APPENDIX D

Port of Anacortes Seepage Study

Port of Anacortes
Petroleum Seepage Study
Anacortes, Washington

November 1, 1983
J-1302

HART
CROWSER &
associates inc.
GEOTECHNICAL & HYDROGEOLOGIC CONSULTANTS
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CONTENTS

PAGE NO.

INTRODUCTION 1
SUMMARY AND RECOMMENDATIONS 2
BACKGROUND 3
HYDROGEOLOGY 3
GROUNDWATER FLOW DIRECTIONS 4
PETROLEUM MIGRATION 4
Mitigative Measures 4

FIGURES
1 Site Location Plan
2 Generalized Subsurface Cross Section
3 Proposed Interceptor Trench

APPENDIX A
FIELD PROCEDURES A-1
Drilling and Well Installation A-1
Surveying and Well Water Level Measurement A-1

FIGURES
A-1 through A-8 Boring Log and Construction Data for Well B-1 through B-8

APPENDIX B
LABORATORY TEST PROCEDURES B-1
Visual Classification B-1
Grain Size Analyses B-1
Petroleum Identification B-1

FIGURE
B-1 Grain Size Classification

J-1302

PORT OF ANACORTES
PETROLEUM SEEPAGE STUDY
ANACORTES, WASHINGTON

INTRODUCTION

This report presents the results and conclusions of our hydrogeologic explorations and analyses related to petroleum seepage into the harbor within the Port of Anacortes, Washington. The purpose of our work is to define the hydrogeologic system and cause of petroleum seepage into the harbor and to recommend corrective actions.

We conducted the following work to meet the project objectives:

- Drilled and soil sampled eight hollow-stem auger borings, observed the excavation of three test pits, and installed nine observation wells (in all borings and one test pit, TP-3).
- Surveyed well head elevations and made water level measurements.
- Measured the thickness of petroleum that had entered the wells.
- Obtained samples of liquid from the wells to identify the type of petroleum.
- Conducted grain size analyses on two soil samples.
- Prepared geologic cross sections.
- Completed hydrogeologic analyses.

Boring and observation well locations are shown on Figure 1. A geologic cross section is presented on Figure 2. Boring logs, well construction features, water level data, grain size curves and results of the chemical analyses are included in Appendix A and Appendix B along with description of our field and laboratory procedures.

This report has been prepared for specific application to the referenced project according to standard hydrogeologic practices. No other warranty, expressed or implied, is made.

SUMMARY AND RECOMMENDATIONS

Below is a summary of our work and resulting recommendations. The main text of the report should be consulted for more complete information and project data.

- o Refined petroleum product was observed seeping into the Port of Anacortes Harbor at two locations (see Figure 1).
- o Free petroleum (petroleum that can migrate in the subsurface) was measured in observation wells B-2, B-3, B-5, B-7 and B-8 (Figure 1). Up to 0.89 feet of petroleum (B-5) has entered the wells (Table 1). Generally the thickness of petroleum measured in a well is about four times greater than in the adjacent soil.
- o Chemical analyses of liquid samples from the wells indicate that the petroleum consists of an approximately equal mix of gasoline and diesel. Dissolved contaminants are also contained in the water (Appendix B).
- o The likely source of the petroleum was the subsurface storage tanks that serve the marina. These tanks are known to have leaked in the past but apparently are not leaking now based upon leakage testing by Petroleum Equipment Service.
- o Boring data indicate that the petroleum is moving above the water table within a silty, fine sand stratum (Figure 2). During our field work the water table was measured 3 to 6 feet below the existing grade (Table A-1).
- o The direction of petroleum migration is generally toward the harbor. Reported buried bulkheads appear to restrict groundwater and petroleum seepage into the harbor. Their presence would tend to allow pooling and lateral migration beneath the street.
- o The volume of petroleum seepage should naturally decrease with time assuming that additional petroleum is not introduced into the subsurface; however, it could take months to several years to decrease to an acceptable level because of the fine grained sols and reported positions of the bulkheads.
- o An interceptor (recovery) system of either a trench or wells could be used to alleviate the seepage (Figure 3). An interceptor trench will likely be more effective than wells.
- o An interceptor trench system is the preferred recovery alternative. The trench should be approximately situated as shown on Figure 1. The drain should extend to a depth of 8 to 10 feet and be backfilled with coarse sand and gravel (Figure 3). The down-gradient trench wall should have an impermeable liner and the drain should connect to a sump.

- We recommend that an experienced contractor who specializes in installing these types of systems be contacted to design and install the recovery system. We should review the proposed system prior to construction.

- Effluent pumped from the system will probably require treatment with at least a water/oil separator. The Department of Ecology should be contacted as to their treatment requirements.

- We recommend that the Port consider either abandoning the petroleum tanks or installing an above ground storage system.

BACKGROUND

Petroleum has been seeping into the Port of Anacortes harbor for several years. Near the seepage sites, a series of buried storage tanks serve the Cap Sante Marina which contain gasoline, diesel and pre-mix. The owner reports that the total available storage is approximately 22,000 gallons.

In 1982 the petroleum seepage was particularly severe and the tanks were the suspected source of the petroleum. Exposing the tanks and piping indicated that both gasoline and diesel had leaked from the system. Repairs were made and a decrease in the volume of seepage was reported; however, some petroleum seepage continued. In July 1983, Norm Blanchard of the U. S. Coast Guard contacted the Port to discuss and initiate a program to correct the petroleum seepage into the harbor.

HYDROGEOLOGY

Soil samples were obtained in borings B-1 to B-8 to a maximum depth of 25 feet. The samples indicate that the geology beneath the project area is relatively consistent from boring to boring. A schematic geologic cross section is shown in Figure 2.

The upper sand is likely dredged sand fill, while the remaining units are natural deposits typical of a tidal flat environment. The top of the silt stratum forms the bottom of a relatively thin water table aquifer located within the upper sand. Fluctuation in the water table will determine the thickness of the aquifer at a given location. During our field explorations in September and October of 1983 the aquifer ranged between approximately 4.5 to 7.5 feet thick. We estimate the hydraulic conductivity of the upper sand to be approximately 10-4 centimeters per second (cm/sec) using the grain size curves, supplemented with field test results for similiar soils.

GROUNDWATER FLOW DIRECTIONS

Water level measurements were made in the observation wells on September 26 and October 12, 1983. The data are contained in Table A-1.

The measurements indicate that groundwater is flowing towards the harbor from upland areas. Our measurements also indicate that water table fluctuation caused by tidal changes is minimal. During our field work the observed changes were on the order of a foot or less with tidal fluctuations of 5 or more feet.

PETROLEUM MIGRATION

Free petroleum was measured in the following wells.

	September 26 Petroleum Thickness (Feet)	October 12 Petroleum Thickness (Feet)
B-2	0.58	0.26
B-3	0.04	None detected
B-5	0.81	0.89
B-7	Not analyzed	0.38
B-8	Not analyzed	0.05

The available data indicate that petroleum is concentrated along the street adjacent to the harbor between "C" and "B" docks. The source of the petroleum appears to be the buried storage tanks which are known to have leaked in the past. Borings and test pits up gradient of the harbor did not encounter petroleum which indicates the local tank source. Recent tank and system testing of the storage facility by Petroleum Equipment Service of Mt. Vernon, Washington, indicate that the tanks are not currently leaking.

Once petroleum has seeped into the ground and reaches the water table it generally moves in the prevailing direction of groundwater flow. The migration direction is complicated by the reported presence of the buried bulkheads which can block the flow of groundwater and petroleum into the harbor. The bulkheads will tend to allow pooling and lateral migration of petroleum beneath the street.

Mitigative Measures

In our opinion the current petroleum seepage into the harbor can best be mitigated by installing an interceptor drain or interceptor wells. Our evaluation is that an interceptor drain will be more effective and less costly (over the long run) than interceptor wells.

Interceptor wells rely upon creating a cone of depression which causes petroleum to migrate to the well. The cone of depression is created by pumping the well which causes the water table to decline in the area surrounding the well. Application of this technique to the Port's situation is limited by the fine grained nature of the soils and relative thinness of the upper sand aquifer. These factors limit the development of a cone of depression over a large area; because of this, we estimate that two to four wells would be required with individual pumping systems.

An interceptor drain is expected to be more effective than wells because it can intercept petroleum over a larger area. The general features of such a system are presented in Figure 3.

The system consists of a trench excavated to three to four feet below the water table. Coarse sand and gravel are placed in the trench and the trench is connected to a sump which removes water and petroleum. An impermeable barrier may also be placed on the down gradient side of the trench. We estimate that the trench drain system would pump less than 500 gallons per day with a lowering of the water table one foot within the trench.

Excavation of a trench appears feasible based upon the excavation of TP-3. This test pit was excavated to a depth of 11.0 feet and penetrated more than four feet below the water.

