FINAL

SITE INVESTIGATION

SUBSURFACE OIL CONTAMINATION–LOWER SUBASE

NAVAL SUBMARINE BASE, NEW LONDON

Groton, Connecticut

WEHRAN
Engineers
& Scientists

FINAL

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WEHRAN
ENGINEERS
& SCIENTISTS

November 30, 1987

Mr. Robert Kowalczyk
Code 114
Naval Facilities Engineering Command
Building 77-L U.S. Naval Base
Philadelphia, PA 19112

RE: Site Investigation
Naval Submarine Base- New London
Groton, Connecticut
Final Report
Lower SUBASE - Subsurface Oil Contamination
WE Project No. 04360

Dear Mr. Kowalczyk:

Wehran Engineering Corporation is pleased to present the attached Final Site Investigation Report for the subsurface oil contamination at the above-referenced facility. This final report has been prepared pursuant to the terms of the agreement between Wehran Engineering Corporation and the Department of the Navy. Wehran has also attached the Navy's October 9, 1987 comment letter regarding the Draft Lower SUBASE Subsurface Oil Contamination Report April 1987, followed by Wehran's point-by-point response to those comments. Three (3) copies of the final report, including our point-by-point response, are submitted for review by Naval Personnel.

Wehran Engineering personnel are available to meet with you at your convenience to review the Final Report. Should you have any questions or require any additional information at this time, please contact this office.

Sincerely
WEHRAN ENGINEERING CORP.

Richard J. Messer

Richard J. Messer
Project Manager

RJM/db

Attachments
cc: W. Mansfield w/Enc. (2)

100 MILK STREET, METHUEN, MA 01844 • (617) 682-1980

DEPARTMENT OF THE NAVY
NORTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
PHILADELPHIA, PENNSYLVANIA 19112-5094

RECEIVED
By______________
OCT 15 1987
WEHRAN ENGINEERING
METHUEN, MA

6280
Ser 2054/1421/RLK
09 OCT 1987

Mr. Richard Messer
Wehran Engineering
100 Milk Street
Methuen, MA 01844

Dear Mr. Messer:

Enclosed are comments on the Lower Subase Subsurface Oil Investigation Report and the Nautilus Park Leaking Underground Storage Tank Investigation Report. The Navy requests revised reports be submitted by 20 November 1987. Along with the revised reports, the Navy requests Wehran Engineering provide supporting information to document the response to each of the comments.

Mr. Robert Kowalczyk, Environmental Engineer, of the Environmental Division at this Command should be contacted at (215) 897-6436 if you have any questions.

Sincerely,

T.G. Sheckels
Head, Restoration Management Section
By direction of the Commanding Officer

Copy to:
NSB New London

Comments on the Lower Subase Subsurface Oil Contamination Report

1. The title of the report should be changed to remove references to the NACIP (now Installation Restoration (IR)) program. A suggested title is " Site Investigation of Subsurface Oil Contamination Lower Subase."

2. Reference to the NACIP program in the Executive Summary, Introduction and elsewhere in the report should be removed. This should include any reference in the text to the characterization study.

Section 2.3 Manhole Sand Cleaning

3. This section should report observations of conditions in the sand manholes, such as if oil was observed on the water surface in the manholes in the afternoon.

Section 2.4 Sampling of Manholes and Utility Trenches

4. This section should include the sampling objectives as outlined in Section 2.2.1 of the plan of action

Section 2.5 Hydrogeologic Field Methods

5. This section should include the data objective for each boring as outlined in Section 2.3.1 of the plan of action.

Section 2.5.5 Tidal Fluctuations Measurements

6. Explain in the text that the abbreviation P.K. means point known.

Section 4.1 Manholes and Trenches

7. Since fluorescence spectroscopy is not a standard method, the report should contain an appendix with information on the method such as, a description, limits of detection, spectrograms and anticipated reproducibility of results.

Section 4.3 Groundwater Quality

8. Some information reported on Table 6 requires additional explanation. Standard procedure to purge wells prior to sampling is to remove three (3) times the volume of water in the well. In four of the wells large volumes of water were purged prior to sampling. The report should explain the reasons for deviating from the standard procedure. Also, the temperature readings for wells WE-1, WE-2 and WE-4 are elevated. The reasons for the elevated temperatures should be explained.

9. There is an attempt to explain the high conductivities in the groundwater samples. The report alludes to metal cuttings from past operating and disposal practices of lubricating or waste oils. The report should provide specific evidence, if found, that the metal cuttings were contained in the water samples. The recommendations should include analysis to determine the reasons of the high conductivity values. An analysis to determine chloride content may be appropriate.

Section 4.4 Analytical Quality Control

10. To completely evaluate the Quality Assurance/ Quality Control (QA/QC) procedures for field sampling and laboratory analysis the following additional information should be reported in Appendix D or E:

- The dates the samples were analyzed.

- The regulatory agencies acceptable holding times and statements whether the samples were analyzed within the acceptable holding times.

- The chain of custody for sample F.O 1. This sample was collected with other oil samples and apparently analyzed and the results reported separately almost two months before the results of the remaining oil sample results.

- An explanation of the loss of sample NSB-WS-WE3-007.

- The reason(s) why the fluorescence spectroscopy results were reported three separate times: December 12, 1986; January 21, 1987 and February 27, 1987.

Section 6.0 Conclusions and Recommendations

11. The recommendations given for the remedial measure around building 79 are weak. The Navy agrees excavation and disposal of the contamination is to expensive. The recommendations to periodically mop-up oil from manholes in not acceptable. The Navy suggests in-situ biological treatment method be evaluated as a clean-up alternative. The reasons to consider in-situ biological treatment are the following: the relatively permeable nature of the subsurface. the apparent localized contamination and the heavy waste and fuel oils that were identified do not readily migrate. Some questions that need to be answered to determine if in-situ biological treatment is applicable are: What is the extent of contamination?, and Can a hydrocarbon consuming organism be found and propagated to tolerate the probable saline conditions at the site?

POINT-BY-POINT RESPONSE TO NAVY'S COMMENT LETTER 10/9/87 (RECEIVED 10/15/87) REGARDING WEHRAN'S DRAFT LOWER SUBASE - SUBSURFACE OIL CONTAMINATION REPORT 5/6/87.

1. Per your request, the report title has been changed from Draft Confirmation Study, Step IA Verification Report, Subsurface Oil-Lower Sub Base to Final Site Investigation of the Lower SUBASE - Subsurface Oil Contamination removing all references to the NACIP program.

   Note: Although the report title has changed, Wehran has been working under one contract #N6242-84-C-1018 which is invoiced in reference to the NACIP Confirmation Study.

2. Per your request, any direct reference to the NACIP program in Wehran's report has been removed. (see note above)

3. Section 2.3 Manhole Sand Cleaning describes the sand manhole cleaning method while Section 2.4 Sampling of Manholes and Utility Trenches describes the condition of the manhole. Page 9 - 4th paragraph - The sand manholes which had been cleaned out in July 1986 (MH-6,7,8 and 9) were re-opened and conditions observed. There was no visible evidence ofcontamination in any of the four manholes.

   To clarify the second paragraph, second sentence, on page 9, the words: visually clear were inserted before the word; water.

4. The sampling objectives were added.

5. The objectives of each individual boring were added.

6. Next to the abbreviation P.K. (point known) was added.

7. The information on the fluorescence spectroscopy method has been put into Appendix F.

8. Standard procedure to purge wells prior to sampling is to remove a minimum of three volumes of water in the well. Additionally when purging a well, measurements of specific conductance should be made until repeatable results are obtained (this was inadvertently missed in the draft report but has been added to the final report on page 14).

   The reason large volumes of water were purged from four of the wells prior to sampling is twofold, (1) it was difficult obtaining a repeatable specific conductance measurement while (2) a high volume (1 gallon per minute) pump was being used. These two factors lead to high volumes of water being pumped. This is not a deviation from standard procedure since a minimum of three volumes was purged.

   Wehran has added to Table 6 Summary of Ground Water Sampling Data the following note: The very warm water temperatures of wells WE-1, WE-2 and WE-4, and the elevated water temperatures of wells WE-3, WE-5, MW-4 and MW-10 seem to reflect a problem with the thermometer. The first three wells WE-4, WE-1 and WE-2 were measured consecutively with all three of the measurements being extremely high, the remaining four measurements are also unrealistic values considering average water temperatures of 10-15°C during this part of the year.

It is not the difference between WE-1, WE-2, WE-4 and the other wells but the fact that all of the temperatures are above realistic values for that part of the year. Wehran feels that there was a problem with the thermometer and this problem was not identified in the draft report.

9. No direct evidence was found in the field to confirm the hypothesis that the high conductivity values present around building 79 were associated with metal cuttings within a lubrication/waste oil from past operations. Therefore a statement was added to page 34 clarifying this fact.

   Salinity measurements were added as part of the recommendations to confirm the salt water intrusion hypothesis.

10. There is no holding time for fuel oil analysis by the fluorescence spectroscopy method provided the sample is kept in an amber jar and out of direct sunlight, therefore the dates the samples were analyzed and the acceptable holding times are not relevant.

    The chain of custody for sample F 01 is in Appendix D Chain of Custody Forms.

    The sample NSB-WS-WE3-007 was broken in transit from York Laboratories to their subcontract lab.

    The Lab did not supply all the information they promised to Wehran in the first report, so following additional requests by Wehran the information was eventually supplied in three reports.

11. Wehran does not believe that the recommended remedial measures around Building 79 are weak for the following reasons:

    Navy's previous Engineer in Charge (EIC) indicated that the Navy was not interested in elaborate, expensive remedial measures (for which Wehran agreed).

    Currently the oil does not appear to be readily migrating which was expected, therefore an immediate response may not be necessary (soil removal). Currently the oil is being naturally collected in several manholes, why not use them as you would a collection well. Obviously the hydraulic pressures created by the tidal changes are forcing the oil into the manholes, similar to any artifically induced system.

    There are several reasons against considering the Navy's recommendation for an in-situ biological treatment method as follows:

    1) The tidal area creates a timing problem when injecting the oxidizers, nutrients and organisms on the upgradient side of the oil contamination.

    2) A #6 oil is thicker and more dense than most fuel oils therefore it becomes more difficult to biologically break down the inner portions of the oil globs due to the anaerobic conditions.

3) It takes several years to develop a stable and active group of organisms that maintain a steady rate of biodegradation.

4) Several additional bore holes and wells would have to be installed in an area of numerous utilities.

5) Operation and maintenance would include pumps, chemicals, mechanical timing devices and periodic sampling.

6) The area of concern doesn't appear to be extensive enough to warrant the capital expenditures.

Wehran feels that in-situ biological treatment is a viable method for the eventual clean up of the site if Navy has the time and money to experiment with the method. There are a few other remedial actions that could be implemented at this site but Wehran recommended only the ones we felt were economically viable, reliable and met the Navy's requirements. So after receiving comment #11, we have added a remedial measure below that could be evaluated during a feasibility study of the site.

Besides in-situ biological treatment, a pump and treat system could be evaluated in which the vicosity of the oil is reduced using heat or emulsifiers and a pumping/injection system is designed to treat the mobile oil. (Due to the number of utilities and the various fill material in this area, an effective pump and treat system would likely be difficult to implement).

FINAL

SITE INVESTIGATION
Of
SUBSURFACE OIL CONTAMINATION - LOWER SUBASE

NAVAL SUBMARINE BASE, NEW LONDON
Groton, Connecticut

WE Project No. 04360

Prepared for
DEPARTMENT OF THE NAVY - NORTHERN DIVISION
Philadelphia, Pennsylvania

Prepared by
WEHRAN ENGINEERING CORPORATION
100 Milk Street
Methuen, Massachusetts

November 1987

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EXECUTIVE SUMMARY

The United States Department of Navy authorized Wehran Engineers and Scientists to conduct a site investigation of subsurface heavy oil contamination at the Naval Submarine Base - New London, Groton, Connecticut. The study consisted of six tasks with a primary objective of determining the horizontal extent and interrelation between the heavy oils found in various manholes and concrete utility trenches.

The focus of the study was on the lower SUBASE in the vicinity of known oil sources. Historically the Navy Environmental Support Office (NESO) 1979 Study and the Initial Assessment Study (IAS) 1982 reported on three areas and three sites respectively, identifying possible or actual oil contamination. In summary, the focal points include the Power Plant (Building 29) (see Figure 6.1), the oil storage tanks adjacent to Buildings 345 and 29, and Building 79, (the historic train engine repair building). Evidence of the oil contamination has since been observed in several manholes and a concrete utility trench, west and east of Building 79.

The sampling plan consisted of ten (10) soil samples from five soil borings, nine (9) sludge oil samples from five manholes, and seven (7) ground-water samples from seven monitoring wells which were submitted to an EPA certified laboratory for analyses. For this site investigation, the fluorescence spectroscopy method of analysis was used on the sampled media (soil, sludge, ground water). This method is used to identify the type (e.g. #2, #6 oil), degree of weathering (e.g. less than one year and general levels of oil contamination (e.g. trace, low).

The analytical results showed #6 oil to be the predominant contaminant found in the manholes / trenches, as well as the study area. The age of the #6 oil was less than one year in the concrete utility trench adjacent to Building 35 and greater than one year in the manholes in the vicinity of Building 79. Waste oils were also present in trace levels in the ground water and soil samples adjacent to Building 79. The sludge oil sample taken from a manhole in the area of Buildings 29 and 345 was different from all other samples. The analysis of this sample resulted in a unique spectra interpreted in the lab as a mixture of #5 and #6 fuel oils.

In conclusion, three separate oil contaminated areas seem to be present:

1) The concrete utility trench contaminated with a #6 fuel oil that is less than one year old.
2) The manholes, soils, and ground water in the vicinity of Building 79, contaminated with a #6 fuel oil that is greater than one year old and trace levels of a waste oil.
3) The manholes, soil and ground water in the vicinity of Buildings 29 and 345 contaminated with #5 and #6 oils.

Recommendations for these three sites include:

1) The inspection of the #6 fuel line and the subsequent cleaning of the trench.
2) Oil mopping of the sludge oil in the manholes and/or excavation of the oil laden soils.
3) An additional study of the operations and distribution of oil in Building 29, including further study of the adjacent contaminated manholes.

