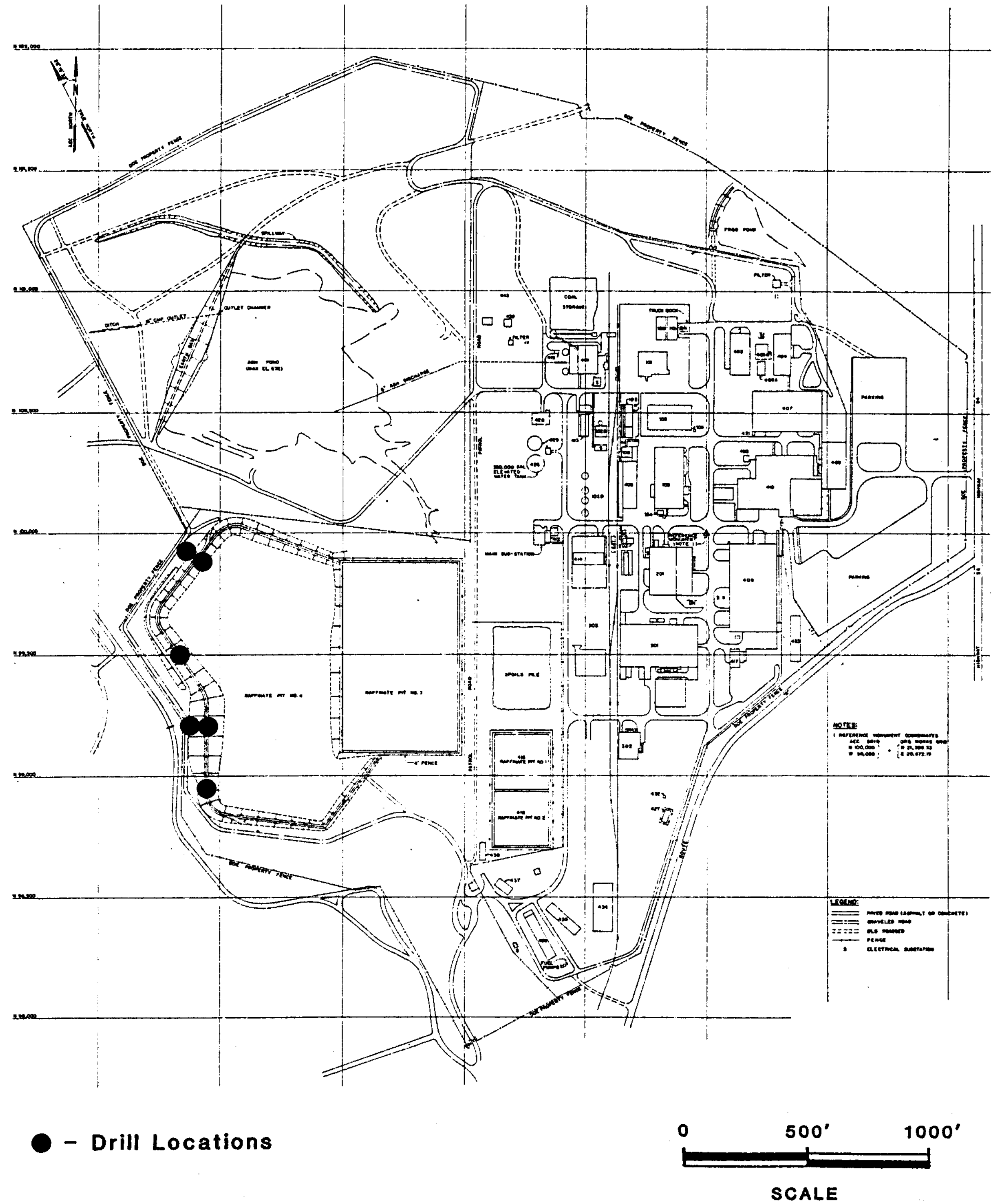


Figure 2

Geotechnical Sample Locations

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

DAILY FIELD ACTIVITY REPORT

SITE NAME : ____________ CONTRACT NO. : ____________ WEEK OF : ____________

F.T.R. : ______________________________ SUBCONTRACTOR : ____________

BILLABLE WORK	ITEM NO.	DATE / UNITS	MON.	TUES.	WED.	THUR.	FRI.	SAT.	SUN.	WEEKLY SUMMARY
F.T.R. INITIALS :										
SUBCONTRACTOR INITIALS :										

Appendix C

Addendum No. 01 to WP024

ENGINEERS
AND
CONSTRUCTORS

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT
ROUTE 2, HIGHWAY 94 SOUTH
ST. CHARLES, MISSOURI 63303
PHONE: (314) 441-8086

PROC-87-SM-298

July 17, 1987

ATTENTION: All Prospective Proposers

ADDENDUM NO. 01

TO

REQUEST FOR PROPOSAL NO. RFP-3589-WP024

GEOTECHNICAL DRILLING AND SAMPLING CHARACTERIZATION

This Addendum No. 01 is issued in accordance with the Request For Proposal documents. Exact copies of this addendum have been sent to all subcontractors on the "Prospective Proposer's List".

The following modifications and/or clarifications are hereby incorporated into RFP-3589-WP024:

I. Add to Specification WP024-01 Section 4.5 Test Pits:

No individuals are to be in any of the test pits, therefore, no shoring is required.

II. Revision to Specifiction WP024-01 Section 2.2 Methods:

Did read:
3.2.1 Standard Penetration Tests (SPT)

Shall now read:
2.2.1 Standard Penetration Test (SPT)

III. Clarification to Specification WP024-01. Section 2.2.1 does state the required method. Tests shall be performed according to the ASTM D1586 method.

WP024ADD.txt

IV. Clarification to Specification WP024-01. Section 2.2.2 does state the required method.

Samples shall be obtained by pushing a new three (3") inch O.D. x thirty-six (36") inch long Shelby tube beneath the lead hollow-stem auger, into undisturbed ground, to its usable length or to a point of refusal.

V. Revision to Specification WP024-01 Section 4.3 <u>Hole Location and Depths</u>.

4.3 Did read:
This project is exploratory in nature. Test pit and boring locations may be anywhere within the area shown in Figure 2 of Section 02, other than areas covered by structures or paving. A total of ten (10) borings shall be drilled to an approximate depth of 50 feet (50') but shall not penetrate competent bedrock.

4.3 Shall now read:
This project is exploratory in nature. Test pit and boring locations may be anywhere within the area shown in Figure 2 of Section 02, other than areas covered by structures. Approximately six inches (6") of concrete covers only one (1) of the boring locations. A total of ten (1) borings shall be drilled to an approximate depth of 50 feet (50') but shall not penetrate competent bedrock.

The due date and hour for proposals under this Request for Proposal remains scheduled for Wednesday, July 29, 1987 at 3:00 p.m. local time. Proposals may be hand-delivered to the cognizant Subcontract Administrator, S. A. Mager, during the 15-minute time period immediately prior to this deadline, or mailed to reach MK-F prior to bid due date/time.

You are reminded that each addenda to this RFP must be acknowledged on the first sheet of the proposal sheet of the

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

proposal form by inserting the NUMBER (i.e. 01) in the space provided.

Sincerely,

S. A. Mager

S. A. Mager
Subcontract Administrator

SAM/kh

Appendix D

Specification WP028, Geophysical Investigation

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

SPECIFICATIONS WP028

SUBCONTRACT NO. 3589-SC-WP028

GEOPHYSICAL INVESTIGATION

MK-FERGUSON COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT

ST. CHARLES, MISSOURI

AUGUST 7, 1987

SPECIFICATION 3589-SC-WP028

WELDON SPRING SITE

GEOPHYSICAL INVESTIGATION

1.0 OBJECTIVE & SCOPE

1.1 OBJECTIVE

The objective of the geophysical investigation is to provide a geological model of the subsurface below the proposed area for the disposal cell. The geological model shall address, in adequate detail for design, the characteristics of the overburden and the bedrock, with particular attention to the configuration of the bedrock surface, and the distribution, orientation, dimensions, and condition of cavities, channelways, and fracture systems within the bedrock.

1.2 SCOPE

The geophysical investigation shall consist of acquisition survey(s), data processing, interpretation, modelling and reporting to provide the Contractor with continuous subsurface information across the disposal cell area.

The investigation shall be limited in geographical extent to an area of about 44 acres: 30 acres within the perimeter of the proposed disposal cell area, plus 14 acres within a 100-foot-wide area surrounding the perimeter (see Exhibit 2). The depth of investigation shall be not less than 200 feet below the top of bedrock.

1.3 The Subcontractor shall submit a report fulfilling the requirements of this Specification. A draft version of the report shall be submitted for review and comment by the Contractor prior to issuance of the final report.

2.0 PROJECT SUPERVISION

2.1 The geophysical surveys shall be designed and conducted by the Subcontractor in close coordination with the Contractor to ensure that the data needs will be fulfilled.

3.0 SITE CONDITIONS

3.1 As shown on Exhibit 2, improved dirt roads and paved roads form an east-west, north-south grid across the area of investigation. However, there may be areas of soft soils which may require working pads should the Subcontractor wish to occupy them with geophysical equipment, instruments, or vehicles.

3.2 Numerous buildings, as well as raffinate pits, coal storage and spoils piles, and other features shown on Exhibit 2, exist on the site, and may influence the physical layout, equipment and types of surveys for a geophysical investigation. The Subcontractor shall be aware of the potential for utilities within or immediately adjacent to the area to be investigated. Power lines, overhead and underground metallic pipelines, and metallic structures are all present.

3.3 Topographically, the area of investigation is one of relatively flat terrain with surface elevations generally between about 640 and 665 feet above sea level. Exhibit 3 shows the topography across the site area.

3.4 The best information available to the Contractor at this time shows that in general, unconsolidated overburden overlies bedrock across the area of investigation. Generally, the overburden, with an average thickness of about 30 feet, consists of topsoil, modified loess, clay (Ferrelview Formation), clay till, basal till, and cherty clay in descending order from the ground surface. The continuity of each of these overburden units across the entire area is suspect.

3.5 Bedrock is comprised of the cherty limestone of the Burlington/Keokuk Formation. The upper surface of the bedrock unit is highly irregular and has been referred to as being "pinnacled." This irregularity, and the variability of the rock mass within its upper 40 feet, has been attributed to dissolution and other weathering phenomena. Underlying the weathered zone of the bedrock, the limestone is competent, fine-to coarse-grained locally fractured and contains solution features.

3.6 The best information available at this time shows a subsurface structure of four layers. The velocity, thickness or depth, and geologic interpretation of each layer are summarized below:

3.6.1 Layer 1 - 950 to 1200 feet per second (fps); up to 15 feet thick; topsoil and possibly other loose overburden such as the modified loess unit.