Treatment of the effluent pumped from the trench will probably be necessary. At a minimum, treatment using an oil/water separator is recommended. Prior to installation of a recovery system we recommend that the system be presented to the U. S. Coast Guard and Department of Ecology for their review and approval.

We also recommend that a contractor experienced in designing and installing this type of system be contacted and that we review the proposed system prior to installation. We would be glad to recommend a contractor to you if desired.

Sincerely,

HART-CROWSER & ASSOCIATES, INC.

Matthew G. Dalton

MATTHEW G. DALTON
Associate Hydrogeologist

Terry L. Olmsted

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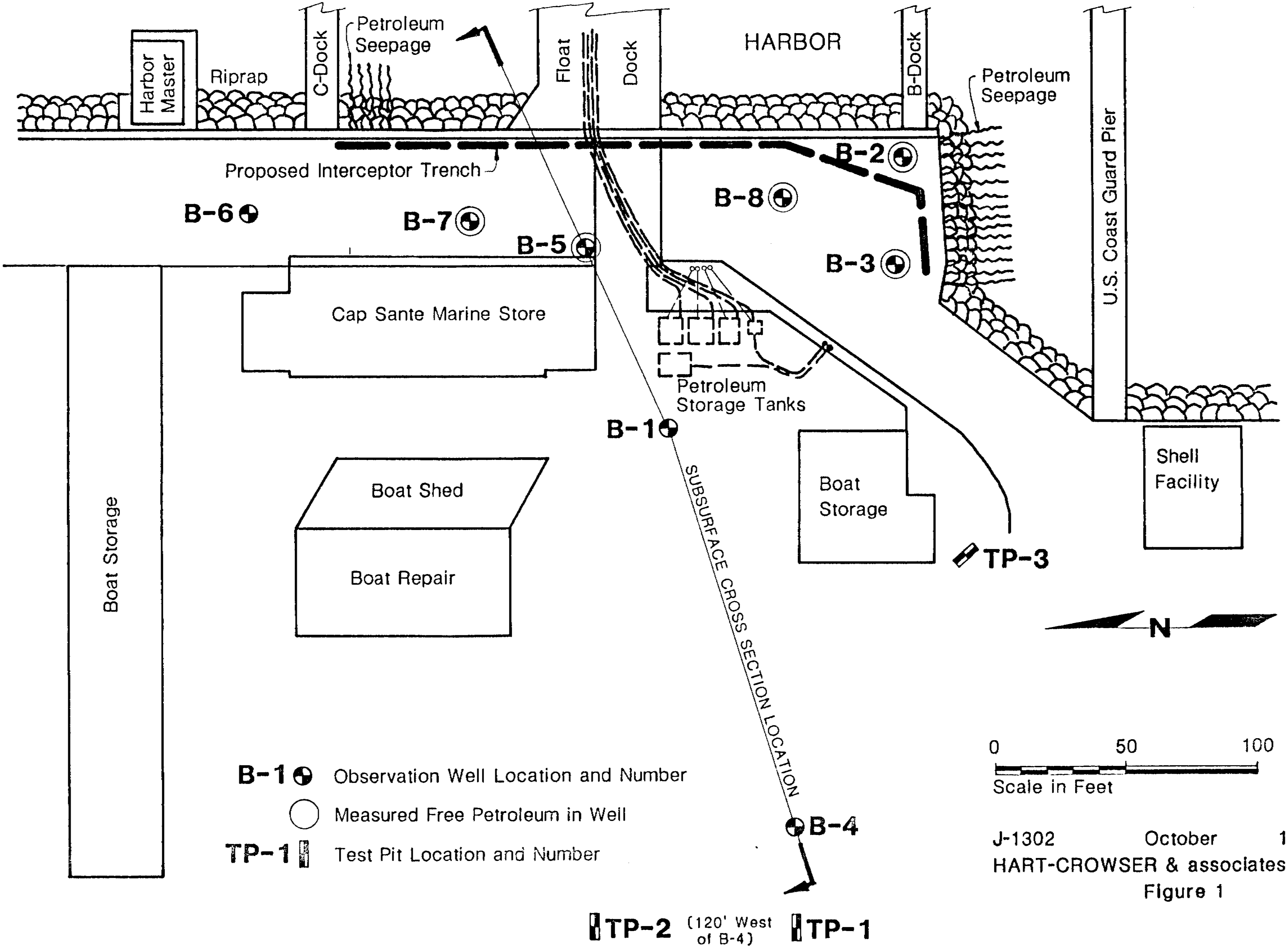
Vice President

MGD/TLO/mgv

Site Location Plan



B-1 ● Observation Well Location and Number

○ Measured Free Petroleum in Well

TP-1 ▮ Test Pit Location and Number

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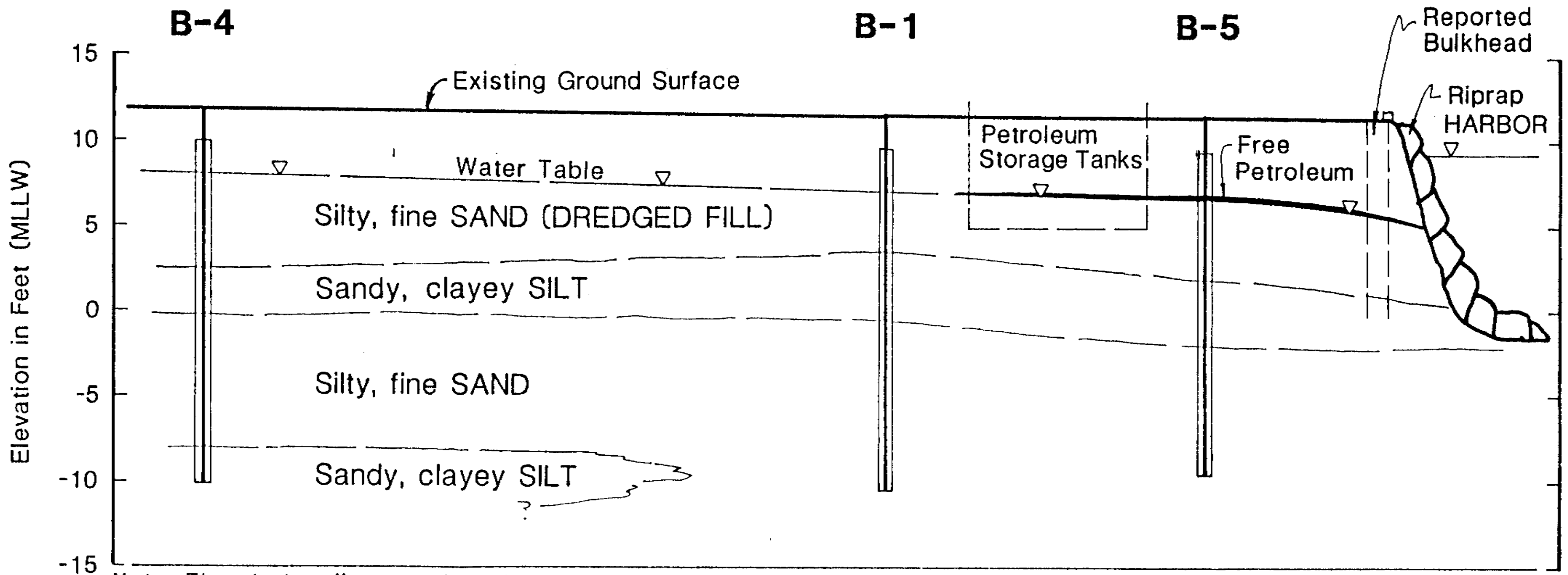
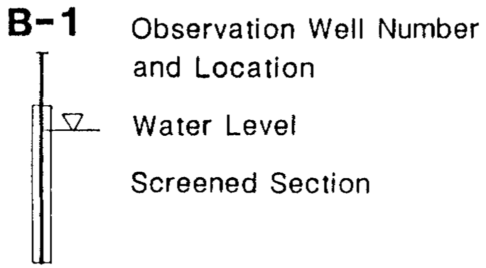
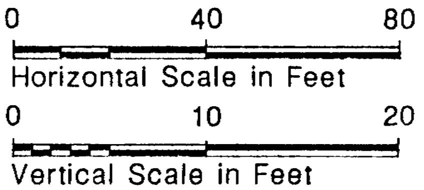
Figure 1

Generalized Subsurface Cross Section



Note: The stratum lines are based upon interpolation between observation wells and may not represent actual subsurface conditions.