1.0 INTRODUCTION

1.1 BACKGROUND

The Department of the Navy has developed an evaluation process for assessing contamination at Naval facilities which focuses on past operational practices that may have involved the handling or disposal of toxic and hazardous materials. The overall objective of the process is to identify and quantify contamination due to hazardous materials, and to further assess the potential impacts of the contamination on human health and the environment. The evaluation process, which was developed as part of the Navy Assessment and Control of Installation Pollutants (NACIP) (currently the Installation Restoration [IR]) program, was conducted along the lower SUBASE by Envirodyne Engineers, Inc. (EEI), St. Louis, Missouri on April 26, 1982. During the Initial Assessment Study (IAS), a records search and a subsequent site visit were conducted by EEI on May 17-28 and June 21-25, 1982, respectively. Through review of the records, personnel interviews and site inspections, a number of potential contamination sites were evaluated. The IAS team identified 11 potentially contaminating sites upon their completion of the evaluation process. Six of the sites were found to have a low or moderate potential, and five sites had a high potential for contributing contaminants to the surrounding environments. Wehran was contracted by the Navy and had initiated the confirmation study for three of the sites on the upper SUBASE when thick black oil was found by Navy personnel in the concrete utility trenches and manholes on the lower SUBASE. Thick black oil had been identified in manholes in the vicinity of Building 79 and in the concrete utility trenches adjacent to Building 35. Wehran's investigation is in part, a continuation of the Navy Environmental Support Office (NESO) February 1979 study, in which remedial measures for an oil problem on the lower SUBASE were recommended and completed by Navy personnel, but since that time the oil has reappeared.

This report provides the results of the site investigation of the lower SUBASE subsurface oil contamination. The report details the investigation procedures that were utilized, the findings of the analytical program, and the resulting conclusions and recommendations for the next phase of the investigation.

1.2 PROJECT OBJECTIVES AND SCOPE OF WORK

Wehran's objective for this site investigation is to identify and delineate the sources of the thick, black oil found in the manholes and concrete utility trenches of the lower SUBASE. Upon completing the identification process, recommendations for further investigations and/or candidate remediation measures are presented.

The scope of work performed included four tasks, with the following specific objectives for each task:

Task I - Pre-Site Investigation

A. Locate, identify and map the oil storage tanks and associated distribution systems in the areas of concern.

B. Develop a comprehensive map of the utility layout in the areas of concern.

C. Develop a cross section of the relieving platform and quay wall

D. Perform a site reconnaissance

E. Develop a work plan for the site investigation

Task II - Site Investigation

A. Investigate oil contamination by examining and sampling manholes, trenches, culverts, and catch basins.

B. Perform five borings with soil sampling, followed by installation and development of monitoring wells.

C. Perform variable head permeability tests

D. Survey the top of casing elevations on the new and old observation wells.

E. Measure water levels in the observation wells during one full cycle of a tidal fluctuation.

F. Sample groundwater

G. Remove sand from manholes

H. Sample contaminated sludge, soil, and/or sediment from manholes and trenches.

Task III - Laboratory Analyses

A. Develop and implement a quality assurance program. Sample collection, preservation and analytical procedures will be in accordance with regulatory standards.

B. Conduct the laboratory analyses in accordance with site specific plan of action.

Task IV - Draft Verification Report

A. Brief restatement of IAS findings and conclusion

B. Description of analytical findings

C. Evaluation of the contamination discovered.

D. An assessment of the extent and magnitude of the contamination including recommendations for further investigations.

E. An evaluation of candidate remediation measures.

1.3 SITE LOCATION

The Naval Submarine Base (NSB), New London, is located in southeastern Connecticut along the east bank of the Thames River. The NSB is within the Townships of Ledyard and Groton and is located north of the center of Groton (see Figure 1.1).

1.4 DESCRIPTION OF THE SITE

The main base encompasses 547 acres, with over 300 structures and buildings. The NSB performs four (4) major services to the operational fleet. First, it serves as home port for submarines and their crews. Second, it provides maintenance and repair facilities for submarines and other assigned craft. Third, it provides basic, advanced, and refresher submarine training classes to Naval personnel. The fourth function is medical care facility, including research and training in the field of medical care for submarine personnel.

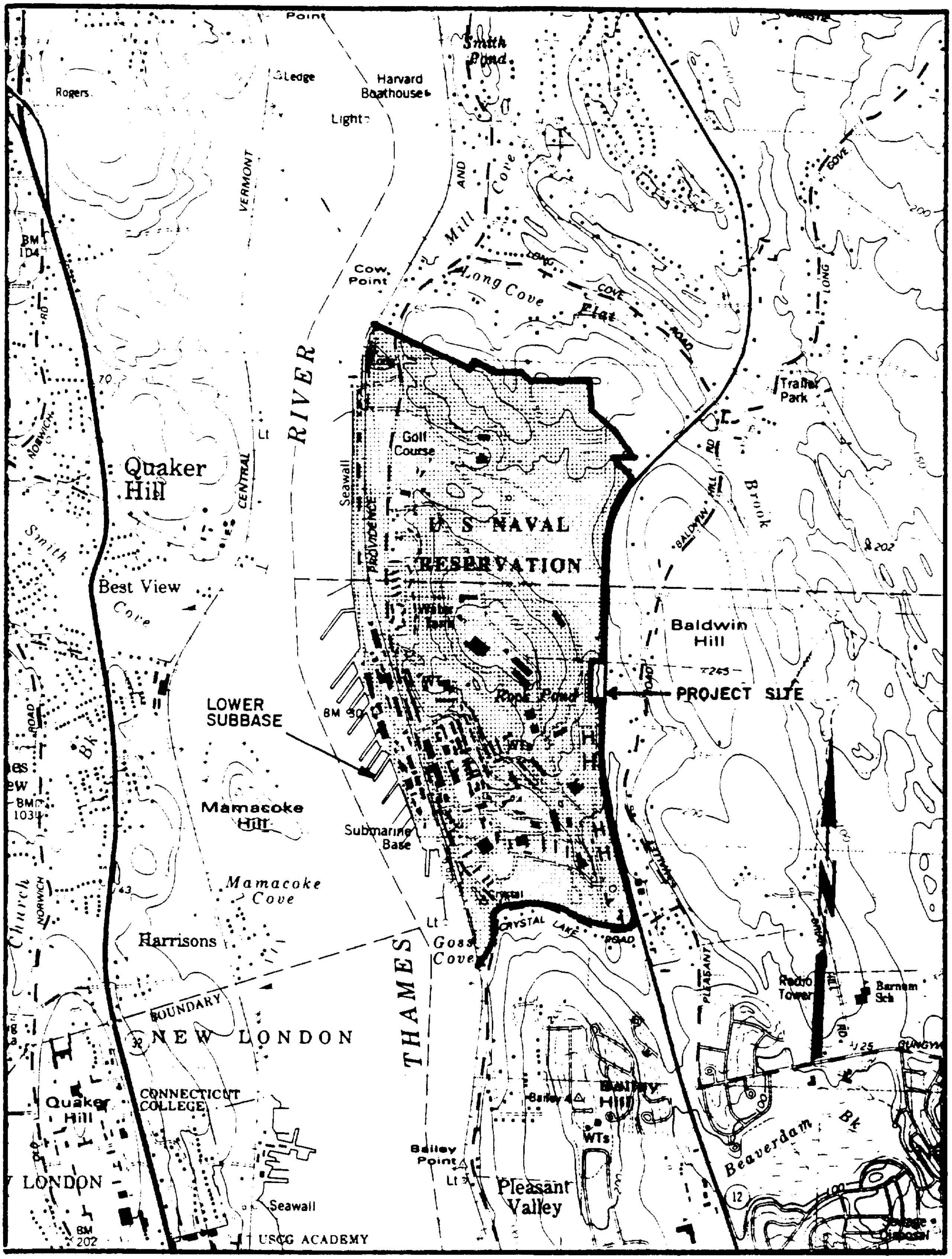
Specifically, the area of interest for this site study is the lower SUBASE. The lower SUBASE encompasses the shoreline area in which the submarines and ships port. The power plant (Building 29) and associated fuel oil storage tanks are located here. In the mid-1970's, Navy personnel observed thick, black oil contamination in several manholes and utility trenches on the lower SUBASE and in the adjacent Thames River. Subsequent to those observations, investigative work was done by the Navy Environmental Support Office (NESO) in February, 1979. The conclusion of this study indicated three areas of oil contamination.

Area 1) Along the water front adjacent to Building 29 Power Plant

Area 2) In the vicinity of the storage tanks adjacent to Building 345

Area 3) The area north and west of Building 79

See Figure 2.1 - Possible Areas of Contamination



0' 1000' 2000' 3000' 4000'

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CONSULTING ENGINEERS

CONNECTICUT

QUADRANGLE LOCATION

1984

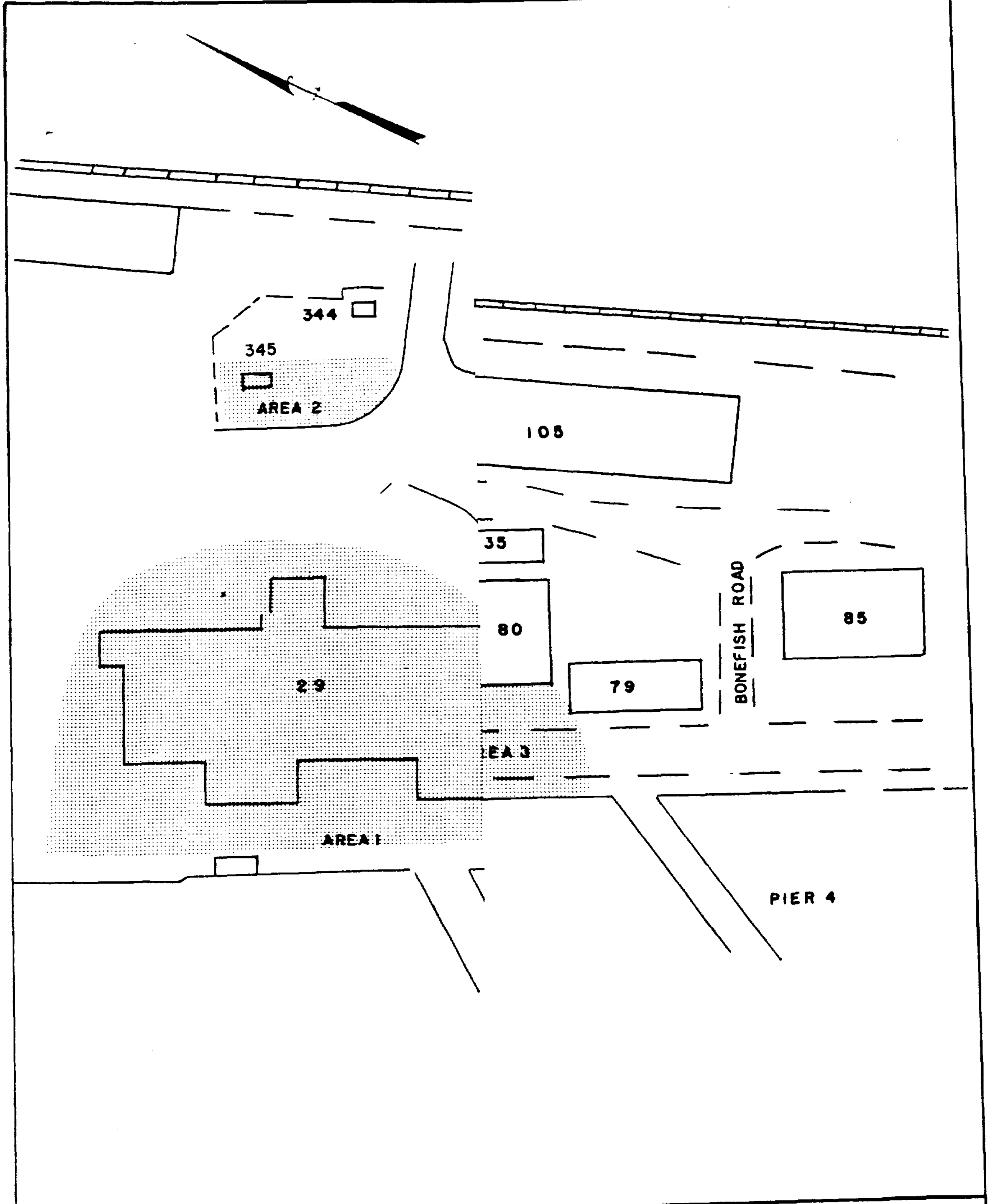
FIGURE 1.1

SITE LOCATION MAP

U.S. NAVAL SUBBASE

GROTON, CONNECTICUT

WE No. 02364360



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Following the completion of the NESO Study (1979) and implementation of its recommendations, the Initial Assessment Study (1982) commenced. Three particular sites discussed in the IAS are suspect fuel oil sources and are briefly discussed below.

1) Power Plant Oil Tanks (east of Building 29) consists of four underground storage tanks, each having 170,000 gallon capacity. These tanks also have been in use since World War II containing diesel and waste oil, and more importantly, No. 6 grade fuel oil which is pumped from the north base tank farms to the power plant, Building 29.

2) Fuel Oil Storage Tanks (adjacent to Building 345) consists of five underground concrete storage tanks containing diesel and lube oils each having 125,000 gallon capacity. The tanks are located approximately 300 feet east of the Thames River and have been in use since World War II.

3) Building 79 Waste Oil Pit is located adjacent to a major portion of the contamination problem. This area contained a railroad spur on which diesel train engines were serviced. The service area included a pit into which waste oil and solvents drained during the cleaning and servicing of the diesel engines. The pit is no longer in use and has been filled with concrete.

A site investigation was initiated focusing on these specific areas and sites, all within the lower SUBASE.

2.0 SITE INVESTIGATION

2.1 PRE-SITE INVESTIGATION

Prior to field work, Wehran performed a study of available information. As part of this study, the oil storage tanks and distribution system, the utility layout, and the relieving platform/quay wall were thoroughly reviewed. Upon the completion of this preliminary study two drawings were developed, one showing the utilities in the vicinity of Building 79 (the area surrounding Building 79 was the most oil contaminated area), the second showing a typical cross section of the relieving platform and quay wall (potential barrier to the oil migration and area for the oil to pocket in). See Figures 2.2 Utility Site Plan and 2.3 Relieving Platform and Quay Wall.

2.2 VISUAL INVESTIGATION OF MANHOLES AND UTILITY TRENCHES

A visual inspection of conditions within the manholes and utility trenches on the lower SUBASE was completed in January, 1986 by Wehran personnel. The visual inspection consisted of lifting manhole covers on the lower SUBASE in the vicinity of Building 29 and 79 and probing with a 15 foot metal rod and inspecting for any signs of oil contamination. The utility trenches were examined in the same area and manner as the manholes. Additionally, several portions of the utility trench east of Building 35 were uncovered due to construction work allowing an inspection of the entire trench. The locations of all visible contamination found in January of 1986 are identified on Figure 2.4. The contamination consisted of either a thick black oil residue which coated the sides of the manhole/trench and/or globs of oil floating on the water surface.