3.6.2 Layer 2 - 1800 to 5000 fps, averaging about 3000 fps, but with anomalously high and low velocities detected; 10 to 43 feet thick;

predominantly overburden, but may include weathered bedrock.

3.6.3 Layer 3 - 4000 to 7650 fps, averaging 6000 fps; depth to top of layer ranges between 15 and 45 feet; predominantly weathered bedrock, but may include compacted and/or saturated overburden.

3.6.4 Layer 4 - 8000 to 25,500 fps, averaging 17,000 fps; depth to top of layer is 43 to 110 feet, averaging 70 to 75 feet; harder, more competent, and less weathered bedrock.

4.0 PERSONNEL

4.1 The geophysical investigation shall be performed by personnel qualified on the basis of education, experience, and training. The professional geophysicists, other degreed professionals, as well as non-degreed technicians that perform the field and central office tasks shall have actual and verifiable experience in geophysical surveying, data processing, interpretation and modelling procedures proposed by the Subcontractor. The Subcontractor shall, prior to starting work, satisfy the Contractor that the Subcontractor's personnel are the same as those proposed. The Subcontractor shall notify and receive approval from the Contractor for any personnel changes.

5.0 PERFORMANCE DOCUMENTATION

5.1 The documentation of the results of the geophysical investigation shall demonstrate satisfactory completion of the investigation and form the basis for the Subcontractor's interpretations, judgements, and decisions. The documentation shall be complete, including as appropriate, the following minimum requirements:

- o Field data forms, logs, and notebooks
- o Land survey data
- o Final computer output
- o Verification of assumptions
- o Photographs
- o Peer review reports
- o Calculations
- o Results and interpretation of the geophysical investigation

All such documentation generated by the Subcontractor shall become a part of the project records.

5.2 The Subcontractor shall provide access at any time to all of the project documentation (field notes, calculations, etc.) necessary to produce the final report.

6.0 EQUIPMENT REQUIREMENTS

6.1 The geophysical survey techniques and equipment proposed by the Subcontractor for the site investigation shall be selected on the basis of the following factors:

- o Site conditions

- Type of information required
- Extent of information required
- Results of previous geological and geophysical investigations
- Suitability of geophysical survey techniques and equipment for fulfilling the data needs and satisfying the stated objective
- Speed, economy and accuracy with which the investigation can be performed and completed.

6.2 Geophysical survey techniques and equipment employed in the site investigation shall be limited to surface methods to ensure that the following data be provided with a high degree of confidence:

- Total thickness of overburden
- Lateral and vertical extent/dimensions of each overburden layer
- Material types, characteristics and variation of each overburden layer, including velocities/densities
- Depth to bedrock
- Distribution, orientation and dimensions of solution channels and other anomalous features or irregularities in the bedrock surface

- o Distribution, orientation, dimensions and depth below bedrock surface of solution cavities, channelways and their interconnections

- o Distribution, dimensions and orientation of joints, solution-widened joints and of other fracture systems

- o Lateral and vertical extent of bedrock layers, including weathered zone

- o Material types, characteristics and variation of bedrock layers, including velocities/densities

- o Nature of cavity, channel or joint infilling material (air, water, clay, other geologic material, or combination)

- o Location of top of saturated overburden/perched water tables

- o Location of water table within the bedrock

6.3 The Subcontractor's proposed techniques, equipment and instrumentation shall ensure that the time at the job-site and the central office is minimized.

6.4 The Subcontractor shall provide all of the personnel, geophysical equipment and instrumentation, and any ancillary equipment necessary to perform and complete the geophysical investigation.

7.0 CALIBRATION OF EQUIPMENT

7.1 The Subcontractor shall assure that the geophysical survey equipment used to obtain field measurements during the site investigation is calibrated and maintained in accordance with documented procedures at prescribed intervals and/or prior to use. The Subcontractor shall calibrate equipment to National Bureau of Standards (NBS) criteria. If NBS standards have not been established, the Subcontractor shall calibrate equipment to the appropriate manufacturer's standard.

7.2 The Subcontractor shall furnish the Contractor with a signed and dated copy of the documented calibration procedures at the time of award and thereafter. The procedures shall be based on the type of equipment, effect of error on the quantities measured, stability characteristics of the equipment, required precision and accuracy, or other conditions affecting measurement control. Procedure content should include, as appropriate:

- o Identification of equipment.
- o Documented or reference calibration methods.
- o Acceptance limits.
- o Frequency of calibration.
- o Tagging of the equipment to indicate calibration status.

- Identification and traceability of calibration standards.

- Segregation and identification of equipment failing calibration to prevent inadvertent usage.

- Required documentation.

7.3 The Subcontractor shall furnish the Contractor with records prepared and maintained for each piece of equipment subject to calibration to indicate that the Subcontractor's established calibration procedures and schedules have been followed. The records should contain a history of calibration, acceptance/failure, and repair. Each file should include, as appropriate:

- Name and identification number of the equipment.

- Calibration frequency.

- Names of individual(s) performing the calibration.

- Acceptance limits.

- Most recent calibration data and results of equipment evaluation.

- Identification of calibration standard and/or test equipment used.

- Certificates or statements of calibration provided by manufacturers or external organizations.

- Schedule of due dates for recalibration.

7.4 The geophysical survey equipment and instrumentation used by the Subcontractor during the site investigation shall be uniquely identified by the manufacturer's serial number or an assigned identification number. Whenever possible, the assigned number shall be indicated by a label or tag attached to the equipment. Calibration status shall be indicated by a label or tag attached to the equipment and showing date of last calibration and due date of recalibration.

7.5 Should the latter be impractical, records traceable to the equipment shall be readily retrievable for reference with the recalibration due date clearly indicated.

8.0 <u>PERFORMANCE</u>

8.1 The Subcontractor shall, at a minimum, design the geophysical investigation to ensure that all personnel and equipment are on-site at the proper time, conduct the field data acquisition and preliminary processing for quality control, process all data acquired during the field surveys, interpret the data, model the results, and prepare and submit the data and final reports of the investigation to the Contractor.

8.2 The Subcontractor, at a minimum, shall design the surveys to provide continuous subsurface coverage across the area of investigation and ensure that the data needs will be fulfilled. During the conduct of the surveys, the Subcontractor shall verbally keep the Contractor informed of the status of the data acquisition process and the outlook for successful and timely completion of the work. The final report shall include a geological model representative of the subsurface at the proposed disposal cell site, with appropriate descriptive and explanatory narrative, as well as appropriate graphical data and interpretation representations.

9.0 SITE CLEANUP AND RESTORATION

9.1 The Subcontractor shall be responsible for site cleanup and restoration required as a result of the geophysical surveys. This shall include:

1. Removing any survey stakes and flagging.

2. Repairing fences or damaged structures.

3. Retrieving detonator leads, backfilling shot holes and inspecting area for remaining explosives, if explosive charges are used for seismic sources.

10.0 DATA PROCESSING

10.1 Processed data shall be legible and in a form suitable for reproduction, filing and retrieval. Calculations shall include assumptions, methods of computation, parameters and physical units so that a qualified individual can review and understand the processing and verify the results. Data processing shall be identified by project name and number, activity or survey type and location, originator and data collected, and reviewer and date reviewed.

10.2 Assumptions shall be documented; assumptions which cannot be verified shall be identified. The methods used for reducing and processing the field data shall be identified. Associated computer output shall be identified by run number or other unique means.

10.3 The results and conclusions of processing large quantities of data shall be summarized. The results and conclusion can be presented in, or form the bases for drawings, graphs and tables.

11.0 DECONTAMINATION

11.1 If the Subcontractor is directed by the Contractor to decontaminate any equipment, he shall be reimbursed at the standby hourly rate.

Appendix E

Addenda Nos. 01 and 02 to WP028

IV. Incorporate the drawings identified on the enclosed Index of Drawings. Drawings are sent as a separate package.

V. Delete in its entirety the Pricing Proposal for RFP WP028. In its place incorporate 3589-SC-WP028 Pricing Proposal Rev. 1.

The due date and hour for proposals under this Request for Proposal remains scheduled for Friday, September 4, 1987 at 3:30 p.m. local time. Proposals may be hand-delivered to the cognizant Subcontract Administrator, Mr. S. A. Mager, during the 15-minute time period immediately prior to this deadline, or mailed to reach MK-F prior to bid due date/time.

You are reminded that each addenda to this RFP must be acknowledged on the first sheet of the proposal sheet of the proposal form by inserting the NUMBER (i.e. 01) in the space provided.

Sincerely,

S. A. Mager

S. A. Mager
Subcontract Administrator

SAM/kh
Enclosure

ENGINEERS
AND
CONSTRUCTORS

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT
ROUTE 2, HIGHWAY 94 SOUTH
ST. CHARLES, MISSOURI 63303
PHONE: (314) 441-8086

PROC-87-SM-336

August 28, 1987

ATTENTION: All Prospective Proposers

ADDENDUM NO. 02

TO

REQUEST FOR PROPOSAL NO. RFP-3589-WP028

GEOPHYSICAL INVESTIGATION

This Addendum No. 02 is issued in accordance with the Request For Proposal documents. Exact copies of this addendum have been sent to all subcontractors on the "Prospective Proposer's List".

The following modifications and/or clarifications are hereby incorporated into RFP-3589-WP028:

I. SPECIFICATION

Delete in its entirety Section 1.2 SCOPE from Specification WP028 dated: August 7, 1987. In its place incorporate the enclosed revised Section 1.2 SCOPE.

II. DRAWINGS

Delete in its entirety Exhibit 3 "Disposal Cell." In its place incorporate the enclosed revised Exhibit 3 Rev. 1.

The due date and hour for proposals under this Request for Proposal is now scheduled for September 18, 1987 at 3:30 p.m. local time. Proposals may be hand-delivered to the cognizant Subcontract Administrator, Mr. S. A. Mager, during the 15-minute time period immediately prior to this deadline, or mailed to reach MK-F prior to bid due date/time.

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

You are reminded that each addenda to this RFP must be acknowledged on the first sheet of the proposal sheet of the proposal form by inserting the NUMBER (i.e. 02) in the space provided.

Sincerely,

S. A. Mager

S. A. Mager
Subcontract Administrator

SAM/kh
Enclosures

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

SPECIFICATION 3589-SC-WP028

1.2 SCOPE

The geophysical investigation shall consist of acquisition survey(s), data processing, interpretation, modelling and reporting to provide the Contractor will continuous subsurface information across the disposal cell area.

The investigation shall be limited in geographical extent to an area of about 75 acres (see Exhibit 3). The depth of investigation shall be not less than 200 feet below the top of bedrock.