Vertical Exaggeration x 4

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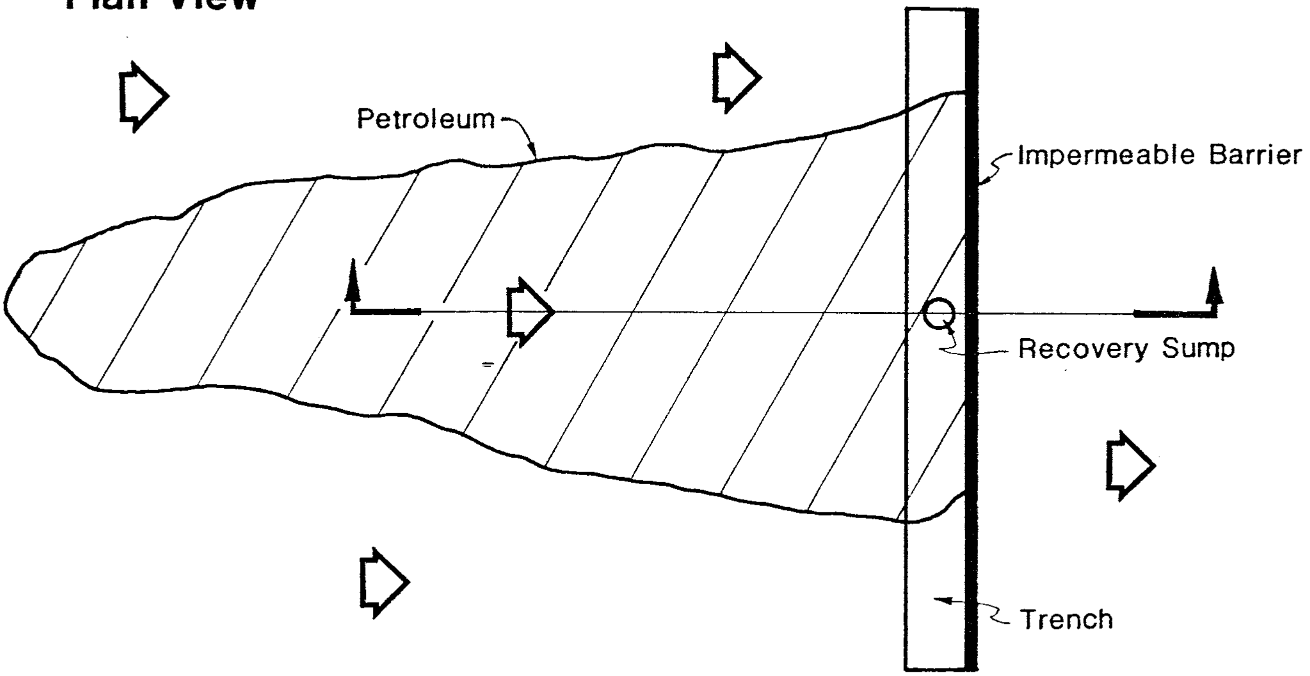
Figure 2

Proposed Interceptor Trench

Plan View



Cross Section

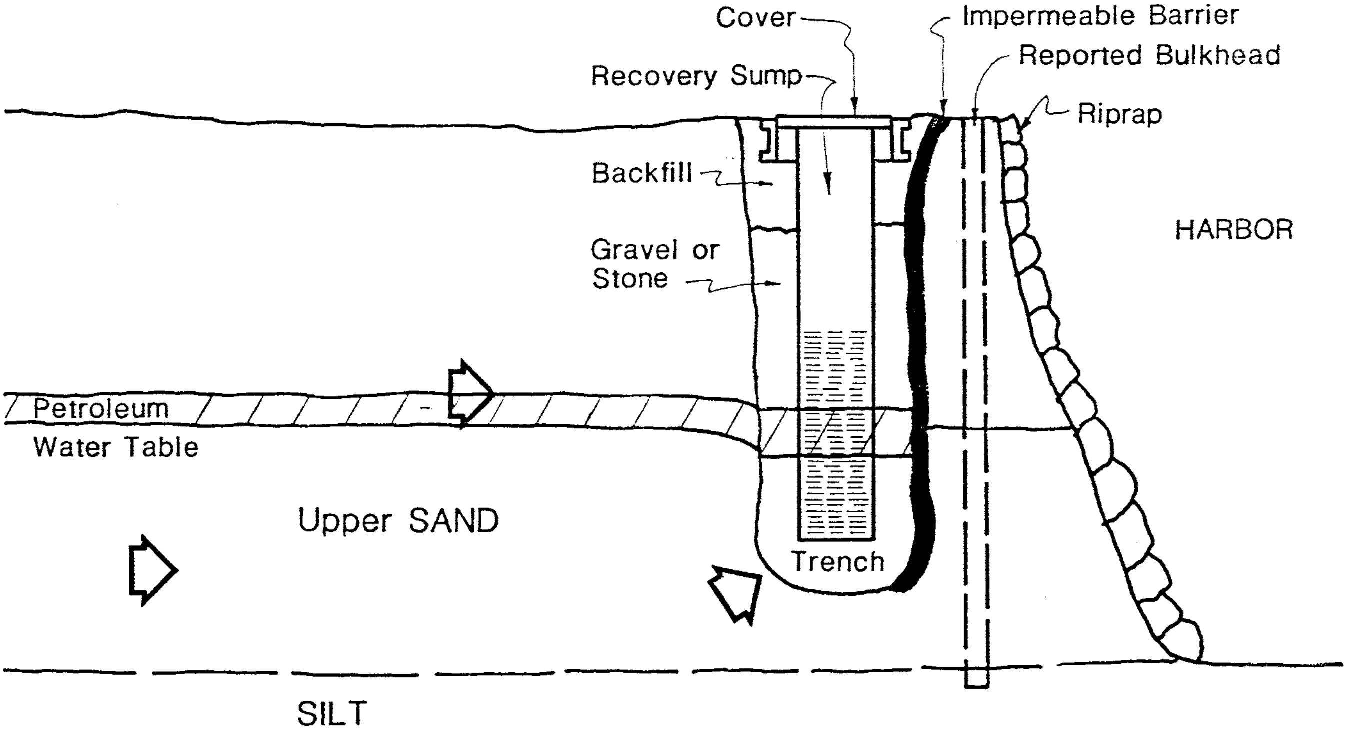


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Figure 3

APPENDIX A
FIELD PROCEDURES

Drilling and Well Installation

Eight wells were completed during September and early October 1983. Scott Wright, a geologist from Hart-Crowser, observed the drilling and well installations, and based upon these observations, prepared geologic logs and drawings of the "as-built" wells. These logs and well construction features are presented in Figures A-1 to A-8.

Drilling was completed using a truck-mounted CME drill rig equipped with a hollow-stem auger. Soil samples were obtained using a 2.5-nch split spoon sampler at selected intervals noted in the boring logs. Samples were placed in jars, capped and returned to the Hart-Crowser laboratory for further visual classification and selected grain size analyses. During sampling, evidence of petroleum contamination was noted.

After the drilling and soil sampling were completed, each boring was converted to an observation well. Two-inch PVC pipe and slotted screen (0.020 inch slot size) was installed through the center of the auger. Aqua No. 8 sand was placed around the screen and the auger was extracted. The wells were finished with a short bentonite seal and metal monument.

Three test pits were excavated by the Port while we were installing the wells. Their locations are shown on Figure 1. The pits were excavated to depths of 5.0 (TP-1), 9.5 (TP-2) and 11.0 (TP-3) feet. A PVC screen was installed in TP-3 from 1.0 to 11.0 feet. The test pits encountered similar soils as the borings.

Surveying and Well Water Level Measurement

Elevation surveying and well water level measurements were accomplished to determine groundwater flow directions. These data are presented in Table A-1.

Water levels were measured using an electric probe. Thickness of petroleum floating on the water table was measured using a tape coated with water and petroleum finding pastes.

Petroleum samples were obtained from wells B-2, B-5 and B-6 using a bailer with a check ball. Samples were placed in glass jars and transported to Am Test of Seattle for product identification.