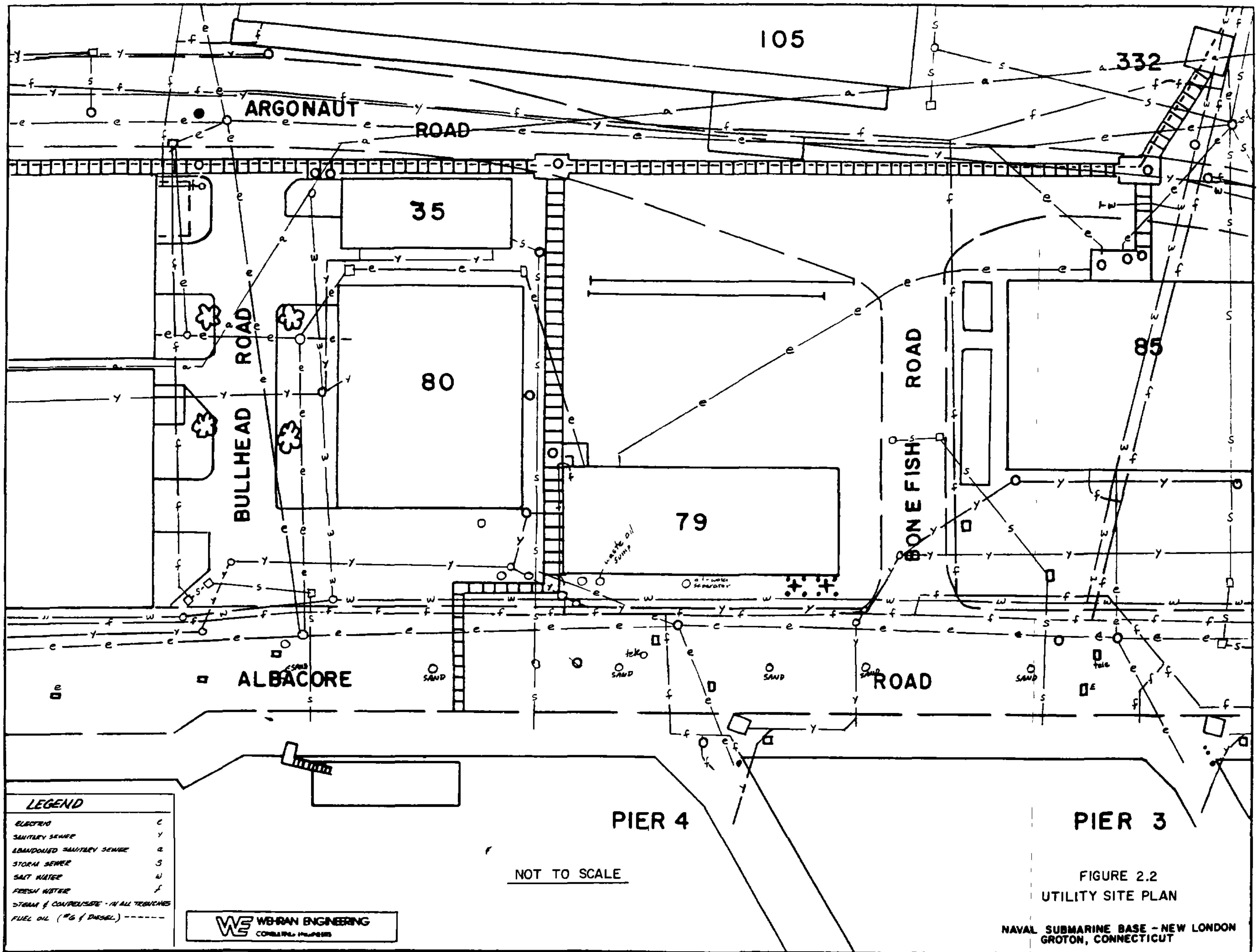

FIGURE 2.2
UTILITY SITE PLAN

NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

00031012

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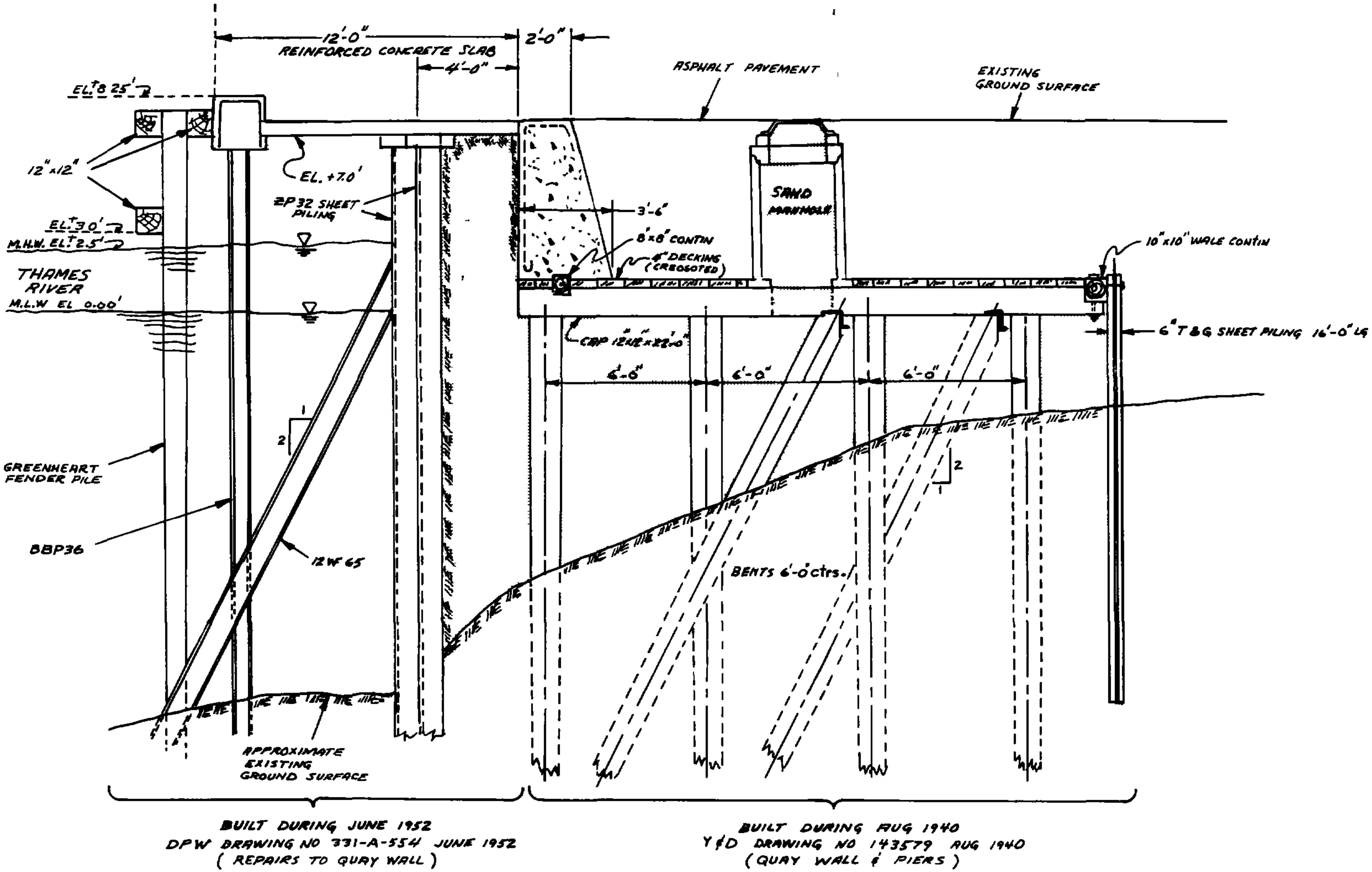

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FIGURE 2.3

TYPICAL SECTION

RELIEVING PLATFORM
AND QUAY WALL

NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

0003 1022

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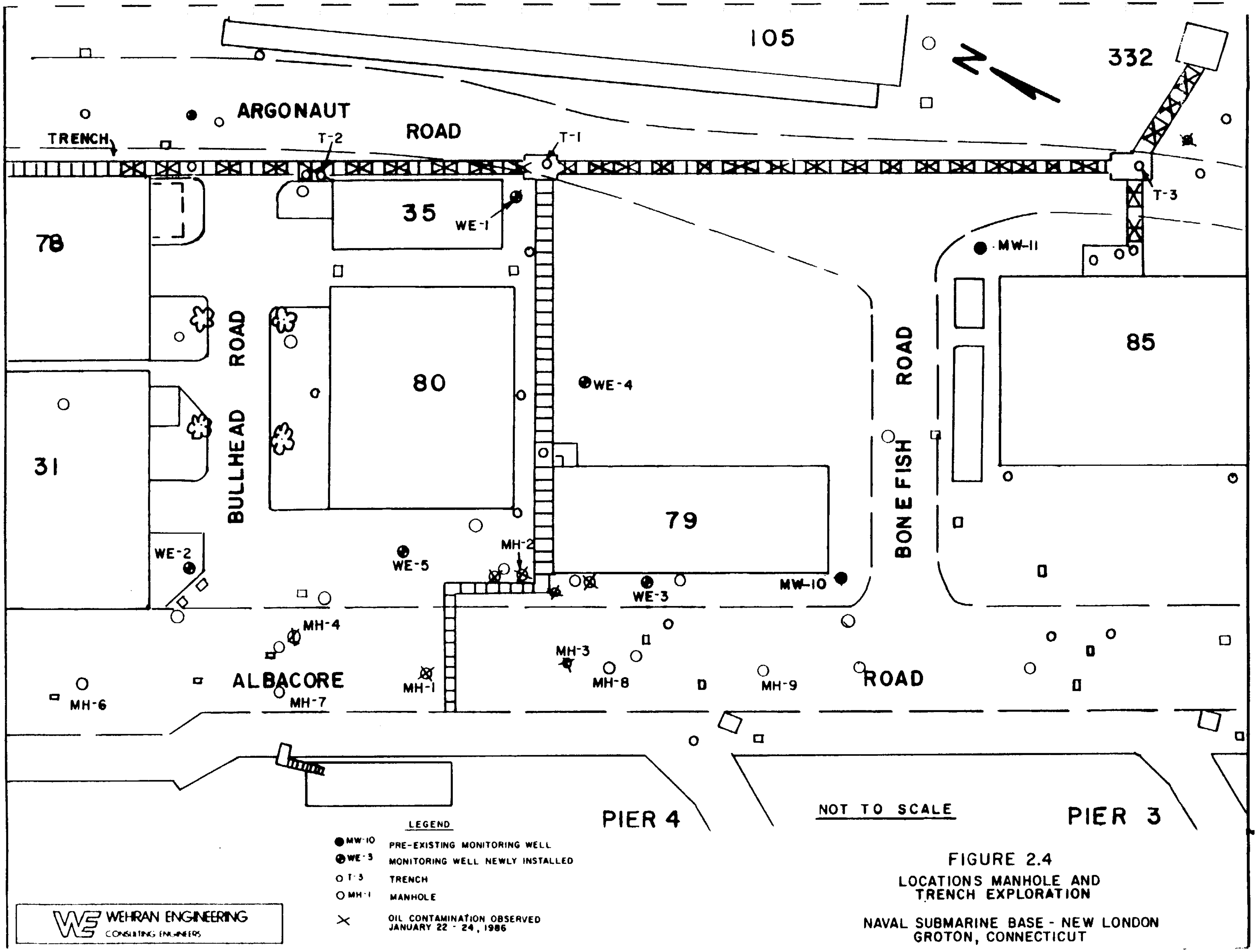


FIGURE 2.4
LOCATIONS MANHOLE AND TRENCH EXPLORATION

NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

2.3 MANHOLE SAND CLEANING

A wooden relieving platform (as shown in Figure 2.3) underlies the length of the lower SUBASE waterfront study area. After completing the new sheet pile wall (1952), the area under the platform was filled with sand. The sand under the platform shifts due to the constantly fluctuating water levels in the tidally influenced Thames River. Periodically, the sand level is replenished by adding sand to several manholes which provide a port to the space below the wooden platform. To determine whether oil contamination is present in this space below the relieving platform in the vicinity of Building #79, it was necessary to pump the sand out of the manholes.

A procedure was formulated to deal with oil contaminated sand if encountered during the sand removal process. The procedure can be described as follows: a manhole would be evacuated using the sand removal equipment until the appearance of oily contamination was found, work would be stopped, and the process repeated at the next manhole. When all four manholes had been emptied to the level of the wooden platform or the suspected oil contamination, the "clean" sand would be transported to the sand stockpile area off Wahoo Avenue for disposal. The "clean" sand removal equipment would then be used to collect the remaining contaminated sand from the manholes. The suspected contaminated sand would be brought to the SUBASE hazardous waste containment area for storage and eventual disposal.

Speedy Sewer Service of New Haven, CT was contracted to remove the sand from MH-6, 7, 8, and 9 (see Figure 2.4). MH-1 showed oil contamination during the January, 1986 manhole investigation and did not require any sand removal. Sand removal activities were performed at the site on July 15, 1986 using a vacuum truck. MH-6 and MH-9 were evacuated until the wooden platform was encountered at a depth of approximately 7 feet. Water was encountered in both manholes at approximately 6.5 feet. At MH-8, what appeared to be oil contaminated sand was uncovered at a depth of approximately 5 feet below grade, and thus work was stopped at that manhole. At MH-7 equipment problems developed that decreased the suction lift of the vacuum hose. Thus, at a depth of approximately 5 feet, the vacuum was no longer strong enough to remove the sand, and work was stopped. The vehicle was driven to the "clean" sand disposal area and emptied.

The vacuum hose was repaired in the early afternoon and MH-8 was reopened in order to remove the potentially contaminated sand. It was found to contain approximately one foot of visually clear water above the sand level. The situation at MH-7 was the same, the rising water above the sand was due to the influence of the high tide in the Thames River. The high water level prevented the removal of the sand below by preventing access to the saturated sands. It was determined that if the water level could rise above the sand at high tide, oil traveling on the water surface would remain as an oil residue on the sand as the tide receded. Therefore, no additional sand was removed from MH-6, 7, 8, and 9.

2.4 SAMPLING OF MANHOLES AND UTILITY TRENCHES

In an effort to identify the source of the contamination in the manholes and utility trenches on the lower SUBASE, samples were collected on August 4, 1986 by Wehran personnel. The proposed sample locations and data objectives from Wehran's Plan of Action, June 1986 were:

- Oil contamination manholes–five (5) locations. The objective is to determine whether the manholes are contaminated by one source of oil and estimate the degree of weathering of the oil. The results will aid in determining the on-site origin of the oil.
- Oil contaminated trenches–two (2) locations. The objective is to determine whether the trenches are contaminated by one source of oil

and estimate the degree of weathering of the oil. The results will aid in determining the on-site origin of the oil.

- Power Plant No. 6 fuel oil–one (1) location. The objective is to provide a background sample of No. 6 fuel oil to which all samples can be compared.
- SUBASE diesel fuel–one (1) location. The objective is to provide a background sample of diesel fuel to which all samples can be compared.

A few of the sampling locations were changed from those proposed, due to encountered field conditions (no visible oil). This action was necessary due to the type of analysis (fluorescence spectroscopy) and the scope of work requested (investigate the thick oil contamination problem). As a general rule, a sample was not collected unless visible oil contamination was present.