EXHIBIT 3 -
DISPOSAL CELL
REV. 1

Appendix F

Specification WP029,
Geotechnical Laboratory Testing

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

SPECIFICATIONS WP029

SUBCONTRACT NO. 3589-SC-WP029

GEOTECHNICAL LABORATORY TESTING

MK-FERGUSON COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT

ST. CHARLES, MISSOURI

Dated: 07-09-87

SPECIFICATION 3589-SC-WP029

SECTION A

DATED 07/09/87

SCOPE OF WORK

GEOTECHNICAL LABORATORY TESTING

1.0 Scope and Objectives

The Subcontractor shall provide the services and supplies required for geotechnical laboratory testing of radiologically and chemically contaminated and uncontaminated soils, rock, sludges, and stabilized sludge in support of MK-F's prime Contract to the U.S. Department of Energy under the Weldon Spring Site Remedial Action Project (WSSRAP).

The objective of this Subcontract is to provide a detailed geotechnical evaluation of the soils at a potential disposal site and the Raffinate pit sludges. Sludge stabilization testing is intended to provide a range of mix designs that will meet workability, absorption, and strength criteria. Mix design will be phased work, closely coordinated and directed by a designated Contractor representative.

The following outlines the proposed scope of services that will be required to obtain geotechnical information of the proposed materials.

2.0 Soil, Rock, and Sludge Sample Containers and Labeling

Sample collection and delivery will be the responsibility of the Contractor. Soil samples will be contained in large and small plastic bags, jars, Shelby tubes, and 2 to 3 inch diameter tube (ring) samples. Bulk samples will be contained in 5 gallon buckets with lids. The samples will be independently labeled by the Contractor for adequate identification as to site, location, sample number, depth, etc. All undisturbed samples (Shelby tubes) as indicated by the Contractor shall be stored in the vertical position.

3.0 On-Site Laboratory Requirements

The Subcontractor may choose to provide a mobile laboratory, to be parked at a designated location on the Weldon Spring Site for approximately four (4) months. The Subcontractor shall direct all wash water and any other water resulting from laboratory operations to the existing sump located at the mobile laboratory site and operate the existing pump in that sump to ensure that the sump does not overflow. An on-site laboratory used by the Subcontractor shall be equipped in accordance with the applicable health and safety regulations.

4.0 Laboratory Testing

Laboratory testing, (as defined below), of retained soil, rock, sludge, and stabilized sludge samples will be required. All testing shall be performed in conformance with the latest edition of the appropriate ASTM Standard or other specified standard. Tests required, but for which no standard exists, will require the Subcontractor to present, in writing, proposed test procedures. These methods will then be approved, disapproved, or approved with modification to the satisfaction of the Contractor and the Subcontractor prior to performing any testing. Tests which may be necessary include, but are not limited to, the following:

Sieve analysis without hydrometer (ASTM ~~C136~~ D422)
Sieve analysis with hydrometer (ASTM D422)
Atterberg limits (ASTM D4318)
Moisture content (ASTM D2216)
Moisture density (ASTM D698)
Capillary moisture relationships (ASTM D3152 and ASTM D2325)
Specific gravity (ASTM D854)
Triaxial permeability (Army Corps of Engineers EM 1110-2-1906)
Three point sets Triaxial (R) (Army Corps of Engineers EM1110-2-1906)
Three point sets Triaxial (Q) (Army Corps of Engineers EM-1110-2-1906)
One-dimensional consolidation (ASTM D2435)
Crumb tests (ASTM Proceedings STP623)
Pinhole (ASTM ~~D422~~ STP 623)
Remolding of samples per test sample
Leaching tests (EP Toxicity)
Partially saturated hydraulic conductivity
Aggregate specific gravity and absorption (ASTM-C127)
Aggregate soundness (ASTM C88-course aggregate only) (Sodium)

Los Angeles abrasion (ASTM C535)
Rock crushing in preparation of samples per bulk samples
Petrographic analysis of rock samples (ASTM C295)

Resistance of rock material to freezing and thawing (ASTM C666 Procedure A)

5.0. Testing Procedures

The following are some specific requirements relating to the testing to be done under the terms of this Subcontract.

1) Compacting Samples of Cohesive Soil and Stabilized Sludge

Samples of compacted soil shall be prepared in a split mold having inside dimensions equal to the dimensions of the desired sample. The soil shall be compacted into the mold in 6 equal layers using a pressing or kneading action of a tamper having a contact area with the soil of less than one-sixth the area of the mold. The surface of the layer shall be thoroughly scarified before placing the next layer. Under no circumstances shall standard impact types of compaction be acceptable.

The sample shall be prepared according to the ASTM D-698 test procedure using an appropriate amount of water to produce the desired water content.

The desired density shall be produced by either kneading or tamping each layer until the accumulated weight of the soil placed in the mold is compacted to a known volume or by adjusting the number of tamps per layer and the force per tamp. For the latter method of control, special constant force tampers are necessary. After each sample has been compacted to finished dimensions and removed from the mold, the appropriate laboratory test may be performed. Input parameters such as moisture content at compaction, etc., will be provided by the Contractor.

Preparation of compacted granular soils shall be performed as outlined in the U.S. Army Corps of Engineers' "Laboratory Soil Testing," publication EM 1110-2-1906.

2) <u>Consolidation Testing</u>

Consolidation tests must include time-rate of settlement plots of all load increments. These plots will be both log-time or square root of time plots, whichever best defines the end of primary consolidation. An on-site laboratory, if used, shall be equipped with a minimum of three (3) consolidation machines.

3) <u>Triaxial Testing</u>

Triaxial testing of select undisturbed or compacted samples shall include one or more of the following: permeability test, unconsolidated undrained tests (Q), and consolidated undrained tests with pore pressure measurements (R). All testing shall be conducted according to procedures outlined in EM 1110-2-1960. A "B" parameter of 0.97 or higher is required on all test samples prior to shearing, unless otherwise indicated. Input parameters such as confining pressures, etc., will be provided by the Contractor. Photographs showing an external view(s) and a cross section view of each sample, at failure, shall be included in the test data.

4) Capillary Moisture Relationships

Capillary Moisture relationships shall be determined for a specific soil sample using a combination of ASTM D3152 and ASTM D2325 test methods to produce a series of moisture contents at tension values ranging from minus 0.1 to 15 bars. The increments used shall be 0.1, 0.3, 0.5, 1.0, 2.0, 4.0, 7.0, 10.0 and 15.0 bars.

Partially saturated hydraulic conductivity tests shall use pressure chamber apparatus and/or suction apparatus as described by Klute and Dirksen.[1] Equipment must be capable of maintaining pressure heads of -7000 cm of water.

Procedures used to determine the main wetting and drying curves of individual samples shall be similar to those used by Klute and Heermann.[2]

5) Partially Saturated Hydraulic Conductivity Tests

Partially saturated hydraulic conductivity tests shall use pressure chamber apparatus and/or suction apparatus as described by Klute and Dirksen.[1] Equipment must be capable of maintaining pressure heads of -7000 cms of water.

Procedures used to determine the main wetting and drying curves of individual samples shall be similar to those used by Klute and Heermann.[2]

[1] Klute, A., and C. Dirksen, "Methods of Soil Analysis, Part I. Physical and Mineralogical Methods, Chapter 29," 1985 Second Edition.

[2] Klute, A., and D.F. Heermann, "Water Movement in Uranium Mill Tailings Profiles", 1978, Fort Collins, Colorado.

6) Leaching Tests

Leachability test procedures will be conducted in accordance with EP Toxicity Test Procedures as described in 40 CFR Part 261 Appendix II. The leachate produced from the first extraction of a series of extractions shall be retained for use as leachant in the subsequent samples. The Contractor will provide the sequencing of samples to be tested.

The Subcontractor shall perform water quality analysis on the leachate produced from the last sample in a series. Analysis will be for uranium and the metals listed in the EP Toxicity Procedures only.

7) Sludge and Stabilized Sludge Testing

A research by design sludge stabilization program is being developed by the Contractor. The Subcontractor will be responsible for mixing (remolding) and testing the stabilized sludge samples. Tests will consist of in-situ moisture content and density for sludge samples and density, moisture content, and unconfined compression for stabilized sludge samples. EP Toxicity tests will be performed on select stabilized sludge samples.

A Contractors Representative will be present during sample preparation and testing to direct and observe the work. The Contractor will provide all dry materials necessary for mix designs. Dry materials will likely be cement, fly ash, and/or other pozzolans.

6.0. Project Schedule

A specific Delivery Order (DO) (Attachment 14) will be given to the Subcontractor with each batch of samples to be tested. All analyses for each phase must be completed no later than four (4) weeks after receipt of the samples unless otherwise specified in the DO as issued. For selected specific gravity, moisture density, gradation, and Atterberg Limits tests a two (2) week completion will be required. Stabilized sludge tests will be performed in coordination with a designated Contractor Representative.

7.0. Quality Assurance

All laboratory testing shall be performed by experienced and qualified personnel in conformance with the applicable ASTM or other required test procedures as indicated in the Laboratory Testing Section. Any deviation from these procedures or any analytical procedures that are not available from ASTM or Army Corps of Engineers shall be submitted in writing to the Contractor for review and approval of required changes of any such procedure, prior to performing the test. These deviations shall be carefully documented and included on the typed laboratory report to be submitted with the effected test results. The laboratory, including equipment, shall be available to the Contractor's Representative prior to and during the testing for inspection.

The laboratory must have a Contractor's approved Quality Assurance (QA) Program in affect to assure that the data transmitted is correct and that the laboratory tests are run according to the required standard. The Subcontractor shall provide a designated person as the primary contact person should any questions arise as to the reliability of transmitted data.

8.0. Subcontract Performance

All testing is subject to review and acceptance by the Contractor. Acceptance or non-acceptance of a deliverable, will be made by the Contractor within 14 days after receipt of test data. Tests improperly or inadequately performed, will be retested at no cost to the Contractor.

All testing must be performed by the Subcontractor. No tests are to be further subcontracted without prior approval by the Contractor. If tests are to be run at a subcontractor owned off-site laboratory, the laboratory used must be specified on Attachments to Section C. Shipment of samples will be paid by the Contractor only to the Subcontractors off-site lab nearest to Weldon Spring, Missouri.

Any discrepancies in data must be identified and explained on the "Comments" section of the forms attached under Section C of this specification; as to the unusual nature or reason for apparent invalid test results.