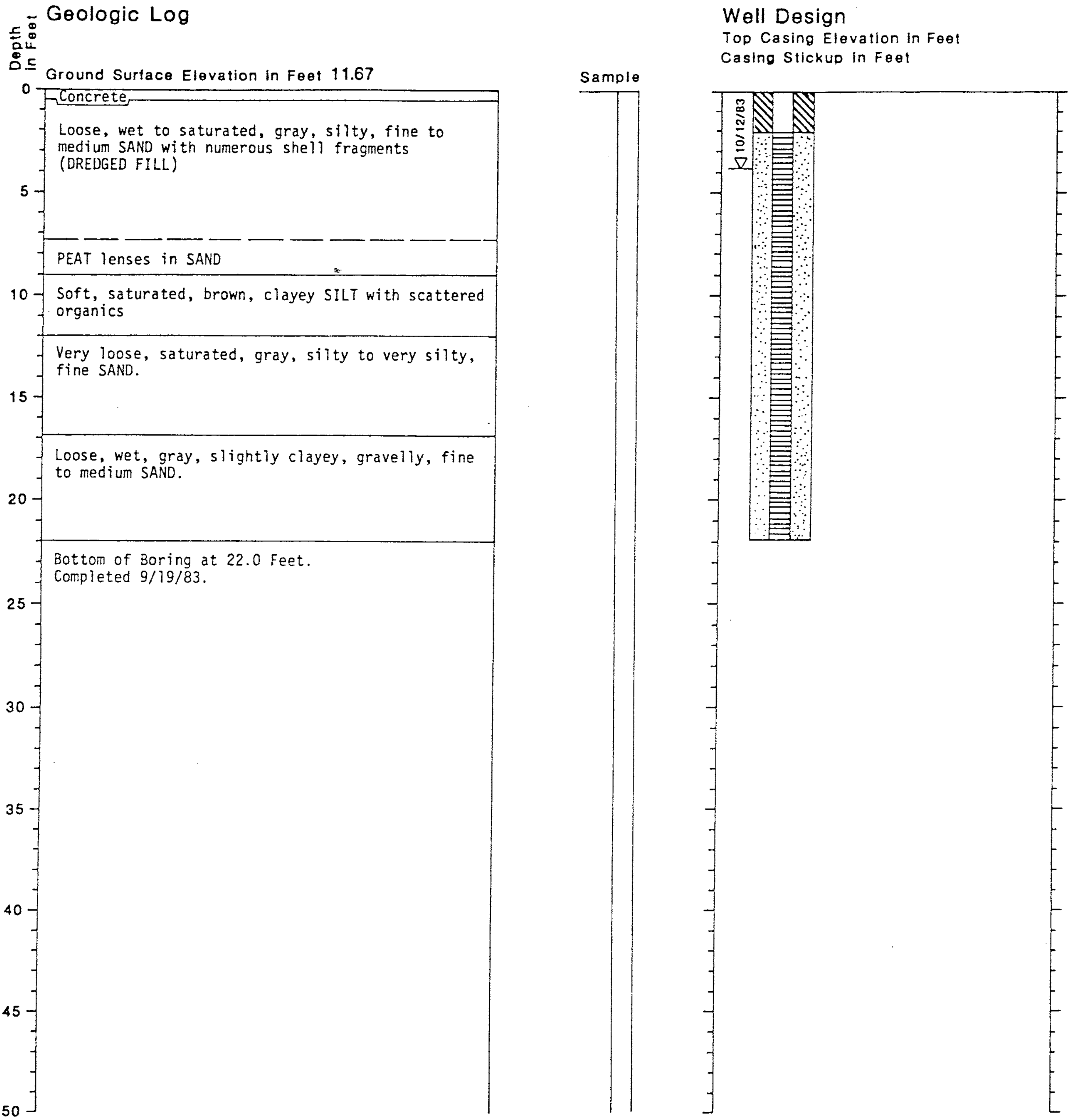
TABLE A-1 Water Table Elevation and Product Thickness Data

OBSERVATION WELL NUMBER	MEASURING POINT ELEVATION IN FEET	September 26, 1983			October 12, 1983		
		DEPTH TO WATER IN FEET	WATER TABLE ELEVATION IN FEET	PRODUCT THICKNESS IN FEET	DEPTH TO WATER IN FEET	WATER TABLE ELEVATION IN FEET	PRODUCT THICKNESS IN FEET
B-1	11.67	4.52	7.15	0.01	3.79	7.97	ND
B-2	11.58	6.22	5.36	0.58	4.74	6.84	0.26
B-3	12.10	6.09	6.01	0.04	5.00	7.10	ND
B-4	11.92	3.48	8.44	0.01	NA	NA	NA
B-5	11.70	5.75	5.95	0.81	4.98	6.72	0.89
B-6	11.71	NA	NA	NA	4.09	7.62	ND
B-7	11.61	NA	NA	NA	5.37	6.24	0.38
B-8	11.95	NA	NA	NA	5.79	6.16	0.05

Note: Measuring point for all observation wells is top of metal monument bolt flange. Elevation datum referenced to MLLW with "B" Dock elevation assumed to be 12.00 feet.

NA - Not Available
ND - None Detected

Boring Log and Construction Data for Well B-1



Concrete

Loose, wet to saturated, gray, silty, fine to medium SAND with numerous shell fragments (DREDGED FILL)

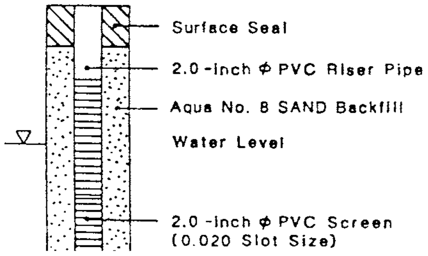
PEAT lenses in SAND

Soft, saturated, brown, clayey SILT with scattered organics

Very loose, saturated, gray, silty to very silty, fine SAND.

Loose, wet, gray, slightly clayey, gravelly, fine to medium SAND.

Bottom of Boring at 22.0 Feet.
Completed 9/19/83.



☒	2-inch O.D. Split Spoon Sample
*	No Sample Recovery
N	Standard Penetration Resistance, Blows per foot
GS	Grain Size Analysis
K	Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

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Figure A-1

Boring Log and Construction Data for Well B-2

Geologic Log

Depth In Feet

Ground Surface Elevation In Feet 11.58

0 Asphalt

Soft, wet, brown, slightly sandy, slightly clayey SILT with scattered organics. (DREDGED FILL)

5 Very loose to loose, wet to saturated, gray, slightly silty, fine to medium SAND with numerous shell fragments (DREDGED FILL)

10 Very soft to soft, saturated, brown, slightly fine sandy, clayey SILT with scattered organics.

15 Very loose, saturated, silty to very silty, fine SAND.

PEAT and ASH lenses

20 Loose, saturated, silty to very silty, fine SAND with numerous shell fragments.

Bottom of Boring at 22.0 Feet.
Completed 9/19/83,

25

30

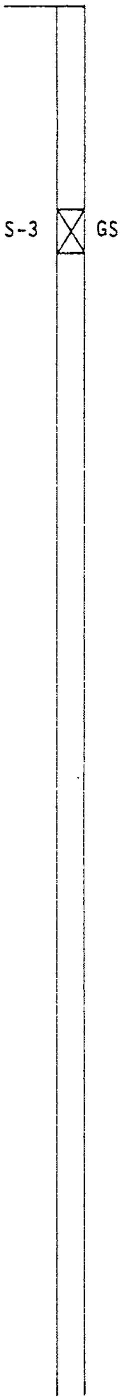
35

40

45

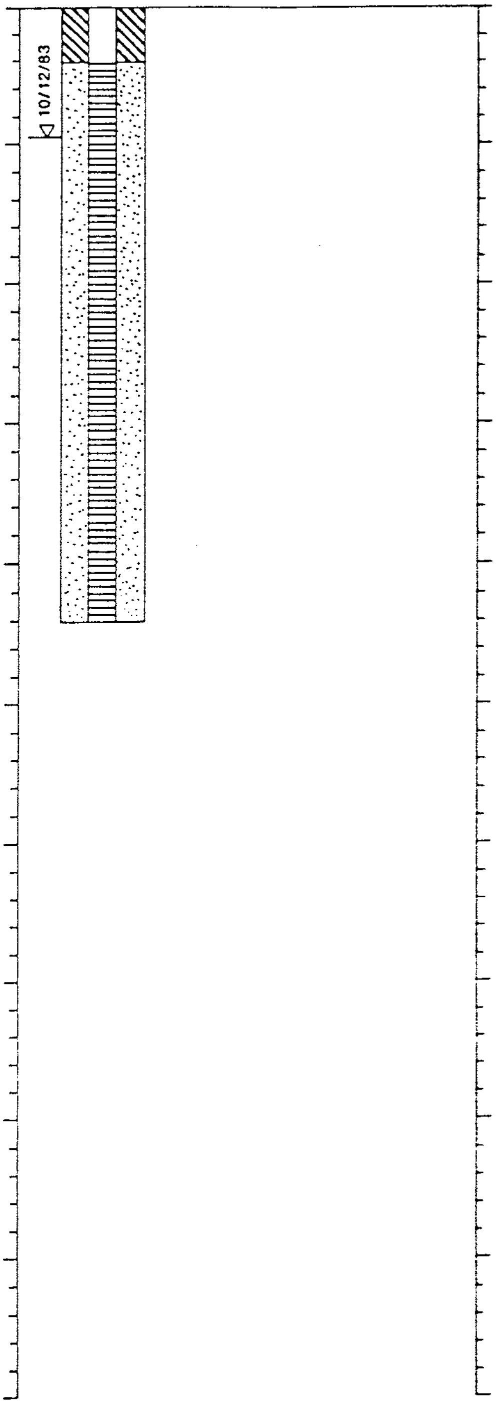
50

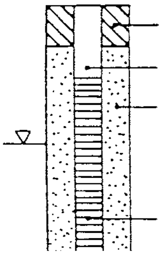
Sample



Well Design

Top Casing Elevation In Feet
Casing Stickup In Feet





☒ 2-Inch O.D. Split Spoon Sample
* No Sample Recovery
N Standard Penetration Resistance, Blows per foot
GS Grain Size Analysis
K Permeability Test