The sand manholes which had been cleaned out in July 1986 (MH-6, 7, 8, and 9) were re-opened and conditions observed. There was no visible evidence of contamination in any of the four manholes. Therefore, none of these manholes were sampled and alternative locations were found. The utility trenches (T) were also re-opened and no visible contamination was seen at T-3, but T-2 had oil contamination, thus T-2 was sampled instead. T-1 remained oil contaminated and was sampled as planned.

The field samples, consisting of a mixture of thick black oil, water, and soils were obtained from manholes MH-1 through 5, and from the utility trenches T-1 and T-2 (see Figure 2.4). With the exception of MH-5, oil had been previously observed at these locations during the January 1986 inspection. During field work performed on August 4th, it was noted that the boots of an electrician working in the manholes on Corvina Road were covered with thick black oil. A short interview was conducted during which the worker indicated that the oil was in the electrical conduit. When he began work he forced the oil into the manholes so he could inspect the electrical lines. A field decision was made to collect a sample from MH-5.

The oil samples were obtained using a telescoping pole with a stainless steel scoop, and were immediately placed in amber glass jars supplied by the analytical laboratory. The sampling equipment was decontaminated (using Wehran's laboratory approved six step procedure) after each sample was taken using a laboratory grade detergent (alconox), methanol, and distilled water. The six step procedure includes a detergent bath, rinse, detergent bath, distilled water rinse, methanol wash, and a final distilled water rinse. The samples were analyzed using fluorescence spectroscopy to determine the type and age of the oil present at each location. In order to provide a reference sample for comparison purposes, samples of the #2 and #6 fuel oils used on the lower SUBASE were obtained from Navy personnel at Building #29, the SUBASE power plant. The sample obtained at MH-3 was also analyzed for PCB contamination to ensure that this additional hazardous substance was not present in the oil at the site.

2.5 HYDROGEOLOGIC FIELD METHODS

2.5.1 Soil Borings, Soil Sampling, and Monitoring Well Installations

A total of five (5) exploratory soil borings were drilled in the lower section of the Naval SUBASE during July, 1986. The proposed boring/soil sampling locations and data objectives were:

- One (1) boring adjacent to the south end of Building 35 in proximity of the oil-contaminated trenches. The objective is to determine if the oil has migrated through the trench bedding. This boring will be completed as a monitoring well for future groundwater monitoring and sampling. In addition to this boring, Navy personnel will be providing a backhoe and crew to excavate an observation trench approximately 10 feet long by two feet wide. The observation trench will allow for an extensive view of the utility trench bedding, a possible migration pathway for the heavy oil.

- One (1) boring northeast of Building 79. The objective is to determine if the oil or its derivatives are moving through the soil matrix. This boring will be completed as a monitoring well fur future groundwater monitoring and sampling.
- One (1) boring west of Building 80 in the vicinity of the destroyed NEBSA Well No. 9. The objective is to investigate previous reports of oil in this area and in Well No. 9. This boring will be completed as a monitoring well for future monitoring of the possible oil layer.
- Three (3) borings in the perimeter of the oil contaminated zone. The objective is to assess the lateral extent of the oil contamination. Two (2) of the borings will be completed as monitoring wells for future groundwater monitoring, including tidal fluctuations. Note: Only two of the borings could be completed due to the number of underground utilities in this area.

The combined purpose of these borings was to 1) determine if the bulk oil or its derivatives are moving through the soil matrix, 2) determine the lateral extent of contamination, 3) provide information on the type and thickness of unconsolidated deposits which underlie the site.

The soil borings were drilled into the unconsolidated deposits with a 4 inch outer diameter (OD) hollow stem auger using a truck mounted drill rig. During the drilling, contaminated soil that was brought to the surface from the spinning augers was placed in a 55 gallon drum. The drum was then collected by Navy personnel for proper disposal off-site.

Soil samples were collected on a continuous basis from approximately six inches below the ground surface to the bottom of the borehole. Soil samples were collected using a 24 inch long, 2 inch OD, stainless steel split spoon sampler. The color, consistency, and texture of each soil sample was described using the modified Burmister Soil Classification System and noted on a geologic boring log (see Boring Logs - Appendix A). In addition to the physical description of the sample, the rate of penetration of the sampler (using a 140 pound drive weight falling 30 inches) was recorded for each six inch interval.

Field screening for volatile organic compounds was performed with an HNU PI-101 photoionization detector. Each soil sample was placed in a glass jar with aluminum foil placed over the top prior to sealing. Once the soil thermally equilibrated to room temperature (approximately 70°F) the jar lid was removed and the probe from the HNU meter was inserted through the foil. The direct meter reading (in parts per million) of the ionization potential from the soil headspace was then recorded on the soil boring logs.

Based upon this field screening and visual observations, selective soil samples were collected for laboratory analysis (petroleum hydrocarbon finger printing analysis by fluorescence spectroscopy). These samples were collected from the split spoon sampler with a stainless steel trowel and placed into sample jars, which were pre-sterilized by the laboratory and the appropriate preservative was added. Standard chain-of-custody procedures were observed with each of these soil samples.

To reduce the possibility of cross-contamination of soil samples within and between borings, the soil sampling equipment was decontaminated following Wehran's laboratory approved procedures after each soil sample was collected. The augers, rods, and all other downhole equipment were steam cleaned between each soil-boring.

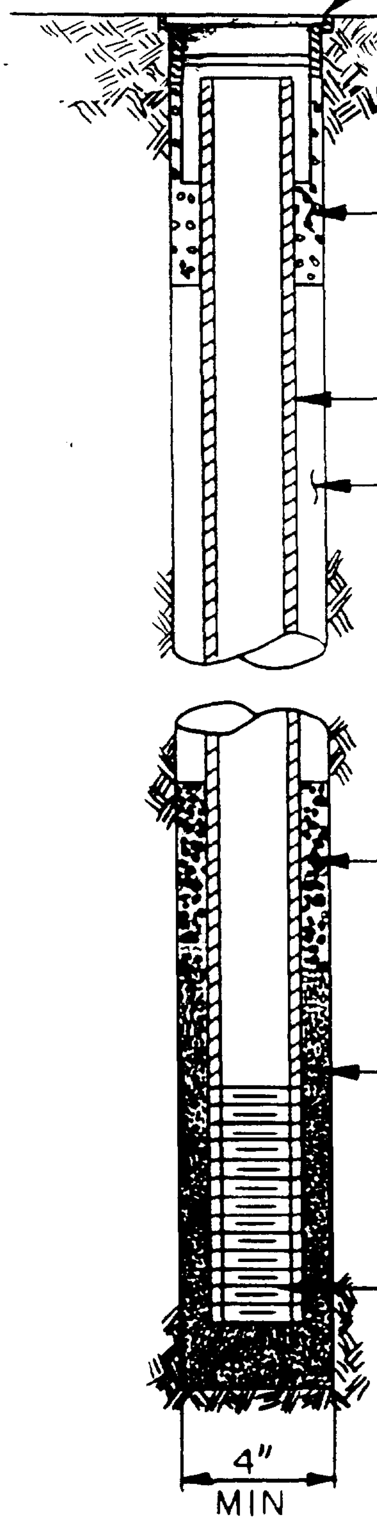
A total of five (5) monitoring wells were installed, one in each of the five soil borings. All five wells were completed as shallow water-table wells, with screens set at an appropriate depth to intercept the top of the water table. The purpose of installing the monitoring wells was to provide: 1) groundwater samples for analysis, 2) in-situ permeability measurements, and 3) groundwater level measurements to determine elevations of the water-table (high and low tide) and horizontal gradients of the water table at the site.

Each monitoring well was constructed of two-inch inner diameter (ID) Schedule 40 PVC with flush threaded joints. No solvent based cements were used in the construction of the monitoring wells. All screens are ten feet in length, and are machine slotted with a slot size of 0.01 inches.

The monitoring wells were backfilled to a point 1 foot above the screened interval with clean medium size silica sand. The sand pack was sealed with a one foot layer of bentonite pellets. The annulus of the boring above the bentonite seal was grouted with a Portland cement/bentonite slurry to grade. At the ground surface, a 3 inch diameter cast iron roadbox was installed to protect and provide access to the monitoring wells (see Figure 2.5).

All monitoring wells were developed on September 9, 1986. The development was performed by pumping each well until the water being evacuated appeared free of fine silts and sediments.

A field elevation survey of each well head (top of the PVC riser) was performed so that water level measurements taken from each well could be used to construct water level contours, calculate groundwater gradients, and estimate groundwater flow directions.



NOT TO SCALE

FIGURE 2.5

TYPICAL
MONITORING WELL INSTALLATION

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2.5.2 Permeability Testing

The permeability (hydraulic conductivity) of the saturated soils in each of the monitoring wells was determined using a rising head test method developed by Hvorslev (1951). This method relates the recovery of water levels in a well which has been pumped or bailed to the permeability of the saturated unconsolidated deposits surrounding the well screen. The field method consisted of measuring the static water level in the well and then lowering the water level using a pump. When pumping ceased, measurements of recovering water levels were made at frequent time intervals. The water level recovery data was then analyzed by calculating the ratio of the observed lowered hydraulic head to the initial hydraulic head for each water level measurement. The head ratio data was then plotted versus time on semi-log graph paper.

The hydraulic conductivity of the soil is calculated from the following equation: (Hvorslev, 1951)

$$K = \frac{r^2 \ln (h_1/h_2)}{2L (T_2 - T_1)} \cdot \ln \frac{L}{R}$$

Where:

K = hydraulic conductivity (cm/s)

r = radius of well screen (cm)

L = length of saturated screen interval (cm)

R = radius of sand pack (cm)

T_1 = time interval corresponding to h_1 (sec)

T_2 = time interval corresponding to h_2 (sec)

h_1 = head ratio at T_1 (dimensionless)

h_2 = head ratio at T_2 (dimensionless)

2.5.3 Groundwater Sampling

A total of nine (9) groundwater samples were collected from the lower SUBASE on September 10, 1986. Groundwater samples were collected from each of the five (5) new monitoring wells and two (2) from the old wells. In addition, a field blank and duplicate sample were collected for quality assurance and quality control purposes.

Prior to collecting the groundwater samples, groundwater levels were measured and recorded, a minimum of three well volumes were purged, and specific conductance values were measured until repeatable results were obtained.

Using a pre-cleaned teflon bailer and dedicated polypropylene rope, groundwater samples were collected and poured into appropriate analytical containers. At each sample collection point, pH, temperature, and specific conductivity were measured by using a direct reading pH meter with temperature probe (VWR, Model 2000) and a specific conductivity meter (Cole-Palmer, Model 1481-50). Calibration of each instrument was performed prior to field use in accordance with recommended manufacturers specifications.

All sampling equipment (teflon bailer, electric water level indicator, measuring tapes and probes attached to the pH and conductivity meters) utilized during the groundwater sampling were pre-cleaned and decontaminated prior to and between each sampling location. To minimize the possibility of cross contamination of groundwater samples between monitoring well locations, samples were collected in a sequential order from suspected clean to contaminated wells.

All groundwater samples were collected, preserved, and stored in compliance with EPA protocols. Standard chain-of-custody procedures were observed during this investigation.

2.5.4 Synoptic Water-Level Measurements

Water-table measurements were taken during times of low and high tide from each of Wehran's five (5) monitoring wells on November 11, 1986. These measurements were taken with an electric water level indicator and converted to elevations, based upon the field survey. The elevation data was then used to construct the configuration of the water table at both high and low tide and the direction of groundwater flow was determined.

2.5.5 Tidal Fluctuation Measurements

Tidal fluctuation measurements were collected from nine (9) locations on the lower section of the Naval submarine base on November 11, 1986. These locations included the five (5) monitoring wells installed by Wehran Engineering in July 1986, two (2) existing wells, and two (2) surface water measurements from newly established bench marks (P.K. [point known] nails) located near piers numbered 4 and 9 along the Thames River.

A total of eight rounds of measurements were collected from each of the nine locations for a total of 72 measurements. The measurements were made starting from nine o'clock (9:00) in the morning until four o'clock (16:00) in the afternoon. The measurements were then converted to water-level elevations based upon Wehran's field survey, and plotted to determine the tidal effects on the water-table in the vicinity of the lower SUBASE.

3.0 HYDROGEOLOGIC CONDITIONS

3.1 SITE GEOLOGY

Based upon the five boring logs derived from the field investigation, there are two major lithologic units within the upper 15 feet of the unconsolidated deposits. These units (below the black macadam or pavement) consist of fill material and alluvium. The approximate lateral and vertical distribution of these units across the site are shown in northwest-southeast and northeast-southwest cross-sections (Figures 3.1, 3.2, and 3.3).

The uppermost unit is fill material and consists primarily of coarse to fine sand and gravel with some fragments of brick. The fill was present in all borings and ranges from 0.5 to 11.0 feet thick.

The underlying alluvium consists of fine sand and silt with some organic matter. This material was probably deposited as a result of periodic flooding of the Thames River bank before the quay wall construction. The alluvium was encountered in borings, WE-1, WE-2, and WE-4, at approximately 11.0 to 13.0 feet below the ground surface (2.2 to 5.0 feet below MSL). The base of the unit was not encountered in any of these borings. Therefore, the unit is in excess of the maximum thickness penetrated (2.5 feet) in WE-1.

The boring logs for wells WE-1 through WE-5 are included in Appendix A (The NESO study boring logs were not found).