9.0. Deliverable Quality Assurance

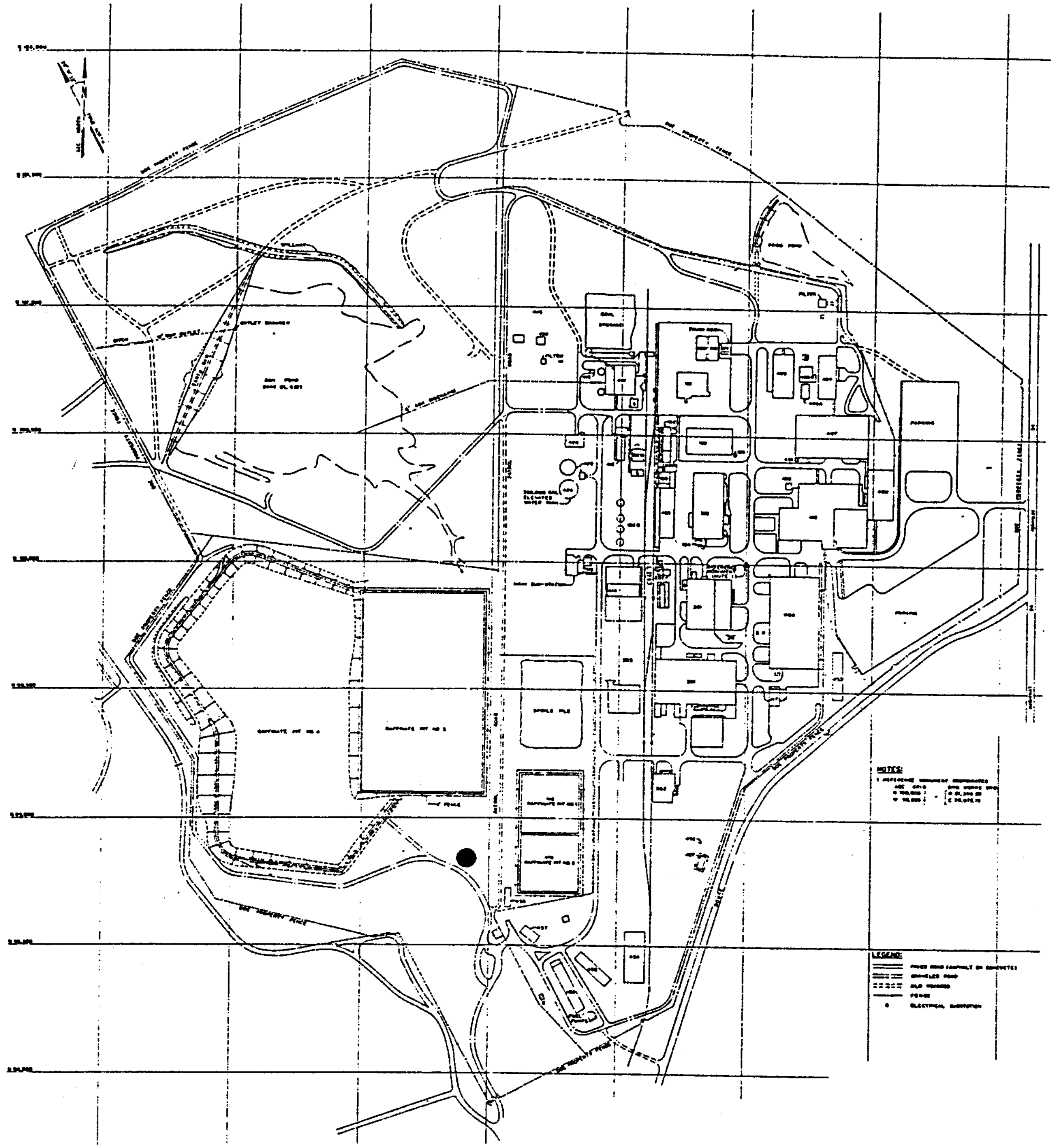
Results of all analyses shall be submitted on the specified reporting forms (Section C) and accompanied by legible copies of all associated laboratory work sheets. Reporting forms shall be typewritten with all lines on the form being completed. The letter designation "N/A" for not applicable or "N/K" for not known will be used in all blank spaces. If some steps or procedures were not performed as specified by delivery order requirements, the reasons must be stated on the appropriate reporting form or submitted as an attachment thereto. All laboratory worksheets shall provide objective evidence that the data has been checked by appropriate personnel other than those performing the tests.

10.0 Sample Storage and Shipment

The Subcontractor must return WSSRAP samples to the Weldon Spring Site. The Subcontractor must certify in writing that the samples being returned are only those received from WSSRAP and are not samples from other sources. Samples must be returned with their original containers, labeled and packaged in accordance with all applicable DOT regulations.

11.0 Health and Safety Requirements

Some of the samples received will be radiologically contaminated. The Contractor will provide personnel to screen and mark contaminated samples. These samples shall be handled in accordance with Special Conditions 10 and 11 of this Subcontract. The Subcontractor shall submit, two (2) weeks after award, a detailed description of the measures to be taken to conform with the applicable health and safety requirements.



● – Mobile Lab And Sump Location

Figure 1

Site Map

SPECIFICATION 3589-SC-WP029

SECTION B
DATED 07/09/87

DELIVERY REQUIREMENTS

GEOTECHNICAL LABORATORY TESTING

The Subcontractor shall provide the testing and analysis as set forth in the individual Delivery Orders (DO) (work plans) and deliver the following items on or before the date indicated therein.

Deliverables	No. of Copies	Contract Delivery Date
1a. Soil laboratory results for selected specific gravity, moisture-density (proctor), gradation, and Atterberg Limits tests reported in accordance with Attachment 1, Attachment 2, Attachment 3, and Attachment 13 of Section C.	2	Two weeks after Work/Plan Delivery Order & samples are received by the Subcontractor
b. Soil laboratory results for the balance of tests not identified in 1a above, reported in accordance with Attachments 2 through 13 of Section C.	2	Four weeks after Work test Plan/Delivery Order and samples are received by the Subcontractor
c. Description of health and safety measures.	1	Two weeks after award

Two copies of the results are required. One copy shall consist of the original data containing both laboratory worksheets, handwritten and edited results using copies of the Attachment 1 through 13 above depending upon the test performed. Also describe condition of samples prior to testing, evidence of disturbance, damage to containers, and any other pertinent information regarding the samples.

MK-FERGUSON COMPANY
A MORRISON KNUDSEN COMPANY

SPECIFICATION 3589-SC-WP029

SECTION C
DATED 07/09/87

REPORTING REQUIREMENTS

Summary of Attachments

FORM NUMBER	ATTACHMENT NUMBER	TITLE
MKF-AL-ENG-1 (4/87)	1	Physical Property Test Results
MKF-AL-ENG-2 (4/87)	2	Mechanical Sieve Test Results
MKF-AL-ENG-3 (4/87)	3	Hydrometer Analysis Test Results
MKF-AL-ENG-4 (4/87)	4	Soil Erosion Properties Test Results
MKF-AL-ENG-5 (4/87)	5	Rocky Material Property Results
MKF-AL-ENG-6 (4/87)	6	In-situ Moisture and Density Determinations
MKF-AL-ENG-7 (4/87)	7	Permeability Test Results
MKF-AL-ENG-8 (4/87)	8	Capillary-Moisture Relationship
MKF-AL-ENG-9 (4/87)	9	Moisture-Density Results
MKF-AL-ENG-10 (4/87)	10	Consolidation Test Results
MKF-AL-ENG-11 (4/87)	11	Unconsolidated-Undrained Triaxial "Q" Test
MKF-AL-ENG-12 (4/87)	12	Unconsolidated-Undrained Triaxial "R" Test with Pore Pressure Measurement
MKF-AL-C-1 (4/87)	13	Deliverable Transmittal/Review*
	14	Delivery Order Form

* Note: Instruction for completing Attachment No. 13, Form MKF-AL-C-1 are as follows:

Check appropriate box: If all analyses required by the Delivery Order are being transmitted, check "Total"; if the delivery is partial, check "Partial" and insert date. The balance will be sent to MK-F.

Add any description, comment, etc., in section provided under "Title/Description of Documents."

Sign and date form under section "Approved By:".

ATTENTION: Should the Subcontractor be required to reanalyze/resubmit analyses, the box "Revision" must be checked and the revision designator assigned to Attachment 1 entered in the blank provided next to the box.

Appendix G

Proposed Modification to Specification WP029

PROPOSED MODIFICATION TO SPECIFICATION WP029

Section II, Health and Safety Requirements, will be modified. Presently, the section states that some samples will be radiologically contaminated. Since this specification was prepared , chemical contaminants have been detected on the Weldon Spring Site. This information will be included in the modified section. The Subcontractor will still be required to submit a health and safety plan to protect workers from contaminated samples.

Appendix H

Specification WP091,
Geotechnical Coring and Sampling

SPECIFICATIONS WP091

GEOTECHNICAL CORING AND SAMPLING

MK-FERGUSON COMPANY

WELDON SPRING REMEDIAL ACTION PROJECT

ST. CHARLES, MISSOURI

3/1/88

SPGE91/TXTMYRNA

SPECIFICATION WP091

WELDON SPRING SITE
GEOTECHNICAL CORING
AND
SAMPLING

1.0 SCOPE AND OBJECTIVES

The purpose of the work is to procure bedrock core samples.

This project is conducted by MK-Ferguson Company (MK-F), to collect geotechnical data at Weldon Spring Site Remedial Action Project.

2.0 LOCATION

The site is in St. Charles County, Missouri approximately 30 miles west of St. Louis, Missouri.

3.0 PROJECT SUPERVISION

All technical activities shall be under the supervision of the MK-Ferguson Company construction engineer (CE). No work shall commence without the Contractor's approval.

4.0 DRILLING AND SAMPLING

4.1 General

Drilling for this subcontract shall be performed in accordance with "Standard Practice Diamond Core Drilling For Site Investigation" (ASTM D2113-83) except as noted in this specification.

4.2 Surface

The surface conditions on the Site and in the area immediately west of the building area is relatively flat and vegetated with grasses. These areas are readily accessible by existing, improved dirt roads and paved roads and thus access problems should be minimal in the area. However, there may be areas of soft soils which will require working pads. Every effort will be made by MK-F to avoid drilling in locations with poor access.

4.3 Boring Location and Depths

Bedrock coring shall be an extension of borings made under the authority of Specification WP024-01. Coring through the uppermost twenty (20) feet of competent bedrock shall be performed in sixteen (16) of the original borings. Coring through the uppermost two hundred (200) feet of competent bedrock shall be performed in two (2) of the original borings. The selection of borings to advance the two hundred (200) foot corings shall be at the discretion of the Construction Engineer.

4.6 Coring Rods and Bits

The Subcontractor shall use NQ wireline rods and NQ wireline bits for this coring program.