NOTES:
1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

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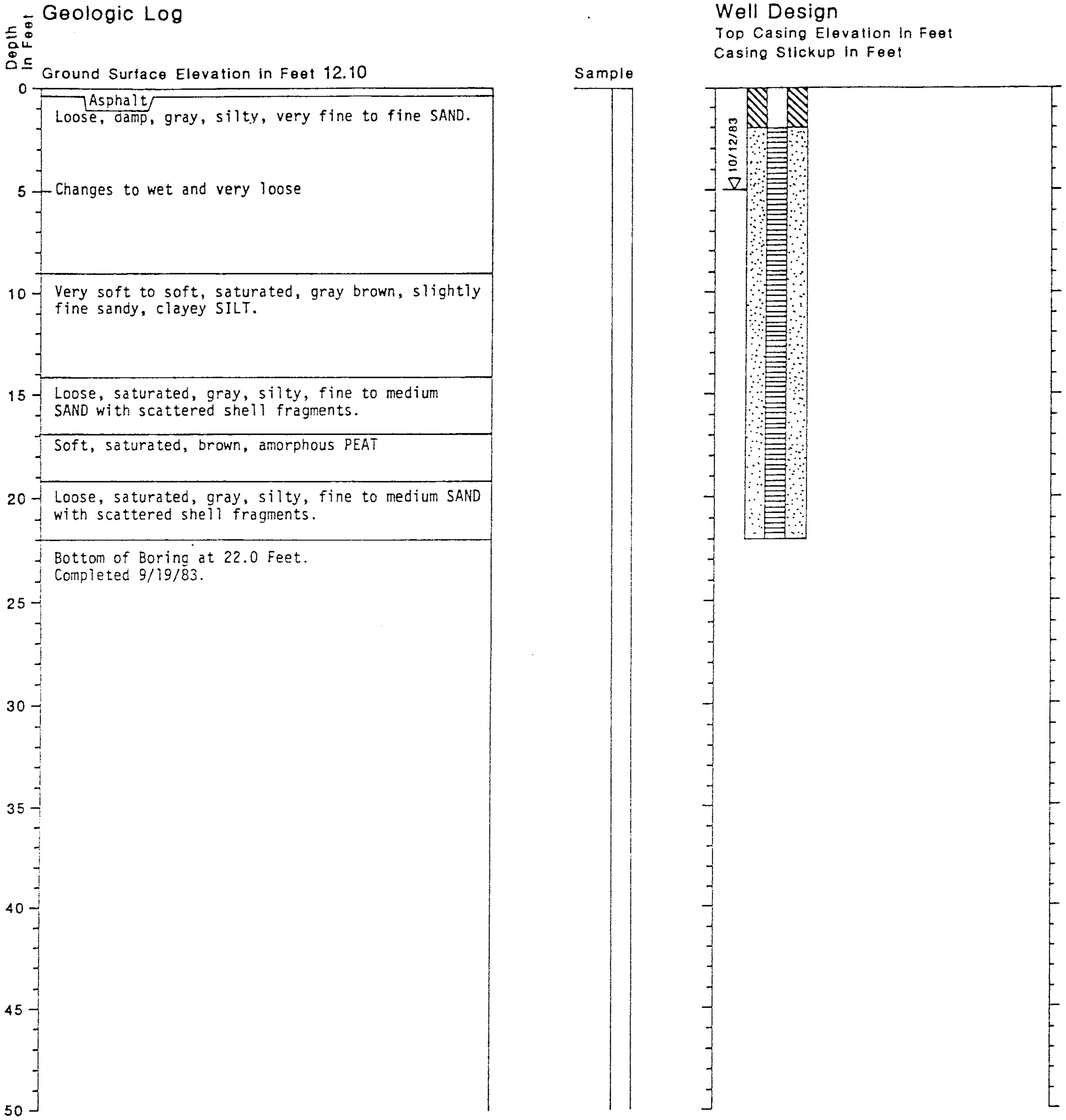
Figure A-2

Boring Log and Construction Data for Well B-3



Loose, damp, gray, silty, very fine to fine SAND.

Changes to wet and very loose

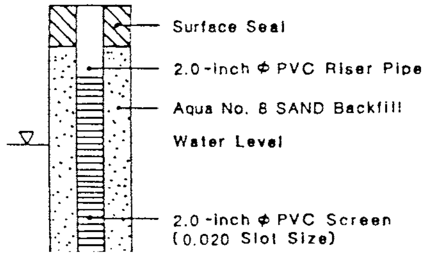
Very soft to soft, saturated, gray brown, slightly fine sandy, clayey SILT.

Loose, saturated, gray, silty, fine to medium SAND with scattered shell fragments.

Soft, saturated, brown, amorphous PEAT

Loose, saturated, gray, silty, fine to medium SAND with scattered shell fragments.

Bottom of Boring at 22.0 Feet.
Completed 9/19/83.



☒	2-inch O.D. Split Spoon Sample
*	No Sample Recovery
N	Standard Penetration Resistance, Blows per foot
GS	Grain Size Analysis
K	Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

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Figure A-3

Boring Log and Construction Data for Well B-4

Geologic Log

Depth in Feet

Ground Surface Elevation in Feet 11.92

Sample

0 Loose, moist, brown, gravelly, silty, fine to medium SAND with occasional cobble

5 Very loose, wet, brown, silty, fine to medium SAND with numerous shell fragments (DREDGED FILL)

10 Very soft, wet, brown, slightly sandy, clayey SILT

Loose, wet, gray, silty, fine SAND with scattered shell fragments

15

Changes to medium dense

20 Soft, saturated, gray, slightly sandy, clayey SILT

Bottom of Boring at 22.0 Feet.
Completed 9/19/83.