3.2 GROUNDWATER FLOW CHARACTERISTICS

3.2.1 Direction of Groundwater Flow

To determine shallow groundwater flow characteristics at the lower SUBASE, synoptic water-level measurements were recorded in the five monitoring wells (installed by Wehran Engineering) on November 11, 1986. Water-table

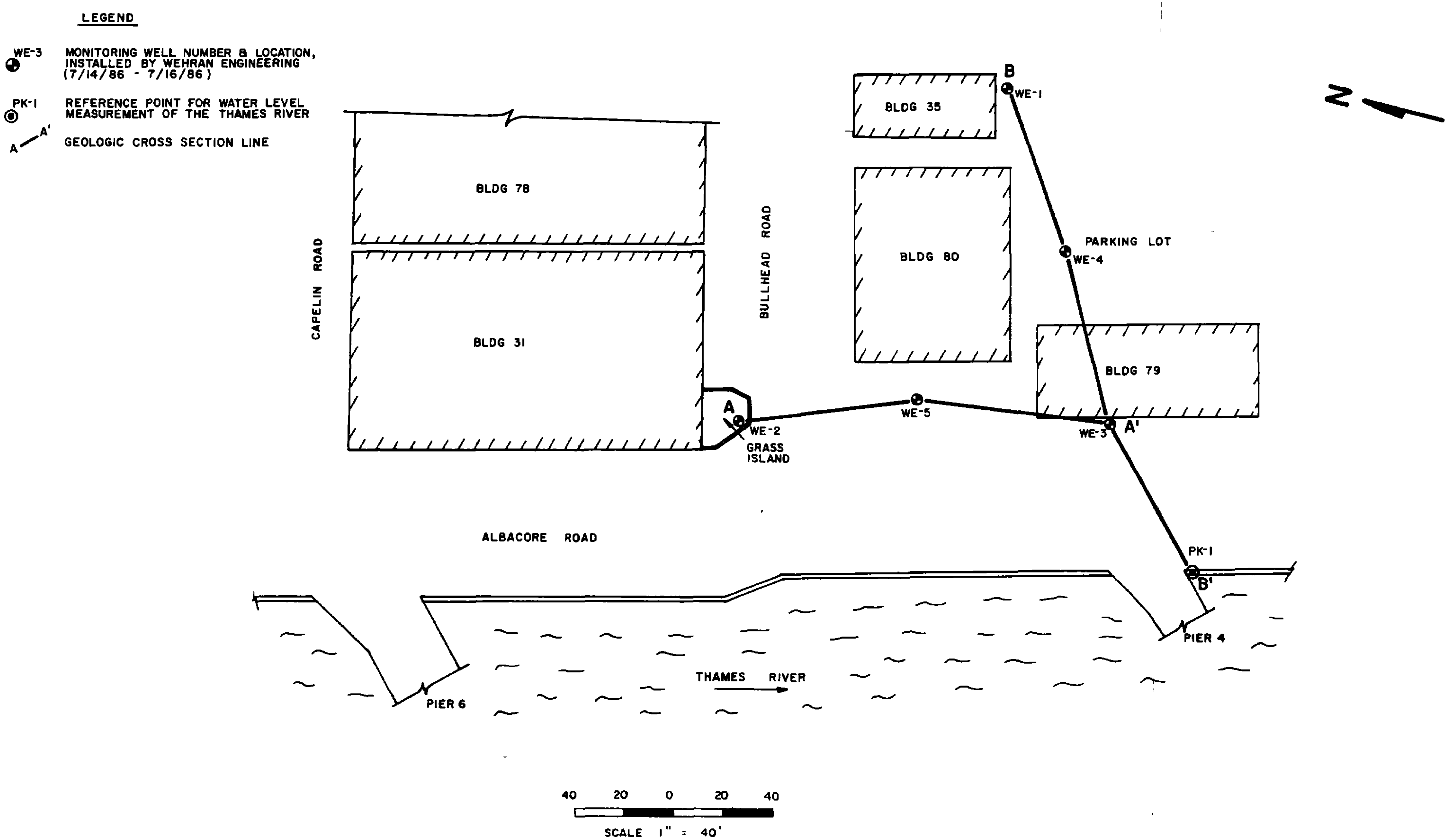

FIGURE 3.1

GEOLOGIC CROSS SECTION LINES

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GROTON, CONNECTICUT

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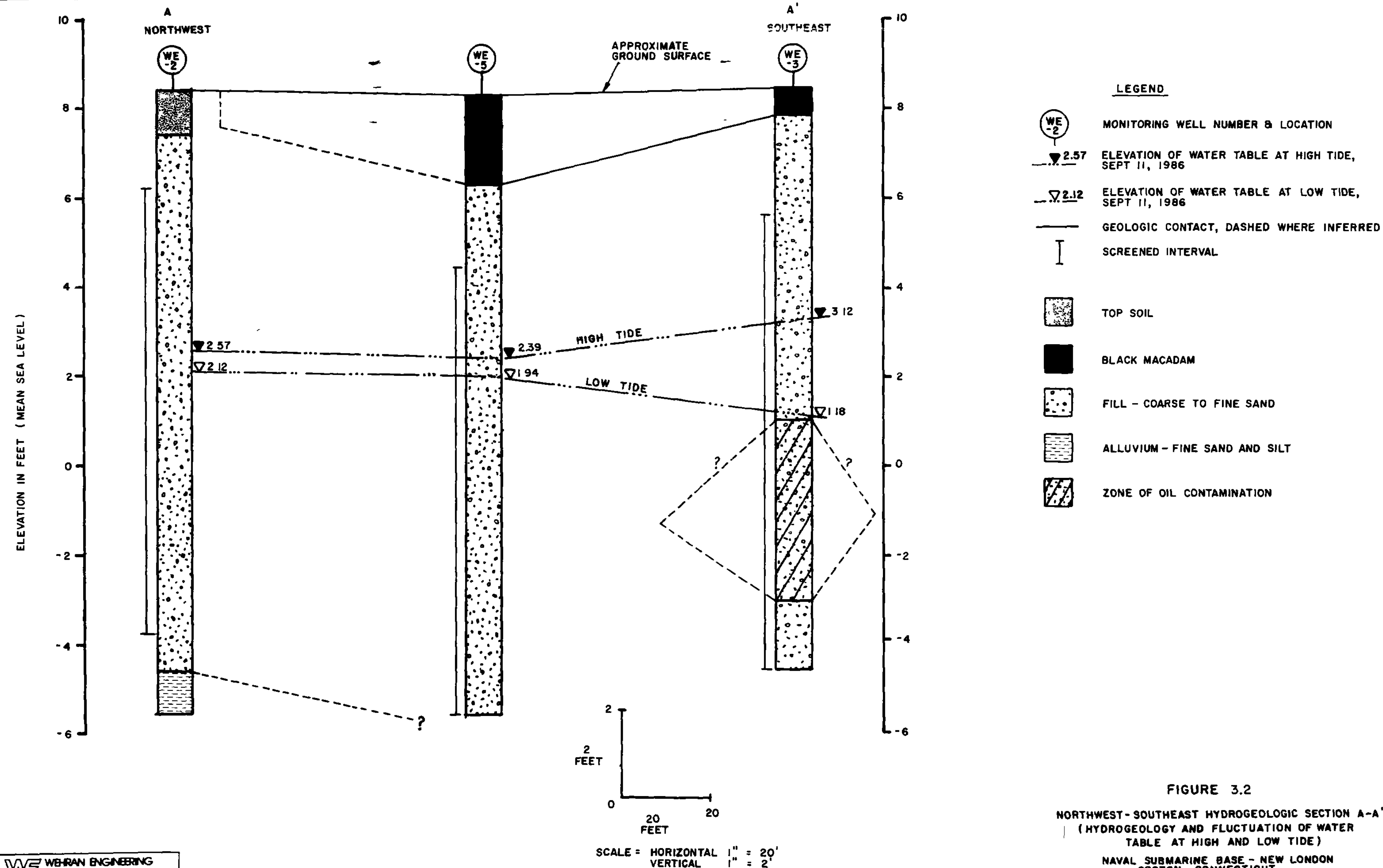

FIGURE 3.2

NORTHWEST-SOUTHEAST HYDROGEOLOGIC SECTION A-A'
(HYDROGEOLOGY AND FLUCTUATION OF WATER TABLE AT HIGH AND LOW TIDE)

NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

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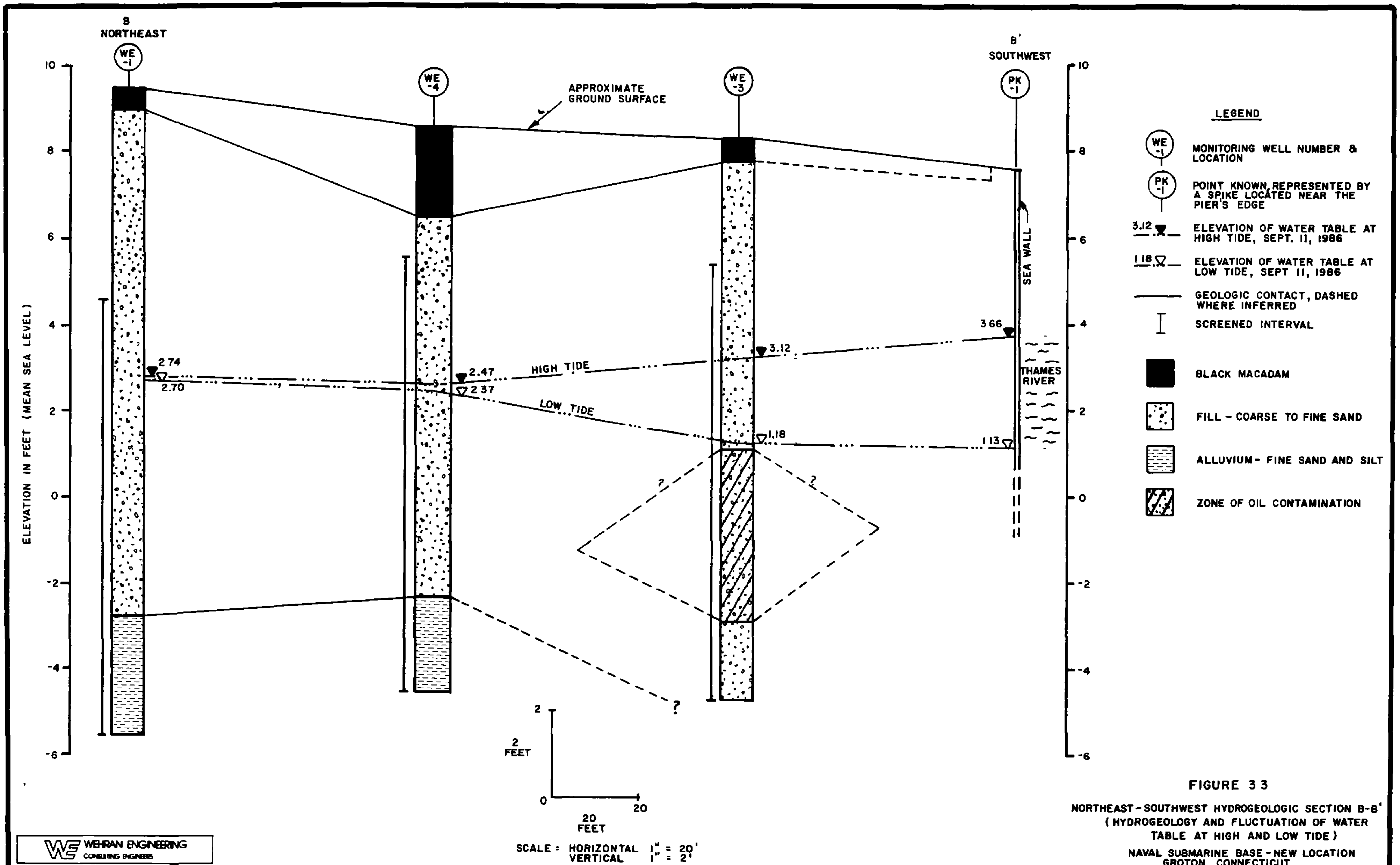

FIGURE 3 3

NORTHEAST - SOUTHWEST HYDROGEOLOGIC SECTION B-B'
(HYDROGEOLOGY AND FLUCTUATION OF WATER TABLE AT HIGH AND LOW TIDE)

NAVAL SUBMARINE BASE - NEW LOCATION
GROTON, CONNECTICUT

0003 1052

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measurements collected during high and low tides were used to show the flow gradients in the hydrogeologic cross-sections and in the groundwater contour maps (Figures 3.4 and 3.5).

In general, during the period of low tide, the direction of groundwater flow is westerly towards the Thames River. The water-table configuration demonstrates a variable hydraulic gradient, with a steeper gradient adjacent to the River, due to the drawdown associated with the low tide. The average horizontal flow gradient along cross-sectional lines B-B' (from WE-4 to PK-1) which trends northeast to southwest during low tide is 0.009 ft/ft.

During the periods of high tide, the direction of groundwater flow is similar to low tide with the exception of the area adjacent to the Thames River. In this area parallel to the River, groundwater flow is reversed in an easterly direction from the Thames River, to where it eventually converges with the westerly flowing regional groundwater as depicted in Figure 3.5. The water table configuration demonstrates a variable hydraulic gradient, with a steeper gradient adjacent to the River, due to the surge associated with the high tide. The average horizontal flow gradient at high tide between the River to WE-4 is 0.009 ft/ft, while between WE-1 to WE-4 the horizontal gradient is 0.004 ft/ft.

The hydraulic gradient will constantly be changing along the River as the River's water level rises and falls. Depending on the severity of the weather and tidal influences, these changes will move the convergence zone back and forth away from and toward the River (see Figure 3.5).

3.2.2 Permeability

The permeability (hydraulic conductivity) of the fill and alluvial deposits was estimated using in-situ test methods (section 2.5.2) in four of the five monitoring wells installed by Wehran Engineering. The hydraulic conductivity of WE-3 (the

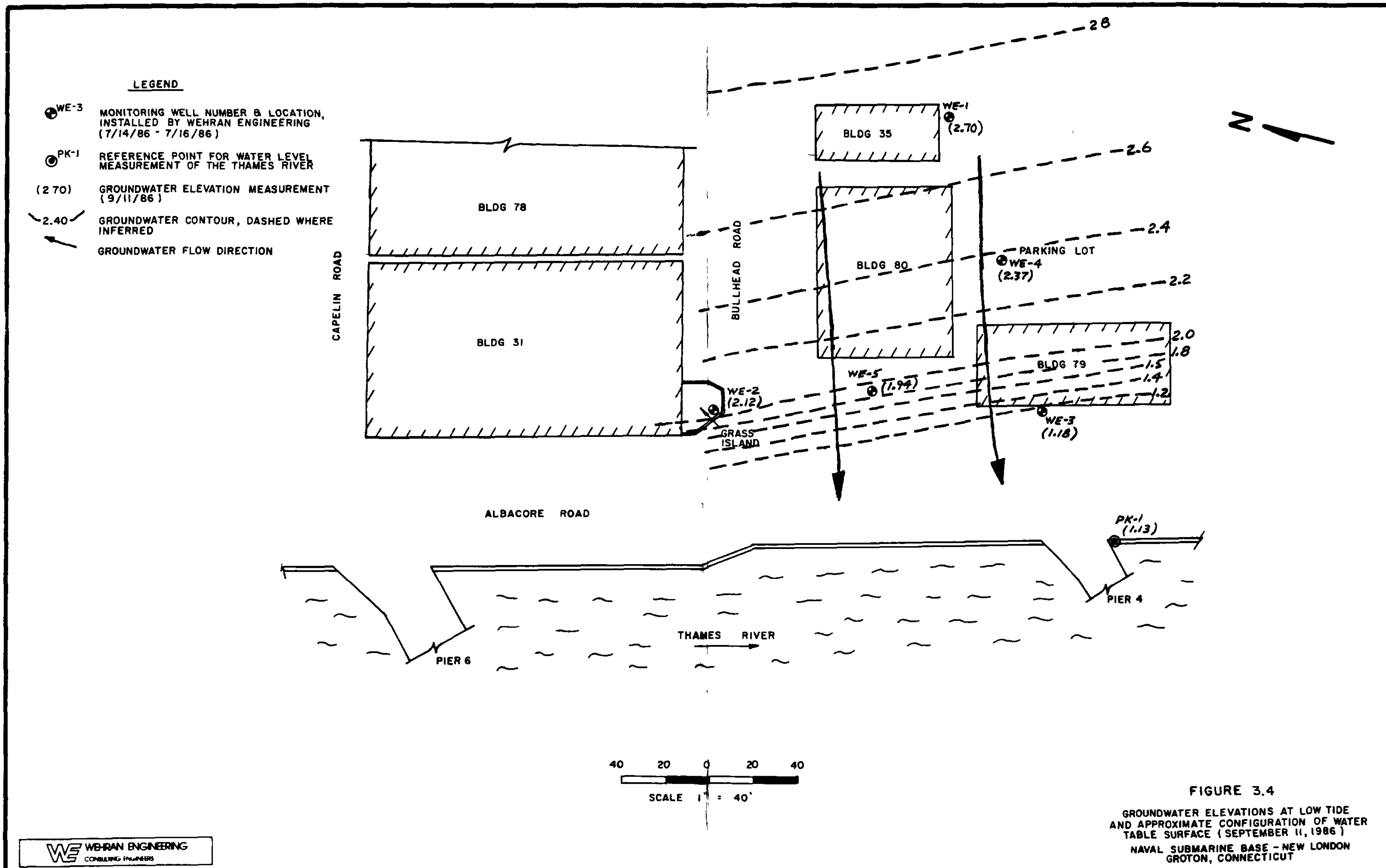

FIGURE 3.4

GROUNDWATER ELEVATIONS AT LOW TIDE AND APPROXIMATE CONFIGURATION OF WATER TABLE SURFACE (SEPTEMBER 11, 1986)

NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

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WE PROJECT NO 04360.SF

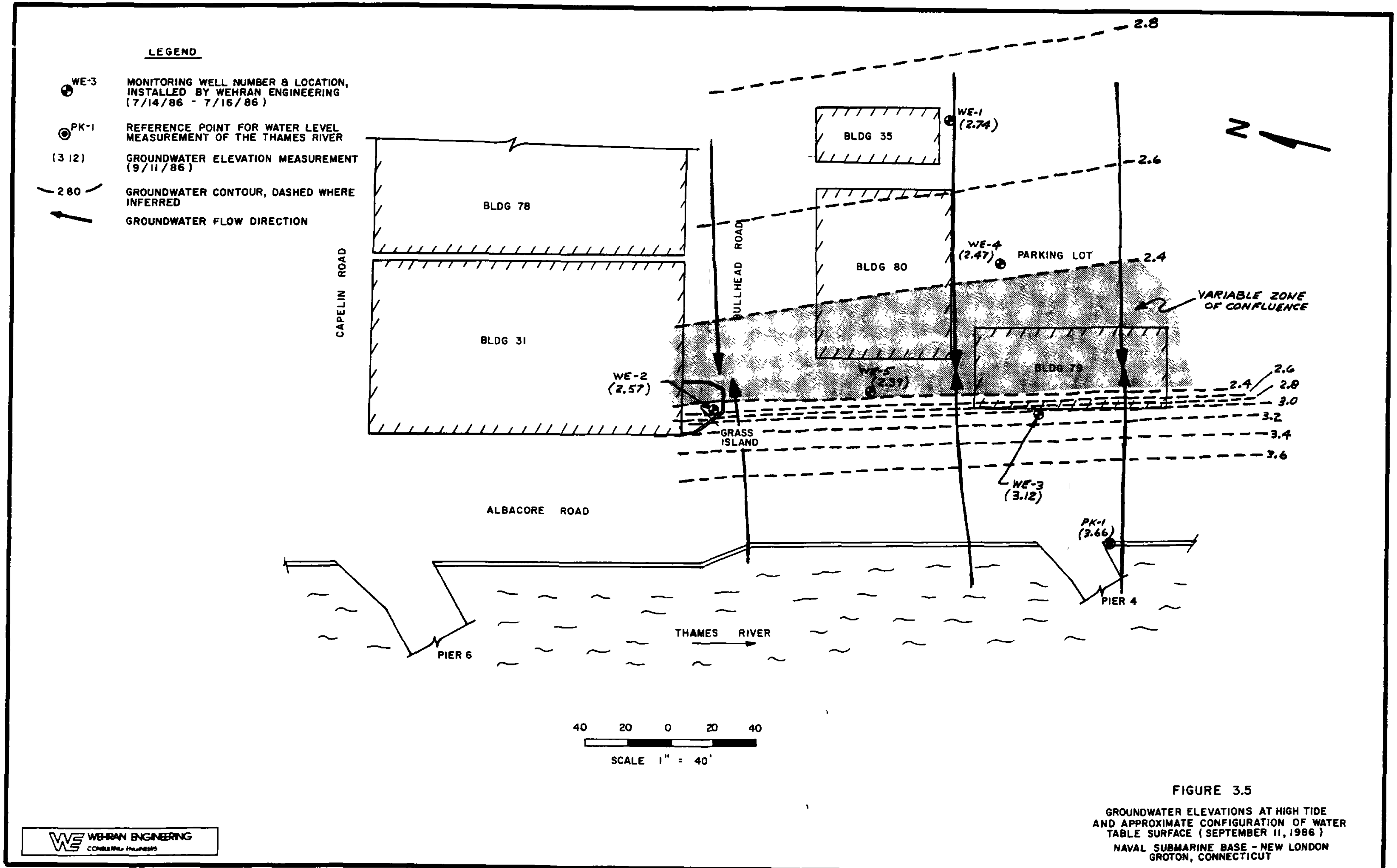

FIGURE 3.5

GROUNDWATER ELEVATIONS AT HIGH TIDE AND APPROXIMATE CONFIGURATION OF WATER TABLE SURFACE (SEPTEMBER 11, 1986)
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

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WE PROJECT NO. 04360 SF

boring with a 2.0′ layer of oil-stained soil) was not determined because groundwater recharged into the well so rapidly that the pumping rate (2 gals/min) was not adequate to produce an effective drawdown for rising head measurements. The high recharge rate may have been caused by the rapid gain of water through the 2.0′ gravel lense in the fill unit. Permeability calculations for WE-1, WE-2, WE-4, and WE-5 are included in Appendix B. Table 1 presents a summary of the calculated permeability values.

Hydraulic conductivity of the fill material has a wide range of values (0.26 feet/day to 15.62 feet/day). The fill material in WE-2 (0.26 feet/day) consisted of finer grained sand and silt, and thus had a lower permeability value than the other wells such as WE-5 (15.62 feet/day) which consisted of primarily coarse to fine sand.

The permeability of the alluvium could not be measured directly because none of the wells were screened entirely in this unit. Its permeability can be approximated however, based on the fact that it is a fine sand with little silt as indicated on the boring logs for wells WE-1 and WE-4. In both of these wells, the fill material is fine, or fine to coarse sand, with trace silt. Therefore, permeability in the finer grained alluvium is probably somewhat less than the values 3.51 and 5.39 feet/day calculated for these two wells.

Table 1

LOWER SUBASE SUBSURFACE OIL CONTAMINATION

SUMMARY OF FIELD PERMEABILITY ANALYSIS OF MONITORING WELLS

Monitoring Well Number	Lithologic Description	Length of Screen (ft.)	Effective* Screen Length (ft.)	Hydraulic Conductivity	
				cm/sec	ft/day
WE-1	80% - FILL 20% - ALLUVIUM	10	7.98	1.24×10^{-3}	3.51
WE-2	100% - FILL	10	6.5	9.17×10^{-5}	0.26
WE-4	80% - FILL 20% - ALLUVIUM	10	6.65	1.90×10^{-3}	5.39
WE-5	100% - FILL	10	8.00	5.51×10^{-3}	15.62

* Effective screen length = effective saturated thickness.

3.2.3 Velocity of Groundwater Flow

The velocity of groundwater flow at the site can be estimated using the data available for hydraulic gradient and hydraulic conductivity for specific events such as high or low tide. The average flow velocity of groundwater for these events may be expressed as:

$$\bar{V} = \frac{k(h_1/h_2)}{\ominus}$$

Where:

$\bar{V}$ = average seepage velocity, ft/day

k = hydraulic conductivity, ft/day

h_1/h_2 = hydraulic gradient, ft/ft

$\ominus$ = porosity

**Note:* *Due to the tidal influence in this area, the average seepage velocity is a dynamic value changing due to the changing hydraulic gradient.*

The average hydraulic conductivity value of the fill and alluvial deposits is 6.20 ft/day. The average horizontal hydraulic gradient along cross-section line B-B', which trends southwesterly in the direction of shallow groundwater flow during low tide, is 0.009 ft/ft. Site specific data for porosity is not available, therefore a representative value for medium sand (0.40) was selected from the compilation of values by Todd (1959). Using these values, the estimated average horizontal velocity of shallow groundwater flowing in the fill and alluvial deposits toward the Thames River is 0.14 ft/day (51.1 ft/year), during low tide situations.

The site is influenced during high tide events with the reversal of groundwater flow. The groundwater adjacent to the River begins flowing in the opposite direction away from instead of toward the Thames River. The velocity of groundwater flowing towards the northeast has been calculated with an average hydraulic conductivity of 6.20 ft/day, a hydraulic gradient of 0.009 ft/ft, and an estimated porosity value of (0.40), thus the average velocity of groundwater flow is 0.14 ft/day (51.1 ft/year).

Water level measurements in the wells indicate that groundwater beneath the site adjacent to the Thames River fluctuates vertically in response to tidal variations, causing variations in the rate of groundwater discharge into the Thames River from the site. During low tide, groundwater discharges into the Thames River whereas during high tide groundwater is recharged from the river. If Thames River was not tidally influenced, then it would receive groundwater from the site on a continuous steady state basis.

The above calculation of seepage velocity is only an estimation, values used in the equation such as in-situ hydraulic conductivity are estimates and vary according to field conditions (depends on screened interval) while porosity is a representative value from a text book. The value is intended to provide only an approximation of groundwater flow. It should be noted that chemical transport rates may vary considerably from the average flow velocity depending upon the chemical/physical solubility and absorption characteristics within the groundwater environment.

3.2.4 Tidal Fluctuation

Eight (8) water level measurements were recorded from each of nine (9) locations on September 11, 1986. The results are presented in Table 2. Figure 3.6 displays the tidal effect, based upon the water level measurements.

TABLE 2 -- Water Level Measurements

WELL #	DATE	TIME	DEPTH TO WATER IN FEET (TOC)	ELEVATION OF WATER TABLE (MSL)
WE-1	9/11/86	9:09	6.71	2.74
		9:57	6.74	2.71
		11:06	6.72	2.73
		12:00	6.75	2.70
		13:02	6.75	2.70
		14:04	6.75	2.70
		14:52	6.75	2.70
		16:04	6.73	2.72
WE-2	9/11/86	9:06	6.15	2.22
		9:59	6.20	2.17
		10:56	6.25	2.12
		11:52	6.25	2.12
		12:52	6.20	2.17
		13:53	6.10	2.27
		14:54	5.90	2.47
		15:57	5.80	2.57
WE-3	9/11/86	9:13	7.20	1.23
		10:03	7.25	1.18
		11:02	7.25	1.18
		11:56	6.90	1.53
		12:57	6.40	2.03
		13:59	5.97	2.46
		14:58	5.60	2.83
		15:55	5.31	3.12
WE-4	9/11/86	9:10	6.15	2.47
		9:55	6.20	2.42
		11:02	6.23	2.39
		11:58	6.25	2.37
		13:00	6.25	2.37
		14:00	6.23	2.39
		14:50	6.20	2.42
		16:06	6.18	2.44
WE-5	9/11/86	9:15	6.20	2.07
		10:01	6.18	2.09
		10:58	6.33	1.94
		11:54	6.33	1.94
		12:55	6.27	2.00
		13:56	6.15	2.12
		14:56	5.94	2.33
		16:00	5.88	2.39

TABLE 2 (cont.) -- Water Level Measurements

WELL #	DATE	TIME	DEPTH TO WATER IN FEET (TOC)	ELEVATION OF WATER TABLE (MSL)
MW-4	9/11/86	9:07	6.20	2.06
		10:01	6.28	1.98
		10:57	6.30	1.96
		11:58	6.20	2.06
		12:55	6.30	2.23
		13:56	6.00	2.26
		14:53	5.90	2.36
		15:56	5.82	2.44
MW-10	9/11/86	9:12	6.10	2.22
		10:05	6.30	1.99
		11:03	6.32	2.00
		12:01	6.32	2.00
		13:01	6.17	2.15
		14:00	5.90	2.42
		15:01	5.52	2.80
		16:02	5.20	3.12
PK-1	9/11/86	9:10	6.30	1.20
		10:04	6.40	1.13
		11:02	6.50	1.48
		12:00	5.73	1.80
		13:00	5.00	2.53
		14:00	4.46	3.07
		15:00	4.10	3.43
		16:00	3.88	3.66
PK-2	9/11/86	9:05	6.40	1.30
		10:00	6.47	1.23
		10:55	6.28	1.42
		11:55	5.92	1.78
		12:57	5.20	2.70
		13:55	4.66	3.04
		14:50	4.20	3.50
		15:55	4.00	3.70

In general, fluctuations in the water table decrease with distance from Thames River. Those wells closest to the Thames River were highly affected by the change in tide with the exception of WE-2. This well was screened in silty material and had the lowest hydraulic conductivity (0.26 feet/day) of the wells tested, thus the water level doesn't respond readily to short term fluctuations. WE-3 showed the most fluctuation of all the wells which may in part be caused by the highly permeable coarse to fine sand and gravel that surrounds the well screen. As mentioned previously, the pumping rate (2 gal/min) which was utilized for the permeability testing could not effectively drawdown the water level in order to perform a rising head test.

Measurements indicated that the water level of the Thames River adjacent to the site ranged from 1.13 feet to 3.66 feet MSL. Based on Figure 3.6, the lag time between each well affected by tidal fluctuations measured on 9/11/86 can be estimated. In general, all tidally influenced wells, with the exception WE-4, reflected water table responses within one hour of the responses measured in the Thames River. For example when the lowest tide level was measured in the river, one hour later the lowest water level was measured in the other wells.

WE-4 responded very little to the tidal fluctuations indicating that the well is within the transition zone of the River's influence on groundwater flow. Very slight variations were observed in WE-1 (attributable to the measuring device and method) which is the furthest measured well from the river. Based upon the estimated direction of groundwater flow during high and low tides, it appears that WE-1 is the only well of the five measured for tidal fluctuations that is not affected by the tide. Perhaps during times of exceptionally high tides, fluctuations in the water table in the vicinity of WE-1 could be observed.