4.5 Soils Logging and Supervision

The Subcontractor shall not be responsible for preparing the boring log as described in Section 7 of ASTM D2113-83 (Boring Log). Bore logging and drilling monitoring will be performed by the Contractor.

4.6 Cross-Contamination Prevention Measures

The Subcontractor shall at all times prevent the contamination or cross-contamination of all borings. Prevention measures include appropriate drilling procedures and decontamination of drilling equipment. A designated representative of the Contractor will observe decontamination activities to assure that no contamination or cross-contamination occurs. Potential contaminants include, but are not limited to oil, greases, hydraulic fluids, fuels, and contaminated soils.

To reduce the potential of contamination occurring, the drilling rig, tools, drilling stem, and all other pertinent equipment shall upon entering the site, be steam cleaned or hot high pressure washed under the direct supervision of the Contractor. All decontamination shall be performed at the decontamination facility located near the south end of the site. The Contractor shall supply a hot high pressure washer.

Cleaning of the entire rig and tools shall be accomplished on a one-time basis before work begins. Decontamination of the entire rig will not be required again, unless the equipment becomes contaminated. If the rig or any other equipment becomes contaminated due to equipment breakdown or the Subcontractor's negligence, decontamination shall be at the Subcontractors' expense. Drill bits, drilling rod, other downhole tools, and hand tools shall be decontaminated between boreholes. Only potable water from the Contractor's source shall be used to supply the hot high pressure washer.

Interior portions of equipment, such as pumps and hoses, which are not accessible for cleaning with a pressure washer shall be thoroughly cleaned and flushed with potable water from the Contractor's source. Oils, greases, or pipe dope shall not be used on pipe threads or drilling rods. Non-hydrocarbon based lubricants, such as silicon or teflon are acceptable.

Drilling equipment used in known or suspected contaminated areas shall be handled with special precautions to prevent the introduction of any contaminants into the well or boring. No hand tools, drill bits, drill stem, or any other equipment other than that in use in the borehole shall be allowed to contact the ground surface at any time. New, clean plastic sheeting shall be required for the temporary storage of such items. If any equipment or supplies come into contact with the ground, or are otherwise contaminated, they shall be thoroughly cleaned by hot high pressure washing.

Cross-contamination shall be minimized by thoroughly cleaning all external and internal surfaces of all drilling equipment, tools, drill bits, drilling stem, mud tubs, pumps, hoses, and all other appurtenant equipment after each hole is completed and before moving to the next drilling location. Cleaning shall be accomplished by completely removing all soil from the equipment and thorough hot high pressure washing.

During drilling operations, the Subcontractor shall prevent soils and liquids other than approved drilling fluids from entering the borehole. Steel surface casing of the appropriate diameter and at least five feet (5') in length shall be used when liquids are present on the surface at a drilling location. The surface casing shall be thoroughly decontaminated by hot high pressure washing prior to use at another drilling location.

4.7 Drilling Fluids

Uncontaminated, potable water shall be used as a drilling fluid for rock coring. The water source shall be provided by the Contractor. The Subcontractor shall be responsible for providing hoses, tanks, and other equipment and transporting water to drilling locations. All tanks, hoses, and other water-handling equipment shall be decontaminated by hot high pressure washing prior to commencing work. Hoses, valves, and other fittings shall be cleaned between drilling locations.

No other drilling fluid or additives other than water shall be used. Absolutely no toxic and/or contaminating substances shall be added to the drilling fluids, nor be permitted to enter boring as a result of the Subcontractor's operations.

4.8 Sampling During Coring

The Subcontractor shall attempt to attain a core run with a minimum of five feet and maximum of 10 feet in length. The Subcontractor will supply pre-manufactured and treated cardboard core boxes capable of holding at least 10 feet of rock core. The cores will be delivered to the Contractor for logging and storage. The Subcontractor will be required to use a 10 foot long core barrel and use his workman-like "best" techniques to obtain full runs.

Competent core will be stored in the cardboard core boxes. Unconsolidated, very friable, or clayey sections of core will be placed in clear, plastic-sheeting core tubing or bags, sealed, and stored along with the competent core in the core boxes. Some sections of core chosen by the Contractor may also be sealed in the core tubing for subsequent chemical analysis. The Subcontractor will assist the Contractor in collecting, sealing, and storing samples.

4.9 <u>Lost Equipment, Lost Boreholes, and Borehole Abandonment</u>

A hole shall be termed "lost" if the Contractor determines that the condition of the hole will prevent its successful completion, or if for any reason it is impractical to continue operations. The term "abandonment" shall mean abandonment to suit the convenience of the Contractor.

A hole which is determined to be lost shall be grouted from its total depth to land surface using a high solids bentonite clay grout. The grout mix shall consist of 50 pounds of grout solids mixed with not more than 23 gallons of water. If the Contractor determines that a hole has been lost for reasons within the control of the Subcontractor, or because of negligence, incompetence, or malpractice on the part of the Subcontractor or Subcontractor's personnel, or because of the use of defective or unsuitable equipment, the Subcontractor shall not be paid for any drilling, demobilization, or other services performed in the lost hole. The Subcontractor will not be paid for equipment lost in the hole. This includes boreholes lost in the event drill bits, drill rod, or other downhole tools are lost in the borehole and cannot be recovered by the Subcontractor's efforts.

In addition, the Subcontractor shall be required to grout the hole from its bottom to land surface, and then move over and drill a new hole in the proper manner to replace the abandoned one. The Subcontractor shall be notified in writing of the decision.

4.10 Standby Time

Standby time shall be defined as time during which the Subcontractor has been instructed by the Contractor to cease working pending further instructions.

Decontamination time shall be defined as time spent decontaminating drilling equipment, well screens, and casing as specified in Section 3.3 and is not considered standby time.

Time spent for clean-up and restoration of drilling locations or for other routine housekeeping or equipment maintenance is not considered standby time.

All standby time shall be recorded on the Daily Field Activity Report discussed below.

4.11 Field Documentation

The Contractor will maintain a "Daily Field Activity Report" (a sample copy is attached as Figure 1) detailing Subcontractor activities. The subcontractor is required to initial this report on a daily basis and note any differences that cannot be resolved. Any differences shall be documented for future reviews and resolution between the Contractor and Subcontractor. This is the only form that will serve to document quantities of work.

A designated Contractor representative will be assigned to each drilling rig to document the activities. The Contractor representative will assure that work is performed in accordance with specifications.

5.0 Health Physics

The Contractor shall provide industrial hygiene and/or health physics support, as appropriate, during all field operations in areas of radiological and/or chemical contamination.

The Subcontractor shall comply with all applicable Federal, State, and local health and safety regulations and requirements, including, but not limited to, those established pursuant to the Occupational Safety and Health Act (OSHA) and the WSSRAP Construction Safety and Health Management Program.

6.0 Quality Assurance

The Contractor shall direct all fieldwork. Periodic Quality Assurance surveillance will be performed by the Contractor to verify compliance with specification requirements.

Appendix I

Environmental Chain of Custody Form

WELDON SPRING SITE REMEDIAL ACTION PROJECT (WSSRAP)
Route 2, Highway 94, St. Charles, Missouri 63303
Phone (314) 441-8086 Telex (314) 447-0803

ENVIRONMENTAL SAMPLE CHAIN OF CUSTODY FORM

WSSRAP Contact: ____________________ WSSRAP File No.: ____________________

Phone Extension: ________ Date Sampled: ____________________

Laboratory Receiving Samples: ______________________________________

Sample Number	No. of Containers	Description	Parameters	Turnaround Time Required

Samplers' Signatures: ______________________________________

Relinquished By:	Received By:	Date	Time	Reason for Transfer

Appendix J

Work Plan Investigation
Geophysical Specification 3589-SC-WP028
Weldon Spring Site

WORK PLAN
GEOPHYSICAL INVESTIGATION
SPECIFICATION 3589-SC-WP028
WELDON SPRING SITE

Prepared for:

MK-FERGUSON COMPANY
St. Charles, Missouri

Prepared by:

GEOTECHNOLOGY SERVICES, INC.
St. Louis, Missouri

May 24, 1988

20961

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES

May 24, 1988 20961

MK-Ferguson Company
Weldon Spring Remedial Action Project
Route 2, Highway 94 South
St. Charles, Missouri 63303

Attention: Mr. S. A. Mager
Subcontract Administrator

Reference: Work Plan
Geophysical Investigation
Specification 3589-SC-WP028

Gentlemen:

Enclosed are three (3) copies of "Work Plan, Geophysical Investigation, Specification 3589-SC-WP028, Weldon Spring Site" for your review and approval. We understand that a meeting has been scheduled for May 31, 1988 at your office to discuss the details of this work plan prior to commencing the field operations.

We look forward to working with MK-Ferguson personnel on this project. If you have any questions regarding the contents of this work plan, please do not hesitate to contact me.

Sincerely,

GEOTECHNOLOGY SERVICES, INC.

Sal M. Gazioglu

Sal M. Gazioglu, P.E.
Principal
Manager - Environmental Services

SMG/sjw

2258 WELDON PARKWAY ● SAINT LOUIS, MISSOURI 63146 ● 314 / 997-7440

TABLE OF CONTENTS

Table of Contents | Page

1.0 INTRODUCTION 1

2.0 PROJECT REQUIREMENTS 2
- 2.1 Purpose of Project 2
- 2.2 Geophysical Systems 2
- 2.3 Application of Integrated Systems 2
- 2.4 Clarification of Specification 3

3.0 TECHNICAL APPROACH 5
- 3.1 Location of Geophysical Surveys 5
- 3.2 Geophysical Data Acquisition 5
- 3.3 Phase I Geophysical Survey 6
  - 3.3.1 Scope of Work 6
  - 3.3.2 Instrumentation 7
  - 3.3.3 Field Procedure 7
- 3.4 Phase II Geophysical Survey 9
  - 3.4.1 Scope of Work 9
  - 3.4.2 Instrumentation 10
  - 3.4.3 Field Procedure 10
- 3.5 Phase III Geophysical Survey 13
  - 3.5.1 Scope of Work 13
  - 3.5.2 Instrumentation 14
  - 3.5.3 Field Procedure 14
- 3.6 Instrument calibration and data references . 15

4.0 PROJECT SCHEDULE 16

5.0 PROJECT TEAM 17

1.0 INTRODUCTION

Geotechnology Services, Inc. has been retained by MK-Ferguson Company to perform a geophysical investigation at the proposed disposal cell at the Weldon Spring Site. The geophysical investigation consists of an integrated program of multiple geophysical data acquisition surveys, data processing, interpretation and modelling to develop subsurface information across the disposal cell area.