25

30

35

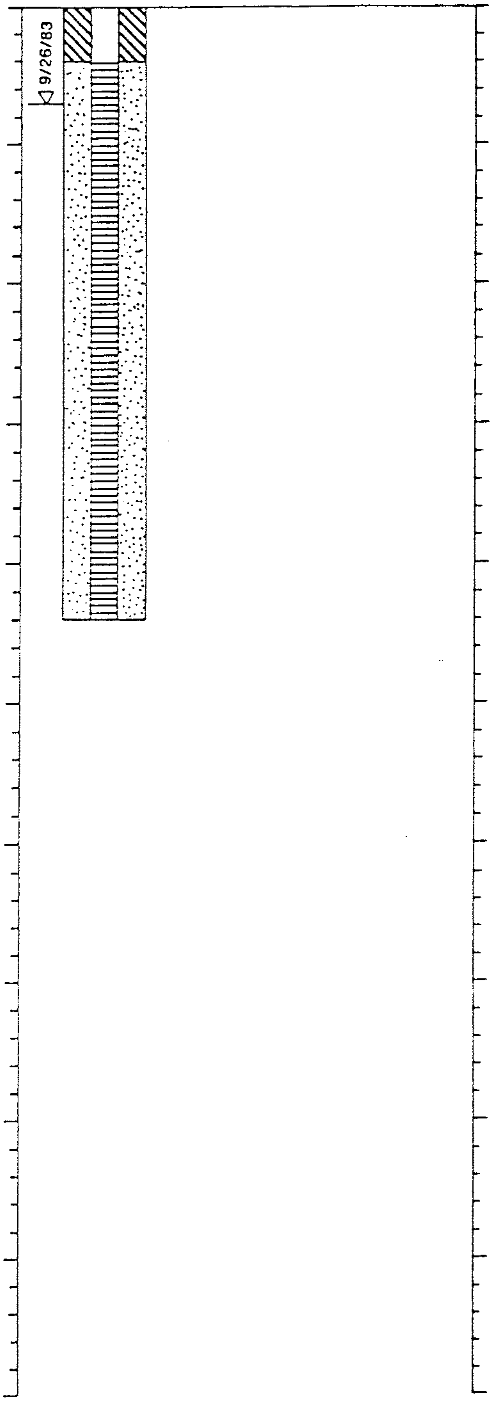
40

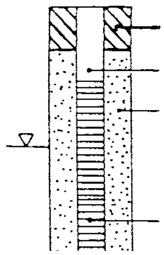
45

50

Well Design

Top Casing Elevation in Feet
Casing Stickup in Feet





☒ 2-inch O.D. Split Spoon Sample

* No Sample Recovery

N Standard Penetration Resistance, Blows per foot

GS Grain Size Analysis

K Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

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Figure A-4

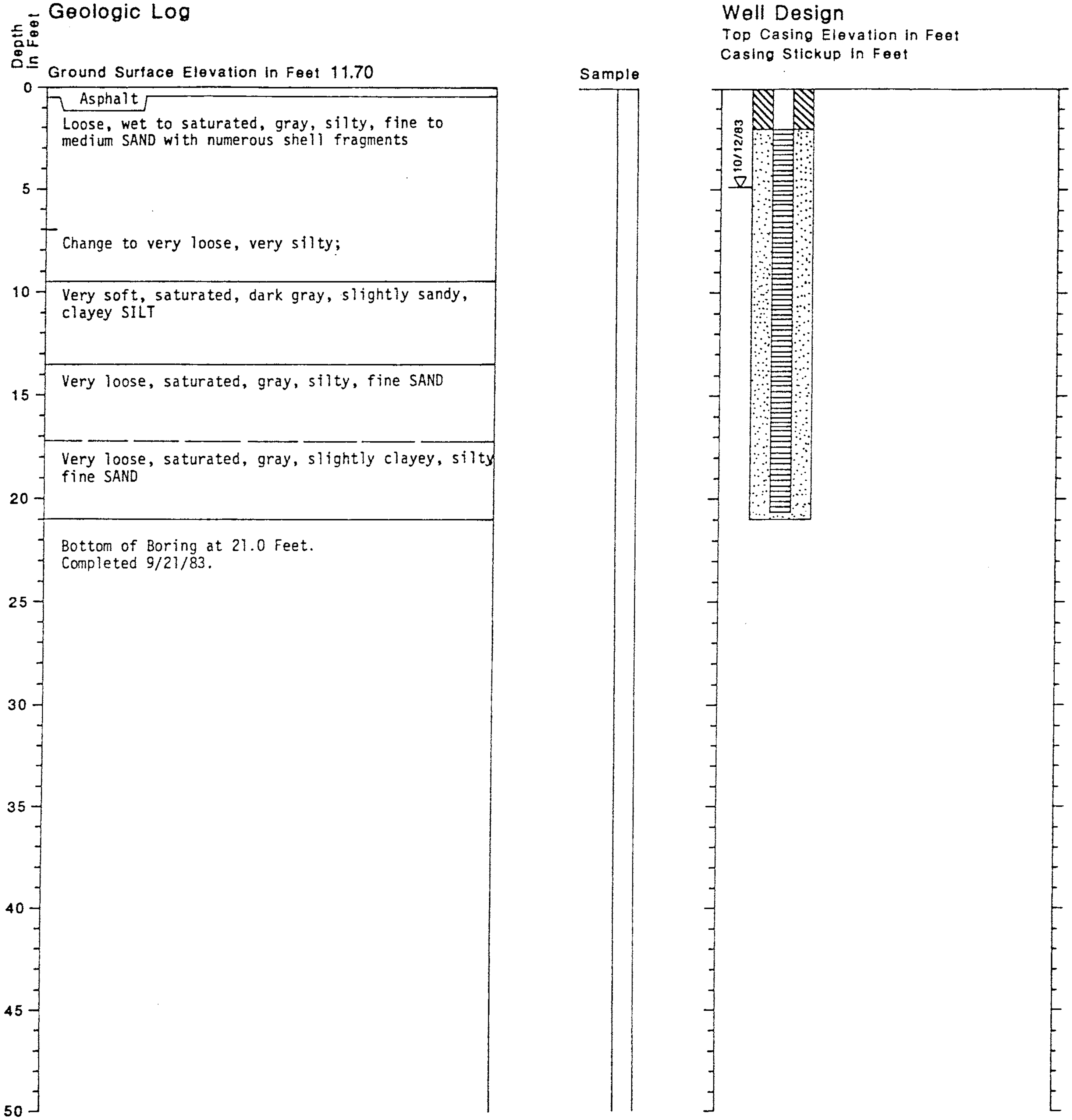
Boring Log and Construction Data for Well B-5

Geologic Log

Ground Surface Elevation in Feet 11.70

Well Design

Top Casing Elevation in Feet
Casing Stickup in Feet



Asphalt

Loose, wet to saturated, gray, silty, fine to medium SAND with numerous shell fragments

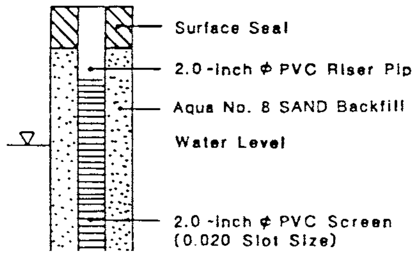
Change to very loose, very silty;

Very soft, saturated, dark gray, slightly sandy, clayey SILT

Very loose, saturated, gray, silty, fine SAND

Very loose, saturated, gray, slightly clayey, silty fine SAND

Bottom of Boring at 21.0 Feet.
Completed 9/21/83.



☒	2-inch O.D. Split Spoon Sample
*	No Sample Recovery
N	Standard Penetration Resistance, Blows per foot
GS	Grain Size Analysis
K	Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

J-1302 October 1983
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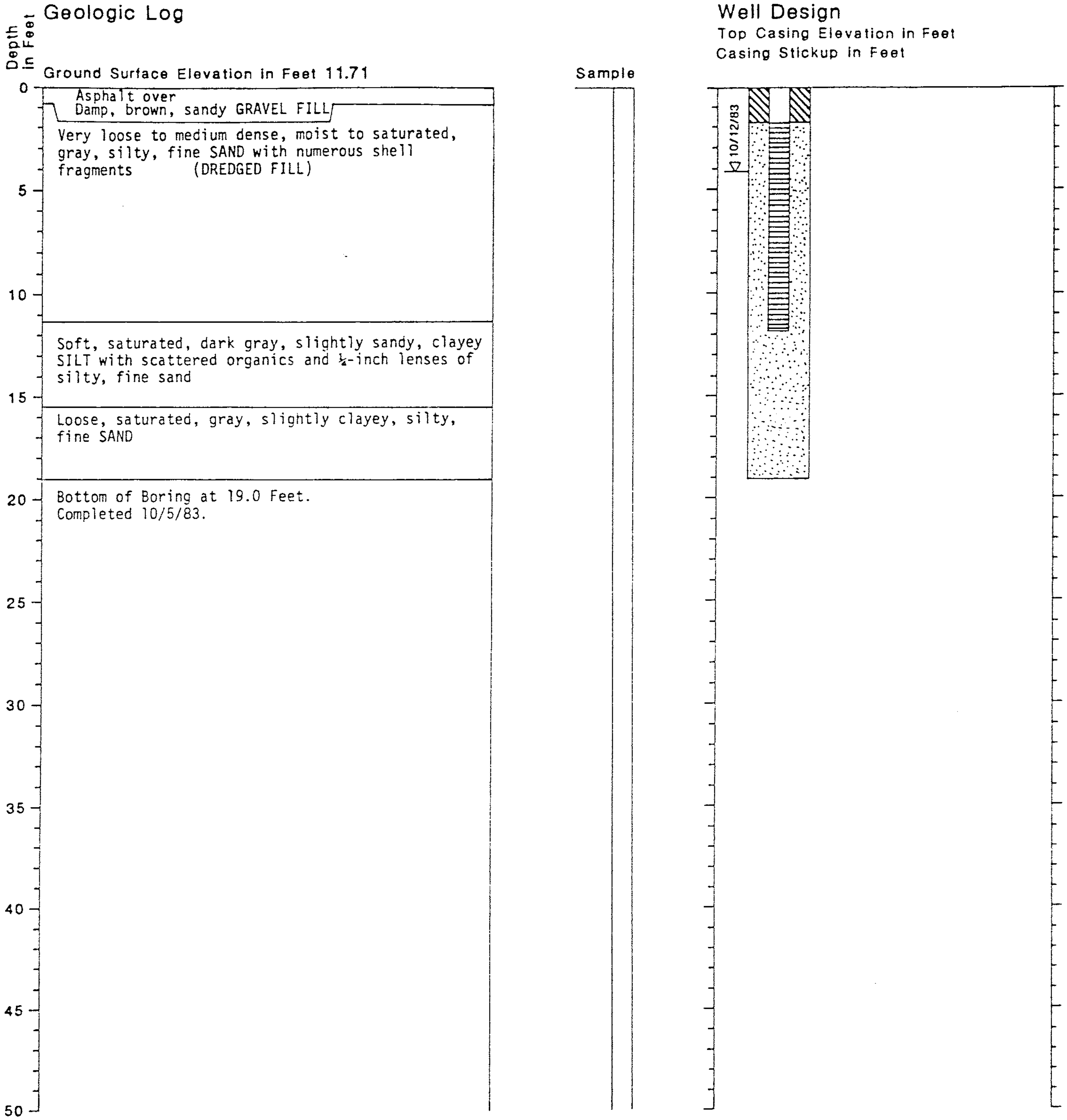
Figure A-5

Boring Log and Construction Data for Well B-6



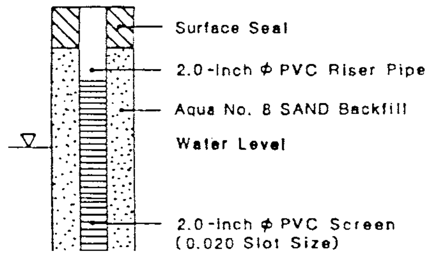
Asphalt over Damp, brown, sandy GRAVEL FILL

Very loose to medium dense, moist to saturated, gray, silty, fine SAND with numerous shell fragments (DREDGED FILL)

Soft, saturated, dark gray, slightly sandy, clayey SILT with scattered organics and ¼-inch lenses of silty, fine sand

Loose, saturated, gray, slightly clayey, silty, fine SAND

Bottom of Boring at 19.0 Feet.
Completed 10/5/83.