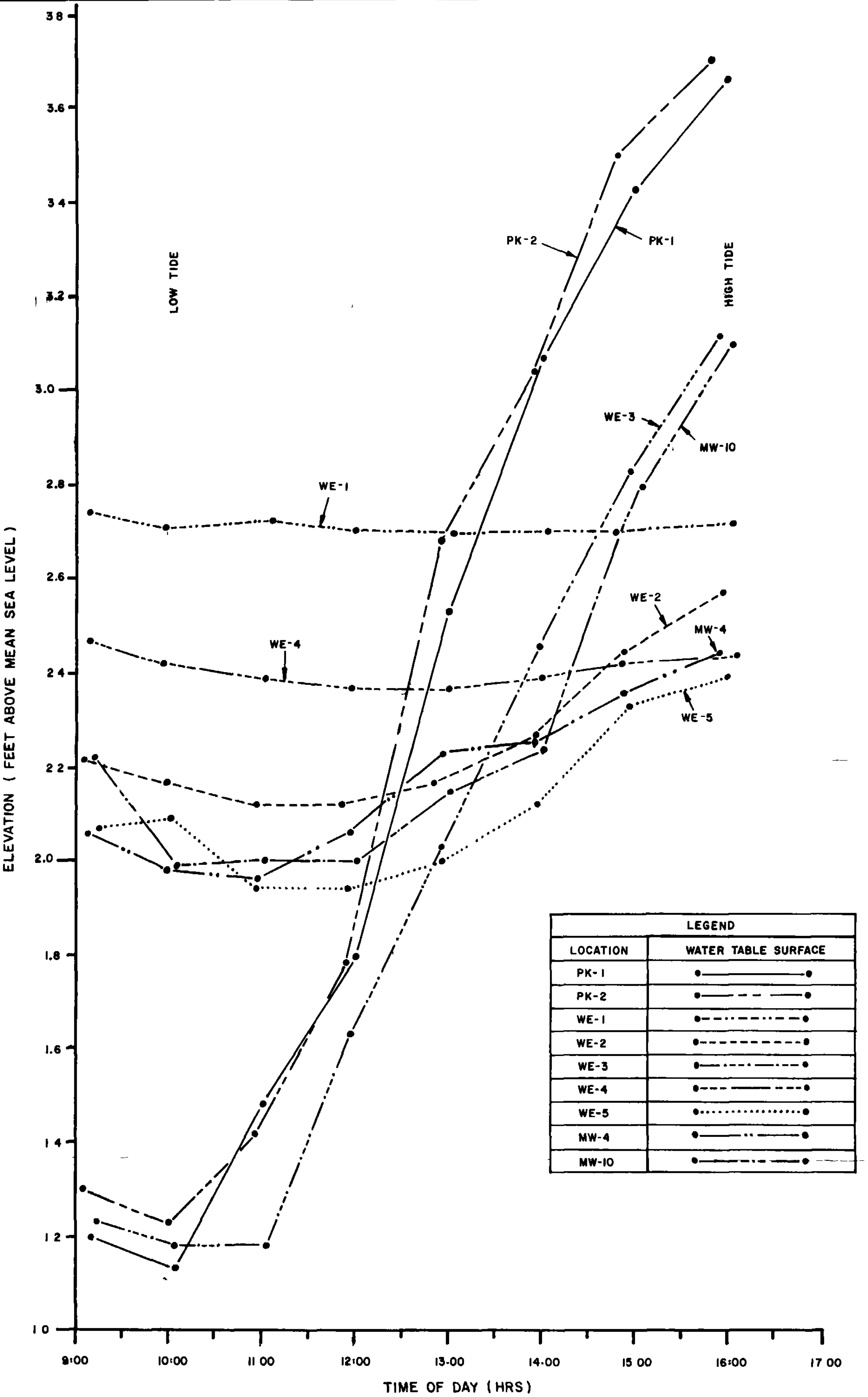

FIGURE 3 6

TIDAL FLUCTUATIONS (9/11/86)
NAVAL SUBMARINE BASE NEW LONDON
GROTON, CONNECTICUT

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CONSULTING ENGINEERS

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4.0 EVALUATION OF SITE CONTAMINATION

4.1 MANHOLES AND TRENCHES

Oil contamination was visually detected in several manholes in the vicinity of Building #79 (Figure 2.4) during the January, 1986 survey of site conditions. In an attempt to determine the source of the contamination, sludge samples were collected from five (5) manholes (MH-1 through 5) and two (2) trenches (T-1, 2) at the lower SUBASE in August of 1986 by Wehran personnel. These samples were subjected to fluorescence spectroscopy analysis (Appendix F–Fluorescence Spectroscopy Analysis Method) (Table 3–Summary of the analytical results). With this method the lab can provide a generalized description of the type (e.g. #6 fuel) and age (e.g. less than 1 year) of the oil. Samples of the #2 and #6 oils, used on the lower SUBASE, were obtained from Building #29 and analyzed to provide a standard for comparison with the other samples.

The samples collected from the utility trench at T-1 and T-2 showed #6 fuel oil contamination with a spectra similar to that of the #6 oil standard. These oil samples exhibited characteristics which the laboratory interpreted as indicating that the oil was less than one year old. This result suggests that the #6 fuel oil line in the trench had been leaking for less than one year prior to the August 1986 sampling event. Therefore, if this leak was to be linked to other oil contamination on-site, these samples should also be determined to be less than 1 year old.

The samples obtained from MH-1, 2, 3, and 4 also contained #6 fuel oil, however, the oil in these samples was found to have a different spectra than the #6 oil standard obtained from Building #29. In addition, the #6 oils detected in MH-1, 3, and 4 appear similar to each other, whereas the #6 oil in MH-2 showed spectral differences from the other three samples. The spectra analysis of all four samples indicated that the #6 oil had been weathered for at least one year prior to its

Table 3

LOWER SUBASE SUBSURFACE OIL CONTAMINATION
SUMMARY OF OIL FINGERPRINTING ANALYSIS BY FLUORESCENCE SPECTROSCOPY OF MANHOLE AND TRENCH SAMPLES

Location	Sample Identification	Analytical Results *
MH-1	MH-1	Spectra typical of a heavy fuel oil such as #6 oil Spectra similar to MH-3 and MH-4 Spectra characteristic of oil weathered for one year or more
MH-2	MH-2	Spectra typical of a heavy fuel oil such as #6 oil Spectra differences suggesting the oil is from a different source than any other samples Spectra characteristic of oil weathered for one year or more
MH-3	MH-3	Spectra typical of a heavy fuel oil such as #6 oil Spectra similar to MH-1 and MH-4 Spectra characteristic of oil weathered for one year or more
MH-4	MH-4	Spectra typical of a heavy fuel oil such as #6 oil Spectra similar to MH-1 and MH-3 Spectra characteristic of oil weathered for one year or more
MH-5	MH-5	Spectra typical of a mixed heavy fuel oil such as a mixture of #5 and #6 oil Spectra differences suggesting the oil is from a different source than any other sample Spectra was uncharacteristic to the standard, no weathering data could be determined
T-1	T-1	Spectra typical of a heavy fuel oil such as #6 oil Spectra similar to T-2 and FO-2 Spectra characteristic of oil weathered for less than one year
T-2	T-2	Spectra typical of a heavy fuel oil such as #6 oil Spectra similar to T-1 and FO-2 Spectra characteristic of oil weathered for less than one year
FO-1	FO-1	Spectra typical of #2 fuel oil Spectra was not similar to any other samples (Standard from Power Plant)
FO-2	FO-2	Spectra typical of #6 fuel oil Spectra similar to T-1 and T-2 (Standard from Power Plant)

* The fluorescence spectroscopy method for oil fingerprinting analysis discriminates between general levels of contamiantion (e.g. trace, low, etc.) while additionally determining the type (e.g. #6, #2, etc.) and degree of weathering (e.g. less than 1 year old).

sampling. The laboratory noted that the weathering of these samples appears to be slow, and thus the samples may be much older than one year.

The sample obtained from MH-5 showed characteristics that were substantially different from any of the other samples, including the #2 and #6 oil standards. The sample was identified as a possible mixture of #5 and #6 oils. Number 5 oil is similar to #6 oil and is a heavy fuel oil typically used by large industry and the military. Due to the lack of a standard for comparison, it was not possible to estimate the age of this sample.

As mentioned in Section 2.4, the sample obtained from MH-3 was subjected to PCB analysis. PCB concentrations were not present in concentrations above the detectable limit of 0.5 ppm.

The locations of the contaminated manholes (Figure 2.4) does not correlate with a specific utility, and thus it appears unlikely that the contamination is traveling through a particular utility line. It is probable that the oil is trapped in the soils in the vicinity of Building 79 and is entering manholes with poor structural integrity.

Oil contamination was not found in the utility trench trending northeast to southwest between T-1 and the Thames River (Figure 2.4). This indicates that the oil in the trench between Buildings #78 and #85 is not traveling to the area surrounding Building #79 through the trench system.

4.2 SOIL CONTAMINATION

Based upon historical information on the oil contamination within the lower submarine base, five (5) soil borings were drilled in areas suspected to be contaminated. Representative soil samples were collected for oil finger printing analysis by fluorescence spectroscopy. Table 4 presents a field summary of analytical samples selected.

TABLE 4 -- Field Summary of Analytical Soil Samples

BORING/ MONITORING WELL NUMBER	SAMPLE IDENTIFICATION	GROUND ELEVATION (MSL)	SAMPLE DEPTH (ft. below grade)	ELEVATION (MSL)	SAMPLE [1] CONDITION	HNu [2] SCREENING (ppm)	REMARKS [3, 4]
WE-1	NSB-WE1-5-7	9.45	5.0 to 7.0	7.45 to 2.45	u	0.2	coarse to fine sand
WE-1	NSB-WE1-13-15	9.45	13.0 to 15.0	-3.55 to -5.55	s	0.2	fine sand and silt
WE-2	NSB-WE2-2-4	8.37	2.0 to 4.0	6.37 to 4.37	u	3.0	medium to fine sand
WE-2	NSB-WE2-12-14	8.37	12.0 to 14.0	-3.67 to -5.67	s	3.0	medium to fine sand
WE-3	NSB-WE3-7-9	8.43	7.0 to 9.0	1.43 to -0.57	s	4.0	thick oily appearance in gravel and coarse to fine sand
WE-3	NSB-WE3-9-11	8.43	9.0 to 11.0	-0.57 to -2.57	s	4.0	thick oil appearance in coarse to fine sand
WE-4	NSB-WE4-7-9	8.62	7.0 to 9.0	1.62 to -0.38	s	0.2	medium to fine sand
WE-4	NSB-WE4-11-13	8.62	11.0 to 13.0	-2.38 to -4.38	s	0.2	silt
WE-5	NSB-WE-5-7-9	8.27	7.0 to 9.0	1.27 to -0.73	s	0.4	coarse to fine sand
WE-5	NSB-WE5-11-13	8.27	11.0 to 13.0	-2.73 to -4.73	s	0.2	coarse to fine sand

Notes

1. u/s = Unsaturated/Saturated soil conditions
2. Headspace analysis
3. Field observations of oil odor and/or soil discolorations
4. All samples analyzed for oil fingerprinting by flourescence spectroscopy

The objective of boring WE-1 was to determine if the oil found previously in the utility trench line, trending northeast-southwest and adjacent to Building 35, has migrated into downgradient soils. The two soil samples collected at this location, one from 5 to 7 feet, and one from 13 to 15 feet below grade, indicated only trace levels of petroleum hydrocarbons in the soils (refer to Table 5). During the soil boring program, no readings above background levels were observed on the HNu photoionization detector from the soil headspace of samples collected from WE-1. A test pit, 3 to 5 feet deep was excavated by the Navy per request of Wehran Engineering, along the utility trench line which runs between buildings 80 and 79. This trench did not have noticeable oil contamination nor any elevated HNu readings.

Borings WE-2 and WE-3 were drilled in areas suspected to be on the periphery of the oil contaminated zone.

At WE-2, from 2 to 4 and 12 to 14 feet, only trace levels of No. 6 fuel oil was analytically detected in soils. Despite relatively high HNu readings (1.0 to 20.0 ppm) in the soils in WE-2, no oil staining was observed by the field geologist. The high HNu readings may be the result of volatile organic compounds (solvents) being present in the soil which would not be detected by the fluorescence spectroscopy analytical method.

Table 5

LOWER SUBASE SUBSURFACE OIL CONTAMINATION

SUMMARY OF OIL FINGERPRINTING ANALYSIS BY FLUORESCENCE SPECTROSCOPY OF SOIL SAMPLES

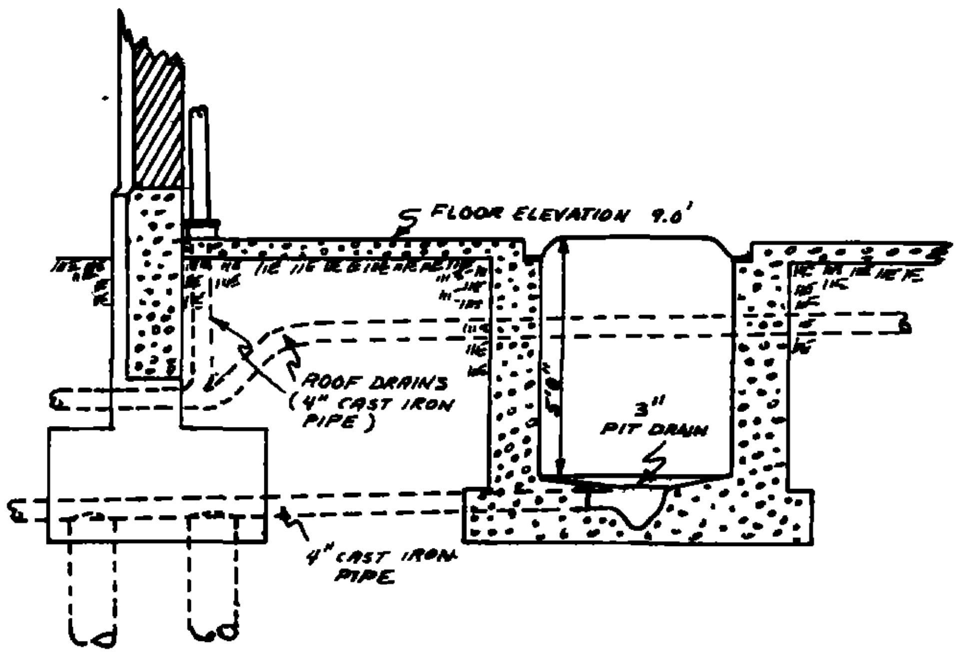
Location	Sample Identification	Analytical Results
WE-1	NSB-WE1-5-7	Trace levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
WE-1	NSB-WE1-13-15	Trace levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
WE-2	NSB-WE2-2-4	Trace levels of a heavy fuel oil (No. 6 fuel oil) detected.
WE-2	NSB-WE2-12-14	Trace levels of a heavy fuel oil (No. 6 fuel oil) detected.
WE-3	NSB-WE3-7-9	Low levels of a heavy fuel oil (No. 6 fuel oil) detected.
WE-3	NSB-WE3-9-11	Low levels of a heavy fuel oil (No. 6 fuel oil) detected.
WE-4	NSB-WE4-7-9	Low levels of a heavy fuel oil (No. 6 fuel oil) detected.
WE-4	NSB-WE4-11-13	Trace levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
WE-5	NSB-WE5-7-9	Trace levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
WE-5	NSB-WE5-11-13	Trace levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.