The Scope of work is outlined in Specification 3489-SC-WP028, dated July 7, 1987 and amended on August 7, 1987, and August 28, 1987 included as Appendix A. As a minimum, surface seismic refraction, DC resistivity, EM induction conductivity, and self potential (SP) surveys are required by the specifications. The area of investigation includes approximately 75 acres, with the depth of investigation ranging up to 200 feet below the top of bedrock.

This work plan provides the details of a geophysical investigation proposed by Geotechnology, consistent with our proposal dated September 15, 1987. Briefly, the work plan includes a discussion of the project requirements, purpose, geophysical systems, application of integrated systems and clarification of specification requirements; detailed discussion of our technical plan, including instrumentation, field procedures and calibration requirements; project schedule; and project team.

2.0 PROJECT REQUIREMENTS

2.1 Purpose of Project

The purpose of this geophysical investigation is to provide a geological model of the subsurface conditions below the proposed disposal cell at the Weldon Spring Site.

2.2 Geophysical Systems

Surface geophysical survey systems will be employed to investigate the specific subsurface, overburden, bedrock and groundwater conditions stated in Specification 3589-SC-WP028, for the Weldon Spring Site. These systems will include:

- Gradient magnetometry
- Engineering seismic refraction
- High resolution shallow seismic reflection
- Vertical D.C. electrical resistivity (VES)
- Spontaneous potential (SP)
- Shallow Electromagnetic induction (EM)
- Deeper Electromagnetic induction (EM)
- Very Low Frequency EM (VLF/EM) (Optional)

2.3 Application of Integrated Systems

All the geophysical data acquired during this project, as well as the previously supplied geotechnical information, will be subject to cross-reference and correlation in order to develop a subsurface model. Based on previous investigations (Bechtel, 1987), it is apparent that any geophysical investigation without external correlation could be misleading for this site. Subsurface data collected by means of borings is usually the prime ground truthing cross-reference data utilized to correlate geophysical interpretations. In order to offset this possibility, all data from an area or zone that yields contradictory results will be thoroughly reviewed before including such data into the final interpreted subsurface model.

2.4 Clarification of Specification

Employment of an integrated geophysical investigation to determine an appropriate subsurface model requires that several requirements of Specification 3489-SC-WP028 be clarified, including:

- Utilizing the geophysical results for "design" (1.1 Objective, line 4, page 1) should require that the interpreted model be confirmed to an acceptable probability level by ground truthing. Such final ground truthing is often acquired long after the acquisition of geophysical data which itself it usually utilized to target the ground truthing program. Therefore, before any parameters for "design purpose" are based upon these geophysical results, the interpreted geophysical model should be subject to revisions (feedback) incorporating all such ground truthing data.

- Although the overall target depth of investigation of the integrated survey is 200 feet below the top of bedrock, some of the proposed geophysical techniques are used to penetrate specific depth horizons or zones.

- The term "continuous subsurface information" usually refers to continuity of information of a 2-dimensional profile presentation based upon data acquired at some meaningful grid or data point spacing. The Weldon Spring site contains several surface and buried obstacles, buildings, utilities, etc., which will inhibit or prevent the overall acquisition of such data. For 3-dimensional coverage, it may be necessary to acquire scattered point data that would enhance a 3-dimensional model but would be disjointed and not continuous information if presented on a 2-dimensional profile without extrapolation between data points.

- An integrated geophysical survey conducted for design purposes which is limited to surface methods only is required to provide with a high degree of confidence (pages 6 & 7, section 6.2) such information as: material types of overburden and rock and their densities; the nature of joints and solution features in overburden and rock, the nature of the infilling material, and water levels. Such identifications may require correlation with core data, geophysical logging, and single-hole and cross-hole compressional and shear wave velocity data. Material types are more accurately described by directly observed geological data. Without subsurface geophysical data, the accuracy of the classifications of material types is reduced to an inference of the character of the material present based on the survey data, particularly in the case of a difficult data site. Therefore, the surface geophysical data should not be utilized for "design" without correlation with other information.

3.0 TECHNICAL APPROACH

3.1 Location of Geophysical Surveys

Specified geophysical techniques will be performed to acquire data in the vicinity of the 8 traverses shown in Plate 1. The traverses are tentatively designated as Lines 1 through 8, and together are comprised of approximately 12,000 lineal feet. The locations of the lines were selected based on the following factors:

- providing sufficient areal coverage;
- utilizing existing subsurface data;
- avoiding surface cover which prohibits or significantly hinders geophysical data acquisition such as buildings, paved roads and parking areas, railroad tracks, shallow underground utilities and raffinate pits;
- aligning electrical and magnetic "noise" such as underground utilities, overhead pipes, railroad tracks, and metal fences, such that they be perpendicular to the survey line or-in a possibly usable but less satisfactory alignment-parallel to the survey line;
- accommodating tentative boring locations and geophysical lines suggested by MK-Ferguson, provided the locations satisfy the above requirements.

Information used to locate survey lines are based solely upon site plans provided by MK-Ferguson Company. Positions of the survey lines may be subject to modifications after the site is physically reviewed. The lines will be surveyed in the field with respect to control points provided by MK-Ferguson by staking at 100-foot intervals.

3.2 Geophysical Data Acquisition

The following data acquisition plan assumes that each technique produces acceptable results. In some areas, particular methods may not provide adequate information due to geologic or manmade conditions that are not conducive to that particular technique. In these instances we may request to adjust the work plan such that a non-informative technique be replaced with additional data acquisition using a technique currently in the work plan.

The geophysical data acquisition will be performed in three phases as follows:

- Phase I - EM induction and gradient magnetometry
- Phase II - Seismic refraction and reflection
- Phase III - SP and DC resistivity

For continuity, the data analysis and interpretation methods are presented within the data acquisition program. Detailed data interpretation and consolidation will take place after all the data have been acquired, however, some preliminary interpretation may be necessary in order to proceed from one method to another. Due to the shortened daily working hours, it may be necessary for the phases to be lengthened or to overlap in time. Additionally, Phase II and Phase III may be interchanged depending upon the quality of data collected in Phase I.

3.3 Phase I Geophysical Survey

3.3.1 Scope of Work

A combination of electromagnetic (EM) and magnetic survey techniques will be used to provide data from which an interpreted layer-conductivity model may be derived. Electrical "noise" due to power lines, overhead and underground pipes, and metallic structures does exist at the site. The effects of electrical noise may be identified and possibly minimized by integrating specific electromagnetic and magnetic procedures. Even though the locations of many utilities, metallic fences and structures are known, several fast-track surveying methods are proposed to evaluate the presence of shallow buried (and surface) conductors from deeper geologic conductors.

3.3.2 Instrumentation

The following instruments, or their equivalent, will be obtained by Geotechnology for use in Phase I:

- SHALLOW EM INDUCTION
  - Geonics EM31-DL terrain conductivity meter
  - Data logger
- DEEP EM INDUCTION
  - Geonics EM34-3XL/DL or EM34-3 terrain conductivity system
  - Data logger
- MAGNETICS
  - EDA OMNI PLUS Magnetic Gradiometer (self-contained data logger)
- VLF/EM (optional)
  - ABEM VLF/EM WADI (self-contained data logger)

Most of the data acquired in Phase I will be downloaded from a data logger (external or internal) onto storage disks via a Zenith 181 portable lap-top computer. A Geonics IBM PC forward modeling program will be used for layered conductivity analysis.

3.3.3 Field Procedures

Initially, a base station area will be surveyed with the EM31, EM34, and magnetic gradiometer for calibration purposes. The area should be free of electrical "noise" from near surface conductors, have relatively constant conductivity (lower than 30 mmhos/meter), and preferably be accessible from outside the control area. A single base station will be selected within this area for calibrating all three instruments. The instruments will be operated at the base station before and after each survey.

The Geonics EM34-3 or EM34-3XL/DL system will be used first at a constant coil spacing and constant dipole attitude in order to quickly generalize the site conductivities and identify areas exhibiting possible noise due to near-surface conductors. The EM34 system is capable of measuring conductivities at coil spacings of 10, 20 and 40 meters for both horizontal and vertical dipoles providing information from depths ranging from approximately 7.5 to 60 meters.

Once areas prone to conductive interference are generally located, shallow EM induction and magnetic methods may be used to assist in delineating the noisy areas. Thus, the shallow methods may be employed predominately in areas where they are most needed.

A Geonics EM31-DL with data logger will be used primarily to depict the non-magnetic conductors, and an EDA OMNI PLUS magnetic gradiometer with self-contained data logger would be used to depict magnetic targets. Both of these systems may be pulsed at short intervals for continuous recording which can be conducted at a slow walking pace. The data stored in the data loggers may be downloaded onto a portable Zenith 181 lap-top computer. These two methods will be run concurrently.

Deep EM induction data will be acquired in areas least susceptible to electric noise due to near-surface conductors, as determined from the previously acquired data. The EM34-3XL/DL or EM34-3 will be used and conductivities for 3 different coil spacings and 2 different dipole attitudes (a total of six readings) recorded at each station. The coverage is anticipated to require 40 stations. A data logger may be used and downloaded onto the Zenith 181. The data would be used later for modeling vertical changes in conductivity.

A VLF/EM (Very Low Frequency EM) system (optional) may be used in addition to the above techniques. This system will be used to locate and delineate the vertical orientations of conductive zones in the overburden and bedrock, as well as to evaluate the relative overburden thickness. VLF/EM relates to the magnetic component of the electromagnetic field (radio waves) generated by long distance very low frequency radio transmitters. Radio waves are distorted by variations in ground conductivity and the perturbations can be measured accordingly.

The proposed VLF system is the ABEM VLF/EM WADI. The ABEM WADI is an automatic, digital system that can be operated by one man at a walking pace. WADI data is stored in the unit, is automatically interpreted and displayed directly on a built-in LCD. The recorded data up to several thousand data points (plotted curves, station values and coordinates, interpreted conductor dips and depths) can be directly downloaded to a standard serial printer.

If the VLF/EM system proves to be very informative, its survey locations would be extended to fill-in and tie-in the seismic refraction and reflection and other geophysical data.

3.4 Phase II Geophysical Survey

3.4.1 Scope of Work

Seismic refraction and reflection data will be acquired in order to detect velocity contrasts present within the overburden, at the surface of the limestone bedrock, and at depths of at least 200 feet beneath the bedrock surface. The refraction and reflection data are intended to complement each other, therefore, a total of 12,000 lineal feet along survey lines 1 through 8 are proposed for each seismic method. Seismic data acquisition should begin immediately after the completion of Phase I.