☒	2-inch O.D. Split Spoon Sample
*	No Sample Recovery
N	Standard Penetration Resistance, Blows per foot
GS	Grain Size Analysis
K	Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

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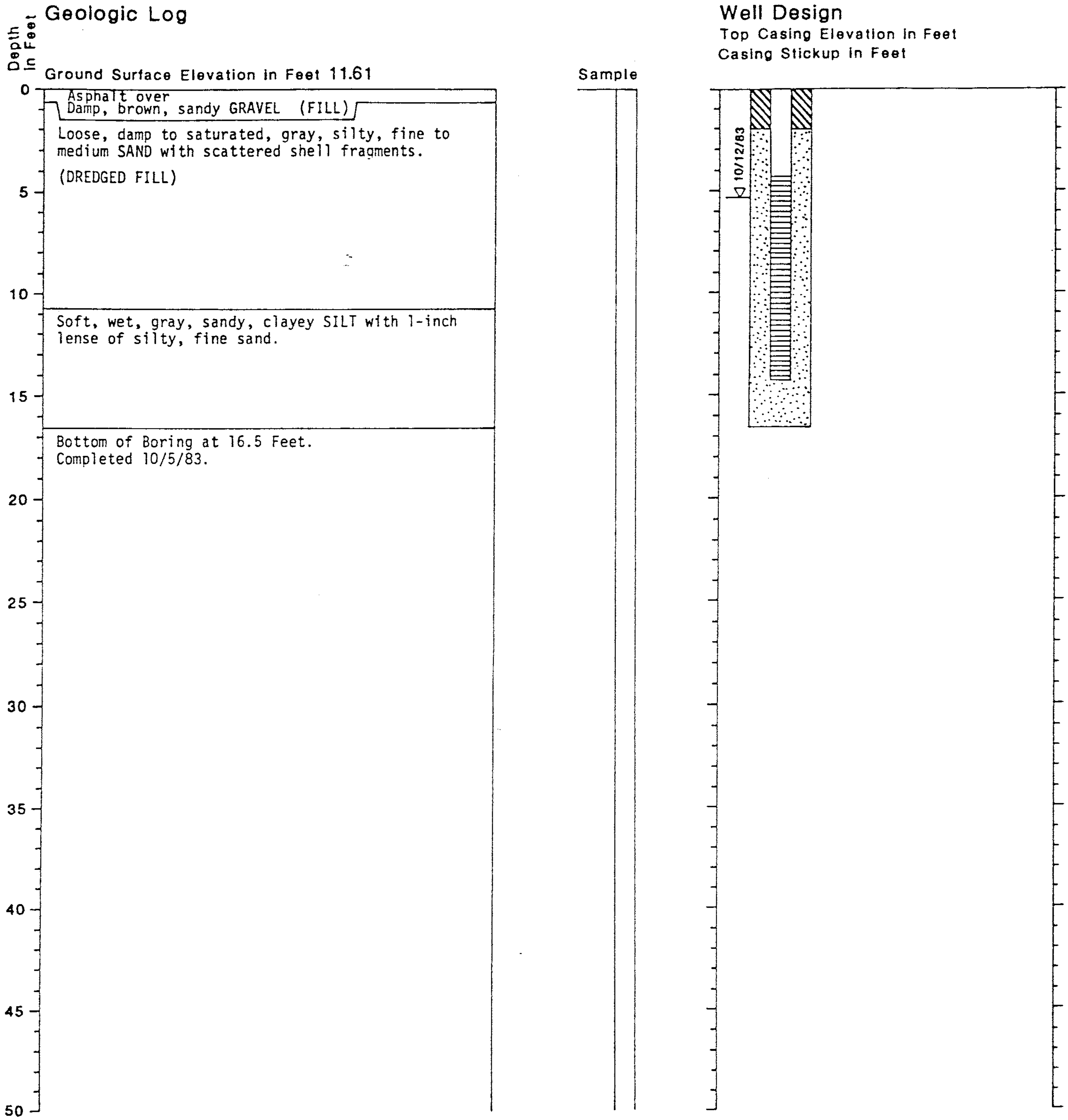
Figure A-6

Boring Log and Construction Data for Well B-7



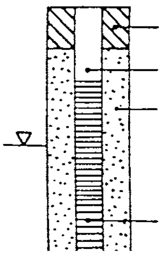
Asphalt over
Damp, brown, sandy GRAVEL (FILL)

Loose, damp to saturated, gray, silty, fine to medium SAND with scattered shell fragments.

(DREDGED FILL)

Soft, wet, gray, sandy, clayey SILT with 1-inch lense of silty, fine sand.

Bottom of Boring at 16.5 Feet.
Completed 10/5/83.



⊠	2-inch O.D. Split Spoon Sample
*	No Sample Recovery
N	Standard Penetration Resistance, Blows per foot
GS	Grain Size Analysis
K	Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD:At Time of Drilling

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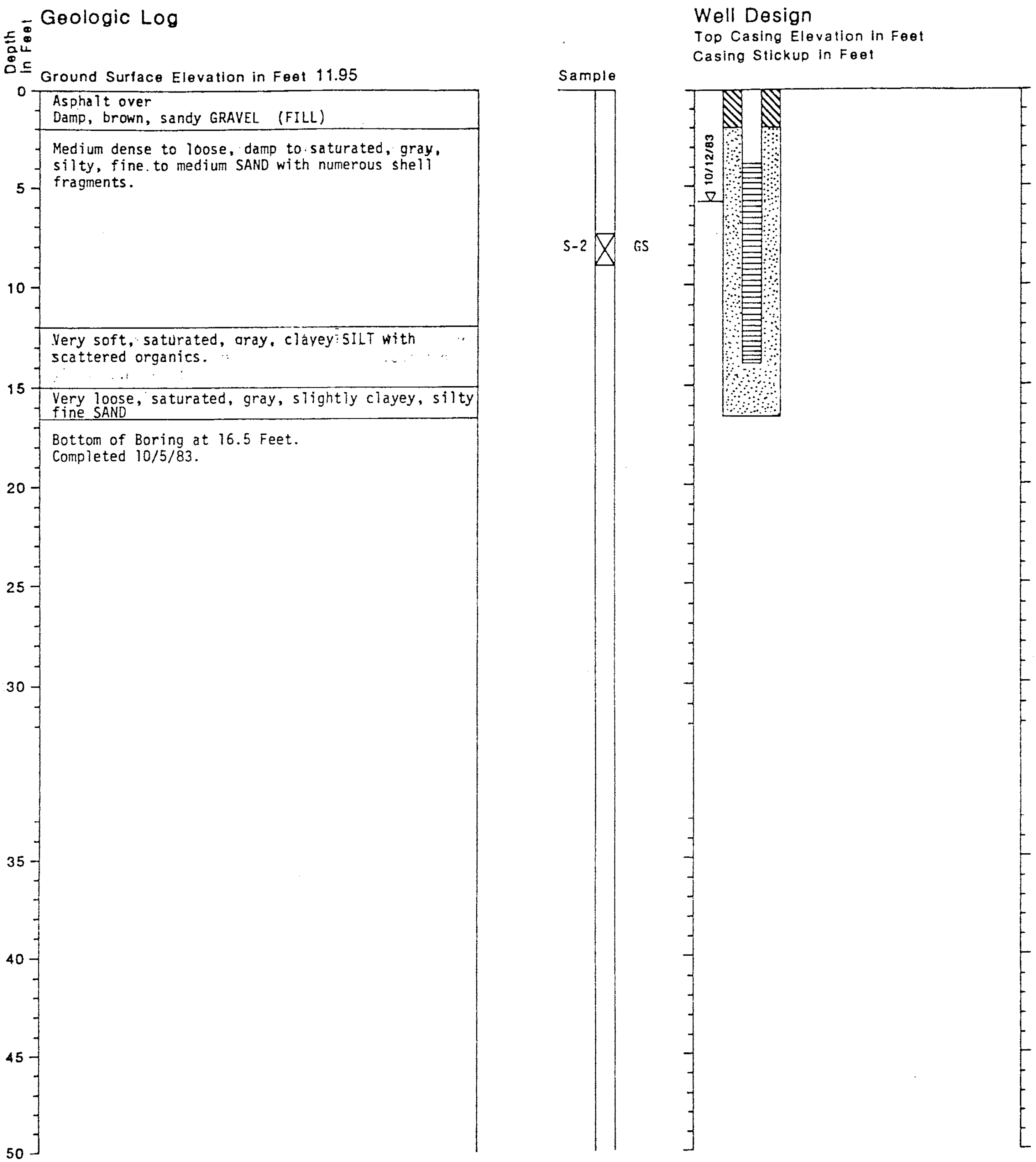
Figure A-7

Boring Log and Construction Data for Well B-8



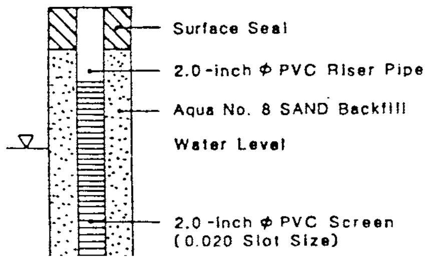
Asphalt over
Damp, brown, sandy GRAVEL (FILL)

Medium dense to loose, damp to saturated, gray, silty, fine to medium SAND with numerous shell fragments.