3.4.2 Instrumentation

Geotechnology plans to obtain the following equipment or their equivalent for the seismic method used in Phase II:

- SEISMIC REFRACTION AND REFLECTION
  - Geometrics ES 1225, 12-channel engineering seismograph
  - Seismic cable, 440 feet (maximum geophone spread length) with 12 geophone takeouts
  - Mark 8 Hz vertical geophones (refraction)
  - Mark 100 Hz vertical geophones (reflection)
  - BETSY downhole electric firing capsules with 8-gauge cartridges (50 to 500 grains of Pyrodex each)
  - Geometrics HVB-1 electric blaster
  - Hammer, strike plate, and trigger switch

Information recorded on the ES 1225 will be transferred to storage disks via a Zenith 181 portable lap-top computer. The Interpex program GREMIX, based on the generalized reciprocal method, will be used to interpret the refraction data. The Geometrics GEOFLEX high-resolution shallow-seismic reflection program will be used to process and interpret the reflection data.

3.4.3 Field Procedures

Initially, refraction data will be acquired along the survey lines located in the southeast portion of the study area. Based on existing subsurface data, the limestone bedrock of this area is apparently shallower than elsewhere on the site occurring at depths ranging from less than 20 feet to 35 feet. Initially, the geophone spacing will be about 20 feet (possibly greater in the central portion of the spread) in order to identify thin overburden layers, diminish hidden layer possibilities, and help to better-define pinnacles. This information, particularly that pertaining to the surface of the bedrock, if detectable, may be helpful throughout the remainder of the subject area. Approximately five shots will be taken for each geophone spread: one at each end of the spread; one near the center of the spread; and a shot off each end of the spread at up to a spread length distance.

In order to avoid interference between charges and geophones, all shots will be taken approximately 2 to 3 feet perpendicularly away from the line that is coincident with the geophone spread. The 8-gauge cartridge charges will be placed in 1.5 to 3 foot deep holes, backfilled and tamped to prevent venting. The charge size may vary from 50 grains to 500 grains of Pyrodex, depending on the source offset, source coupling and subsurface conditions. Water and/or a mat cover may be applied to each shot hole in order to promote source coupling and control airborn dust and debris. Each cartridge requires 50 volts for ignition to take place. The Geometrics HVB-1 blaster produces a 200-volt signal, therefore, two cartridges may be connected in parallel if a larger charge is required, specifically for off-end shots. Open shot holes will be filled and all cap wires will be gathered.

The presence of asphalt pavement along a survey line may require the removal of small portions of the asphalt and underlying base course, if present, at the locations of shot holes and geophones.

The field data recorded on the ES 1225 seismograph will be transferred to a Zenith 181 computer and stored on disk. First breaks will be picked and time-distance graphs will be plotted and analyzed to check for data accuracy and to establish layers and layer velocities. All seismic data will be hand-reduced by phantoming, parallelism, and end-time analysis before applying computer modeling techniques. The computer analysis may require several cycles of manual changes and correlation with external data before the computer program can be used to refine the model and produce a final interpretation.

Soil identification by examination of shot hole material and surface trawling material would be used to help evaluate the overburden horizon on which the seismic spread lies. If possible, each spread would be laid out over the same surface material for continuity so that the interpretive techniques used would deal with more narrow velocity values and not average of a wide span of values. Horizontal changes in layering sequences would be interpreted by split-spread analysis rather than averaging velocities across the spread.

To complement the seismic refraction data and to extend the depth of seismic data acquisition to at least 300 feet, a high-resolution seismic reflection survey is proposed. Water table horizons and variations within bedrock may be detected by reflection, though it is probable that the overburden layering, and possibly the top of bedrock, may be too shallow to resolve adequately. It is possible to reach penetration to 300 feet by seismic refraction, however, a spread length of at least 1000 feet would be required, as well as the use of large quantities of explosives.

The shallow high-resolution seismic reflection method proposed is referred to as "common offset" and is based on test shooting off the end of a geophone spread to establish an optimum distance between the source and the receiver. Once established, this distance remains a fixed parameter up to the next test spread.

Reflected and refracted events are digitally recorded on the ES 1225 seismograph which contains high-pass reflection filters. A short cable with geophone spacings of 10 to 20 feet is utilized with high-frequency 100 Hz reflection geophones. A sledge hammer source may be used in place of the 8-gauge cartridges provided that sufficient energy is produced to give information from at least 200 feet beneath the surface of the limestone bedrock.

The field data is transferred to a storage disk via a Zenith 181 computer. The common offset records are then reviewed on the monitor for picking first break "static" data. The static-corrected common offset records are sequentially printed out and then inspected for character of the seismic signals and presence of weak and strong reflectors. Different processing and filtering techniques are applied to the data to enhance definition of the stratigraphic horizons. The processed data is stored and the final seismic pseudo-sections are produced. Velocity analyses are then conducted and the selected velocities utilized to calculate depth intervals.

3.5 Phase III Geophysical Survey

3.5.1 Scope of Work

Self-potential (SP) data and vertical electrical soundings (VES) D.C. resistivity will be acquired in Phase III geophysical surveys.

The SP would be useful in analyzing telluric current flow between the alkaline groundwater fluids and any oxides above the water table. Current flow through conductors or disseminated conductors (contaminants) and channeling through porous zones such as fractures and solution channels, may generate a Streaming Potential.

A standard 4-electrode (Schlumberger or Wenner) VES D.C. resistivity would be used to detect different overburden and bedrock layers based upon their electrical characteristics. The locations of the soundings will be selected depending on the need to resolve the seismic problems of hidden layers, velocity inversions, and velocity overlaps. Additionally, areas containing large amounts of electrical interference due to surface conductors, as noted by the EM induction and magnetic data, will be avoided.

3.5.2 Instrumentation

Geotechnology plans to obtain the following equipment or their equivalent for the SP and D.C. resistivity methods:

- SP AND D.C. RESISTIVITY
  - ABEM Terrameter 300B with current and potential electrodes
  - ABEM Terrameter Booster 2000 (optional D.C. resistivity only)
  - Cables and reels
  - Gossen Geohm - 3 Earth Resistivity meta (optional - D.C. resistivity only)

The forward and reverse modeling program RESIX, by Interpex, will be used for layered resistivity analyses of the VES data.

3.5.3 Field Procedures

The SP method will require only 2 potential electrodes, cable and the receiver within the Terrameter 300B. One electrode, designated as the base electrode, will be placed at the beginning of a survey line; the other electrode will be placed at successively greater distances along the survey line away from the base electrode and the natural potential between the electrodes will be measured at every separation.

VES is conducted by measuring the voltage that is generated between the two potential electrodes when the transmitter induces current into the ground through the two current electrodes. To define 300 feet of penetration requires an electrode spacing to at least 1,000 feet. It is anticipated that the Terrameter 300B will provide sufficient current out to the desired spacings. However, the Terrameter Booster 2000 will be used if more voltage is necessary due to highly resistive near-surface conditions.

The shallow portion of the VES configuration is proposed to supplement the seismic refraction data. Five-foot linear electrode spacing will be used for the upper 50 feet and the normal logarithmic electrode spacings used for the deeper penetration. The linear data will be manually analyzed and the logarithmic data will be computer analyzed for multi-layering (up to 10 layers) and inverse modeling.

3.6 Instrument Calibration and Data References

All instruments will be calibrated to the manufacturers specifications traceable to the National Bureau of Standards (NBS). All data except for VES, SP, and deeper EM data, will be digitally recorded and entered into data loggers, or directly into computers or printed out in hard copy. Additionally, data summary sheets will be maintained for all geophysical techniques and will be referenced to time, date, site, traverse line, station number or coordinate, instrument operator, methodology, and with pertinent remarks and logs. Elevation control and positioning will be referenced to the supplied topographic map. All data, data sheets, notebooks, calculations, publications, photographs, time sheets, work schedules, instrument logs, work logs, computer plots and derivations, pertinent documentation and project records generated for this project will be filed as project material.

4.0 PROJECT SCHEDULE

The schedule shown in Plate 2 gives the order and duration of field work required for each geophysical method. Without contingency and barring delays due to mobilization/demobilization, weather, instrument downtime, holidays, etc., the field work should be completed in 38 working days. Additional time has been allotted for preliminary interpretation during the data acquisition portion. Approximately 4.5 weeks will be required to process and interpret the data after the field work is complete. Though some computer programs provide selection of velocity horizons as an option, because of the complexity of this site, this approach is likely to be unreliable. As a result most of the initial data reduction must be done manually, which accounts for the additional time required to process the data. The final report should be available 6.5 weeks after the completion of field work. Preliminary information will be available during the progress of data processing and interpretation.

5.0 PROJECT TEAM

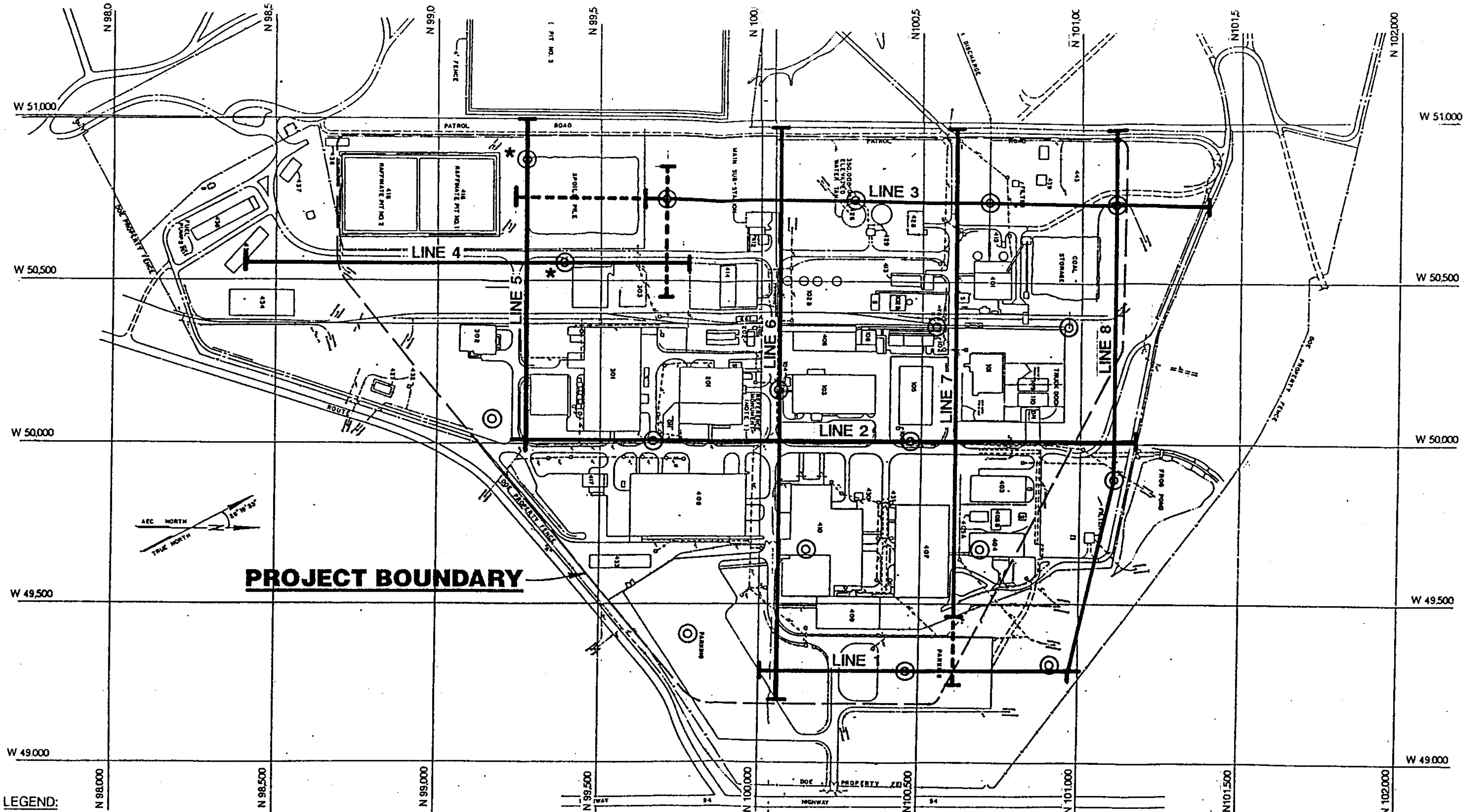
The Project Team is organized as shown on Plate 3 and consists of the following individuals:

Project Manager - Sal M. Gazioglu, P.E.

Principal Geophysicist - Marvin Ehrlich, R.Gp., P.E.

On-site Superintendent - Lawrence C. Rosen, M.S.

Field Technicians - Douglas W. Lambert, M.S.
David Cisiewski
Alan K. Renner



LEGEND:

- Proposed Geophysical Survey Line
- Possible Extension of Geophysical Line
- ◎ Proposed Boring Location
- * Boring location has been adjusted to overlie survey line.

NOTE:
Plan adapted from undated Morrison-Knudsen Engineers, Inc. drawings titled "Storm Sewer and Drainage Ditches"

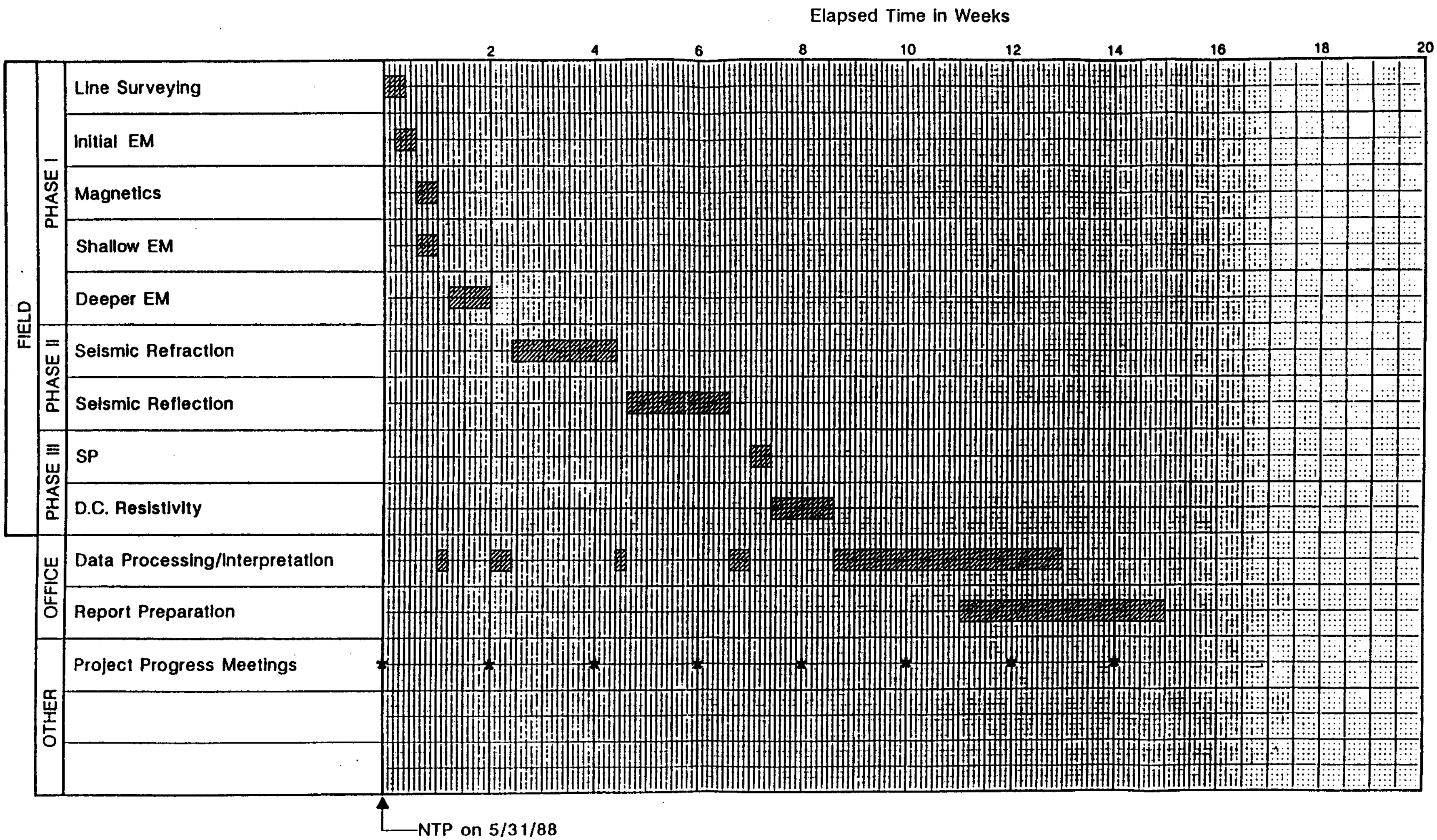
Geophysical Investigation
Weldon Spring Chemical Plant

PLAN OF SITE AND PROPOSED GEOPHYSICAL SURVEY LINES

GEOTECHNOLOGY

PLATE 1

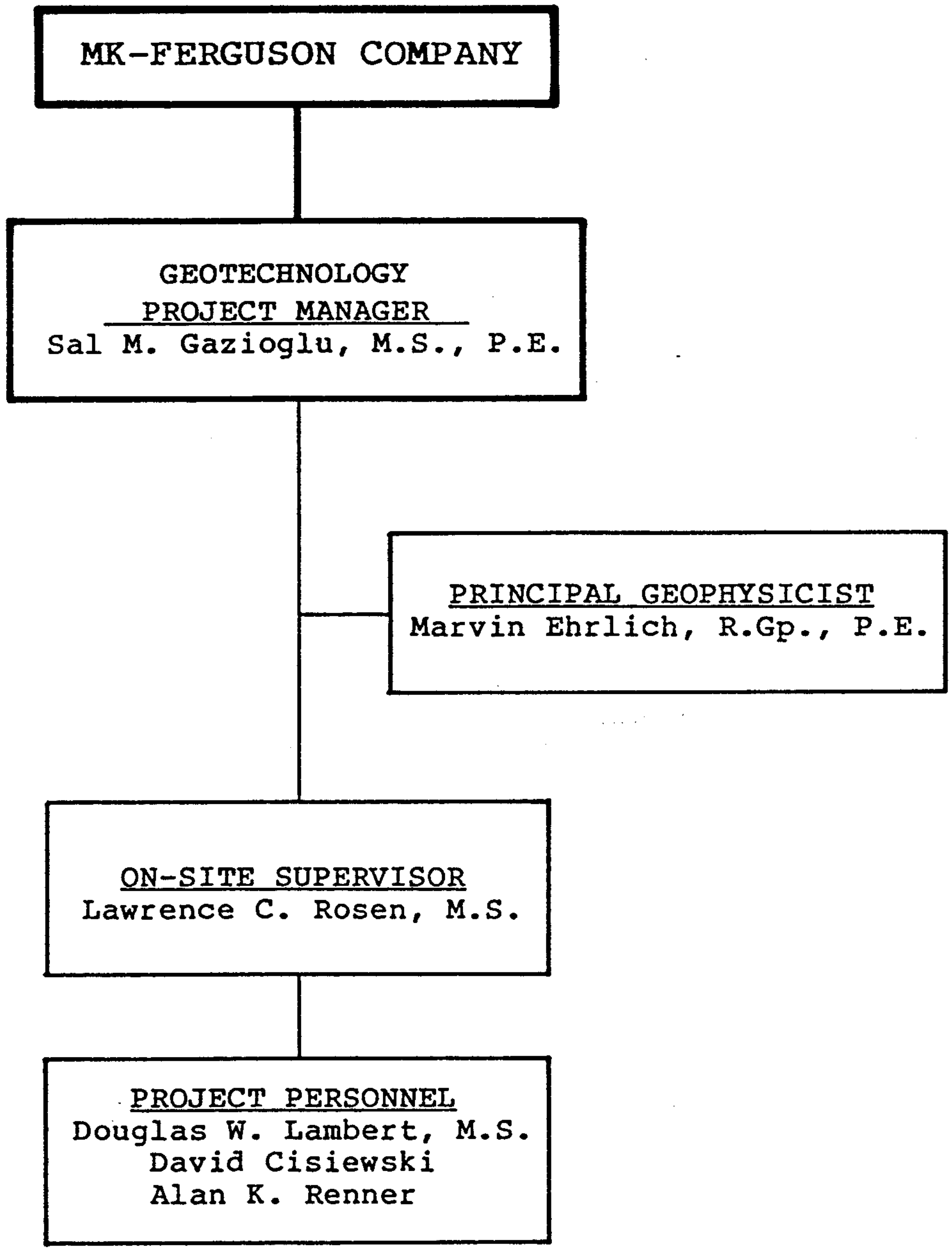
20961.02



Geophysical Investigation
Weldon Spring Chemical Plant
PROPOSED PROGRESS SCHEDULE

GEOTECHNOLOGY

PLATE 2



Geophysical Investigation
Weldon Spring Chemical Plant

PROJECT ORGANIZATION CHART

GEOTECHNOLOGY
ENGINEERING AND ENVIRONMENTAL SERVICES
SAINT LOUIS, MISSOURI