Very soft, saturated, gray, clayey SILT with scattered organics.

Very loose, saturated, gray, slightly clayey, silty fine SAND

Bottom of Boring at 16.5 Feet.
Completed 10/5/83.



☒ 2-inch O.D. Split Spoon Sample

* No Sample Recovery

N Standard Penetration Resistance, Blows per foot

GS Grain Size Analysis

K Permeability Test

NOTES:

1. Soil descriptions are interpretive and actual changes may be gradual.
2. Water Level is for date indicated and may vary with time of year. ATD: At Time of Drilling

J-1302 October 1983

HART-CROWSER & associates, inc.

Figure A-8

APPENDIX B
LABORATORY TEST PROCEDURES

Laboratory tests that were completed for this study included visual classification and grain size analysis of selected samples. The procedures are outlined below.

Visual Classification

All samples obtained from the test borings were visually classified in the field and then transported to our laboratory where their classifications were visually checked. Classifications were made in accordance with the Unified Soil Classification System. Visual classifications included soil consistency or density, color, moisture content and major soil type, as well as the modifying fractions in the sample. The visual classifications of the samples are presented in the boring logs (Appendix A).

Grain Size Analyses

Grain size analyses were performed on two selected granular samples in order to determine the grain size distribution and provide an evaluation of the permeability of the upper sand.

The tests were performed in general accordance with the procedures described in ASTM D422-63. The wet sieve analysis method which determines the size distribution greater than the No. 200 mesh sieve size was used. The results of the tests are presented as curves on Figure B-1, plotting percent finer by weight versus grain size.

Petroleum Identification

Laboratory analyses of three samples were completed by Am Test of Seattle. Free petroleum samples from B-2 and B-5 were analyzed using ASTM methods D-86 and D-121F. A third sample obtained from B-6 was analyzed for oil and grease using standard method 503B. The test results are presented in tables B-2 and B-3.

TABLE B-1

T-1302

AT am test inc.
4900 9TH AVENUE N.W., • SEATTLE, WASHINGTON 98107-3697 • 206/783-4700

ANALYSIS REPORT

CLIENT: Hart Crowser

DATE RECEIVED: 9/28/83

REPORT TO: Charles T. Ellingson
1910 Fairview Avenue East
Seattle, WA 98102

DATE REPORTED: 9/29/83

Laboratory Sample Number			9-566	9-567
Client Identification			B2	B5
Distillation Range :	Initial Boiling Point	(°C)	29	47
	10% Distilled	"	74	84
	20% " "	"	96	110
	30% " "	"	136	127
	40% " "	"	172	156
	50% " "	"	206	181
	60% " "	"	235	211
	70% " "	"	257	244
	80% " "	"	274	266
	90% " "	"	295	288
	End Point	"	306	304
Specific Gravity (60/60)			0.8003	0.8009

Sample #9-566 (B-2) has some very light ends and appears to be approximately 48% gasoline and 52% diesel fuel.

Sample #9-567 (B-5) has few light ends and appears to be approximately 55% gasoline and 45% diesel fuel.

REPORTED BY William A. Birch
William A. Birch

WAB:bc

TABLE B-2

5-1302

AT am test inc.

4900 9TH AVENUE N.W., • SEATTLE, WASHINGTON 98107-3697 • 206/783-4700

ANALYSIS REPORT

CLIENT: Hart Crowser & Associates

DATE SAMPLE RECEIVED: 10-11-83

REPORT TO: Mr. Charles Ellingson
1910 Fairview Avenue E.
Seattle, WA 98102

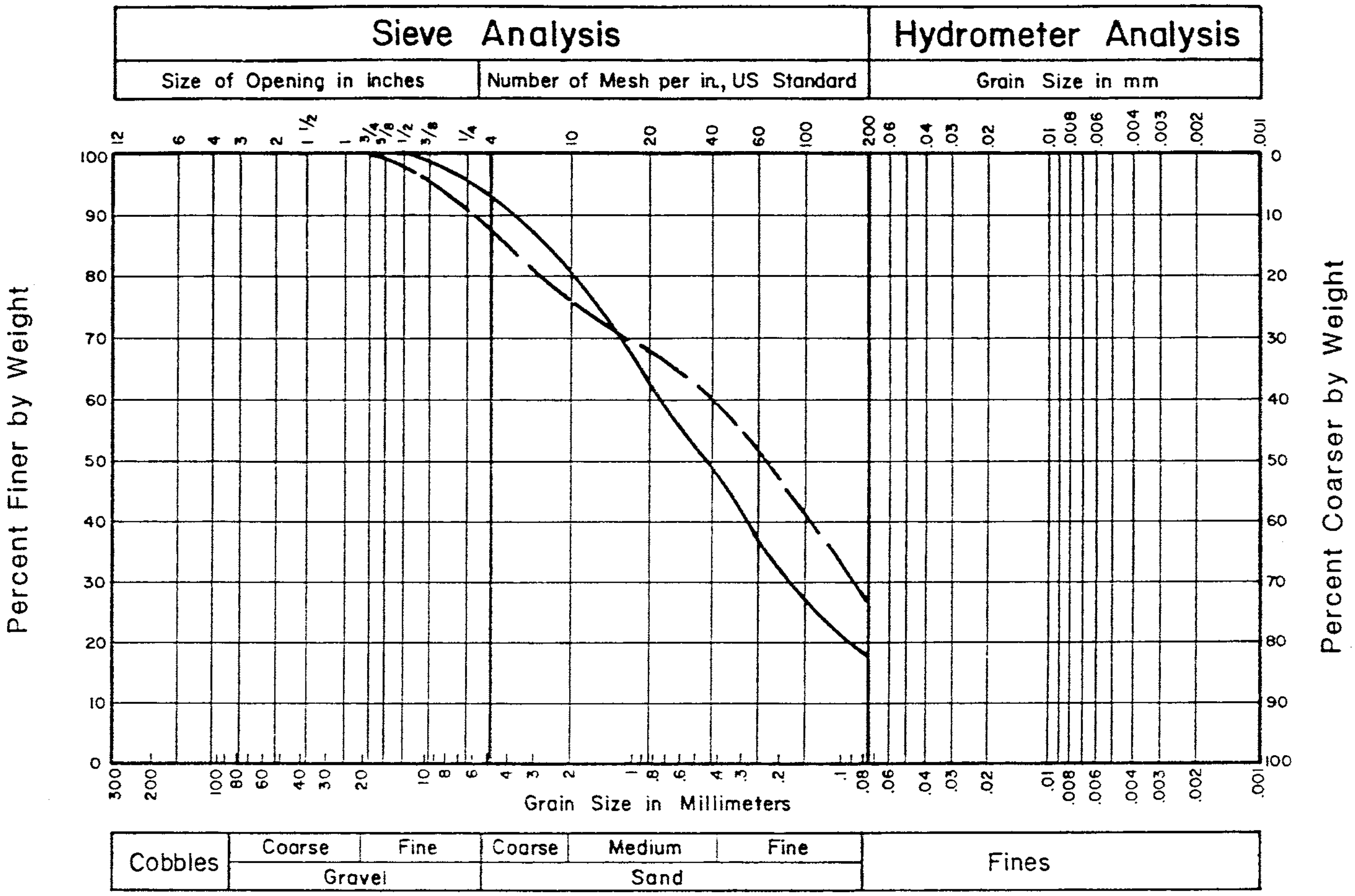
DATE SAMPLE REPORTED: 10-12-83

Laboratory Sample No.	71575
Client Identification	B-6 J-1302 10-10-83
Oil and Grease (mg/l)	386.

REPORTED BY
John M. Blunt

nr

Grain Size Classification



LINE SYMBOL	BORING NUMBER	SAMPLE NUMBER	DEPTH IN FEET	CLASSIFICATION	UNIFIED SOIL CLASS.	WATER CONTENT PERCENT
———	B-2	S-3	7.5- 9.0	Slightly gravelly, silty SAND with shell fragments	SM	28
— —	B-8	S-2	7.5- 9.0	Gravelly, silty SAND with shell fragments	SM	30

J-1302 October 1983
HART-CROWSER & associates, inc.
Figure B-1