The analytical results of the soil boring investigation found WE-3 soils to contain the highest level of contamination (No. 6 fuel oil). In WE-3, from 7 to 11 feet, the soils were observed to contain thick oil and HNU soil headspace readings of 4.0 ppm. The oil appeared to be migrating through a very coarse gravel layer. A potential source area requiring further discussion is the railroad spur that once existed within Building 79. Oil from the train engines was periodically discharged into a pit drain which discharged into the surrounding subsurface soils. Based upon a 9/29/36 map of the "Engine House" this pit drain was located at an elevation of approximately 4.0 feet above mean sea level. An open ended 4 inch cast iron pipe extended from the drain sump into the surficial soils outside the perimeter of the building, near the vicinity of WE-3 (see Figure 4.1). It is therefore likely that the contamination observed in WE-3 and the surrounding soil is in part a direct result of this historical operation. This pit has subsequently been filled with concrete.

Laboratory analysis of soils from gravelly zone detected low levels of heavy fuel oil. The visible thick, black oil contamination discovered in WE-3 suggests that historical dumping of oil from Building 79 (the Engine house) may be a contaminating source and that a larger "pocket" of heavy oil may be present within the vicinity of this boring traveling through the very coarse layer of gravel.

The main objective of boring WE-4 was to determine if the oil or its derivatives were moving through the soil matrix between the oil contaminated utility trench and the oil found on the northwest side of Building 79. No gross contamination was observed in the soil collected from this location, however, from depths of 7 to 9 feet low levels of heavy fuel oil were detected. This low level of contamination may be attributed to the northeasterly migration of hydrocarbon constituents from the Building 79 area during high tide.

The objective of WE-5 was to investigate previous reports of a thick layer of oil measured in the destroyed NESO well No. 9. The boring and well is located in the



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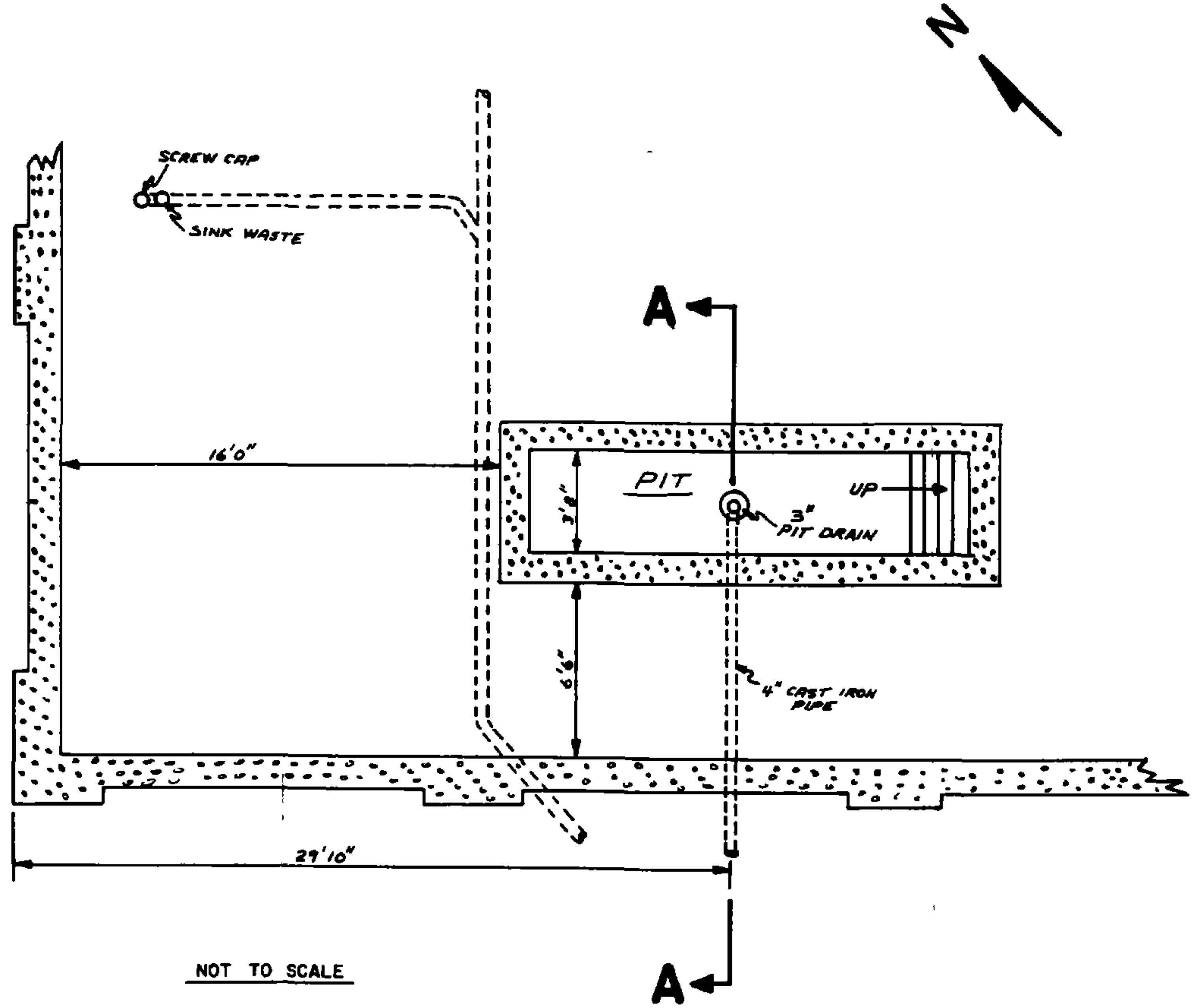

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NOTE DETAILS TAKEN FROM NAVAL PUBLIC WORKS DRAWING NO'S 1-502 & 1-504 (9/26/36)

FIGURE 4.1

NORTHWEST CORNER OF ENGINE HOUSE (BUILDING 79) DETAILING PRE-EXISTING PIT DRAIN AND DISCHARGE PIPES

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center of the previously suspected oil contamination zone. During our investigation, no oil constituents were observed in the soil matrix. Samples were collected for laboratory analysis from depths of 5 to 7 and 11 to 13 feet. Both samples contained trace concentrations of petroleum hydrocarbons resulting in poor resolution spectra for which the laboratory concluded: "no usable data was obtained".

Laboratory data (indicating only trace to low levels of oil) coupled with field observations (finding visual heavy fuel oil contamination in only one boring) suggest that the number 6 fuel oil is relatively immobile and that the bulk or "pocket" of oil which is suspected to exist in the soils based on the manhole contamination, was not encountered during the field investigation. The data indicates soils are more likely contaminated with heavy fuel oil near Building 79 than in the vicinity of Buildings 80 or 35. Additional borings or test pits would be required to further delineate the zone of heavy fuel oil contamination.

4.3 GROUNDWATER QUALITY

Groundwater samples were collected from seven (7) monitoring wells (WE-1, WE-2, WE-3, WE-4, WE-5, MW-4, and MW-10) on September 10, 1986. Table 6 is a summary of data recorded during collection of the samples. Included in the table are pH, conductance, and temperature measurements that were obtained in the field. As shown in the table, all groundwater samples were analyzed for oil fingerprinting by fluorescence spectroscopy.

In general, the pH values in each of the wells were nearly neutral, ranging from 6.5 to 7.12. Specific conductance values; however, showed extreme variations. WE-3 (adjacent to Building 79) exhibited very high conductance (>20,000 umho) which is atypical of groundwater under most circumstances, except extreme chemically contaminated conditions, highly saline conditions and when a contaminant containing a high level of metals is present. The specific conductance of

MW-10 (which is located near WE-3) was also high (11,910 umho). Metal cuttings within a lubrication/waste oil stemming from past operations and disposal practices associated with building 79 could explain the high conductivity values present in this area although no direct evidence was observed during this investigation. High conductivity in MW-4 (6,370 umho) could be the result of saline water and/or contamination from another source area because that well is located upgradient from both buildings 79 and 80. MW-4 does appear downgradient from buildings 29 and the several oil storage tanks, both of which could be potential source areas. WE-2 specific conductance value was 1,688 umho, which indicates that it may be influenced by saline waters and/or be on the periphery of the contamination plume and that the soluble constituents of the heavy oil contamination problem have migrated. WE-1, WE-4, and WE-5, all had similar specific conductance values (518, 502, and 500 umhos, respectively). These values are elevated slightly, indicating low levels of contamination, or a small influence from saline waters.

Table 6
LOWER SUBASE SUBSURFACE OIL CONTAMINATION
SUMMARY OF GROUNDWATER SAMPLING DATA*

Monitoring Well Numbers

	WE-1	WE-2	WE-3	WE-4	WE-5	MW-4	MW-10
Date	9/10/86	09/10/86	9/10/86	9/10/86	9/10/86	9/10/86	9/10/86
Time	11:30 a m	12:35 p m	3:33 p m	10:45 a m	4:20 p m	1:20 p m	3:55 p m
Weather	Sunny ~80°F	Sunny ~80°F	Sunny ~80°F	Sunny ~80°F	Sunny ~75°F	Sunny ~80°F	Sunny ~75°F
Sample Identification	NSB-WS-WE1-002	NSB-WS-WE2-003	Duplicate NSB-WS-WE3-006 NSB-SW-WE3-007	NSB-WS-WE4-001	NSB-WS-WE5-004	NSB-WS-MW4-009	NSB-WS-MW10-008
Water Level Depth (TOC)	6.70'	6.20'	5.40'	6.02'	6.15'	2.46'	5.30'
Water Level Elevation (MSL)	2.75'	2.17'	3.03'	2.60'	2.12'	5.80'	3.02'
Well Volumes Pumped Prior to Sampling	16	pumped well dry twice	14	13	62	3	3
pH	6.50	7.12	6 59	6.50	6.68	7.10	6.96
Specific Conductance (umhos)	518	1,688	>20,000	502	500	6,370	11,910
Water Temperature (°C)**	35	31	24	32	22	22	21
Water Appearance	clear to very slightly silty	clear to slightly silty	clear to very slightly silty	clear to very slightly silty	clear to very slightly silty	dark gray, silty	dark gray, silty

* Chemical analysis consisted of Oil Finger Printing Analysis by Fluorescence Spectroscopy

** The very warm water temperatures of wells WE-1, WE-2, and WE-4, and the elevated water temperatures of wells WE-3, WE-5, MW-4, and MW-10 seem to reflect a problem with the thermometer. The first three wells WE-4, WE-1, and WE-2 were measured consecutively with all three of the measurements being extremely high, the remaining four measurements are also unrealistic values considering average water temperatures 10–15°C during this part of the year.

Based upon data collected from the soil boring program, water table fluctuations and changes in the direction of groundwater flow caused by tidal influences, it is likely that the bulk of heavy oil is remaining relatively immobile near building 79. However, based upon groundwater data and laboratory results, showing waste and fuel oil contamination (Table 7), soluble constituents of the oil "pockets" are migrating with the groundwater to locations which are upgradient from suspected source areas during high tide, and downgradient from suspected source areas during low tide. To define this more specifically, refer to the hydrogeologic cross sections, Figures 3.2 and 3.3, both of these cross-sections display the fluctuations of the water table at high and low tide creating a rinsing action back and forth past the heavy oil pocket. The soluble oil constituents are stripped and carried with the groundwater to various locations, depending on the groundwater flow pattern during that particular sampling event.

During low tide, horizontal gradients are such that groundwater flows from buildings 79 and 80 toward WE-3, the well which was determined through field observations and laboratory analysis to be the most contaminated with #6 fuel oil. During periods of high tide, groundwater flows in two opposing directions and the confluence of the two flows is between WE-4 and WE-5. Both of these wells were contaminated with a low level mixture of waste and fuel oil. During both normal low and high tides, WE-1 was actually upgradient from the suspected source areas near buildings 79 and 80. Contamination present in WE-1 suggests that other upgradient source areas may be prevalent on the lower SUBASE, or during times of extremely high tides or flooding a change in flow conditions may occur. Very high river levels would allow WE-1 to be affected by the source areas that under normal conditions would be considered downgradient.

Table 7

LOWER SUBASE SUBSURFACE OIL CONTAMINATION
SUMMARY OF OIL FINGERPRINTING ANALYSIS
BY FLUORESCENCE SPECTROSCOPY OF GROUNDWATER SAMPLES

LOCATION	SAMPLE IDENTIFICATION	RESULTS
WE-4	NSB-WS-WE4-001	Spectra typical of a heavy waste/fuel oil.
WE-1	NSB-WS-WE1-002	Spectra typical of a heavy waste/fuel oil.
WE-2	NSB-WS-WE2-003	Spectra typical of a waste oil.
WE-5	NSB-WS-WE5-004	Spectra typical of a heavy waste/fuel oil.
Field Blank	NSB-WE-FB-005	No petroleum hydrocarbons detected.
WE-3	NSB-WE3-006	Spectra typical of #6 fuel oil.
WE-3	NSB-WS-WE3-007	Results unavailable-sample lost during processing.
MW-10	NSB-WS-MW10-008	Spectra typical of #6 fuel oil.
MW-4	NSB-WE-MW4-009	Spectra typical of #6 fuel oil.

4.4 ANALYTICAL QUALITY CONTROL

The analytical quality control program for this project is designed to assure that analytical data will be scientifically valid, defensible, and of known precision and accuracy. The quality control program consisted of the following:

- All bottles used in the field were supplied by the contract laboratory pre-cleaned and labeled for the specific needs of this project.
- Samples were acquired in succession from the least suspected contaminated to the most contaminated sample location.
- All sampling equipment was cleaned using Wehran's six part wash as established in Section 2.5.1 of this report regardless of whether visual contamination was present or not.
- Standard chain of custody procedures were used for sample handling.
- The analytical method used for the oil spill identification is fluorescence spectroscopy. This method provides a means of fingerprinting oil by spectral characteristics and thereby matching a field sample to a suspect source oil sample. This method is under review by the USEPA, the D.O.D., the D.O.T. and various state agencies, so currently there is no EPA method number. The oil identification process is simply a direct comparison of the sample's spectrum with the spectra from the suspected source samples over the spectrum range from 280 nm to 500 nm. No additional quality control samples are tested.
- The one polychlorinated biphenyl sample was analyzed via GC/ECD. The instrumentation used was a Perkin-Elmer Model Sigma 3 gas chromatograph equipped with an electron capture detector (Ni^{63}). No separate quality control was executed on this one sample, instead it was run with another sample set. This sample was tested to ensure that the oil in the manholes did not contain PCBs.

5.0 SUMMARY

In January of 1986 Wehran initiated their pre-site investigation including a file search and review. It was found that the #6 fuel oil pipes were contained in concrete utility trenches. The trenches were contaminated east of Building #35 while manhole contamination was present 200 feet west of the trenches.

In July of 1986 a soil boring and monitoring well installation program began. Five soil borings completed as wells were installed.

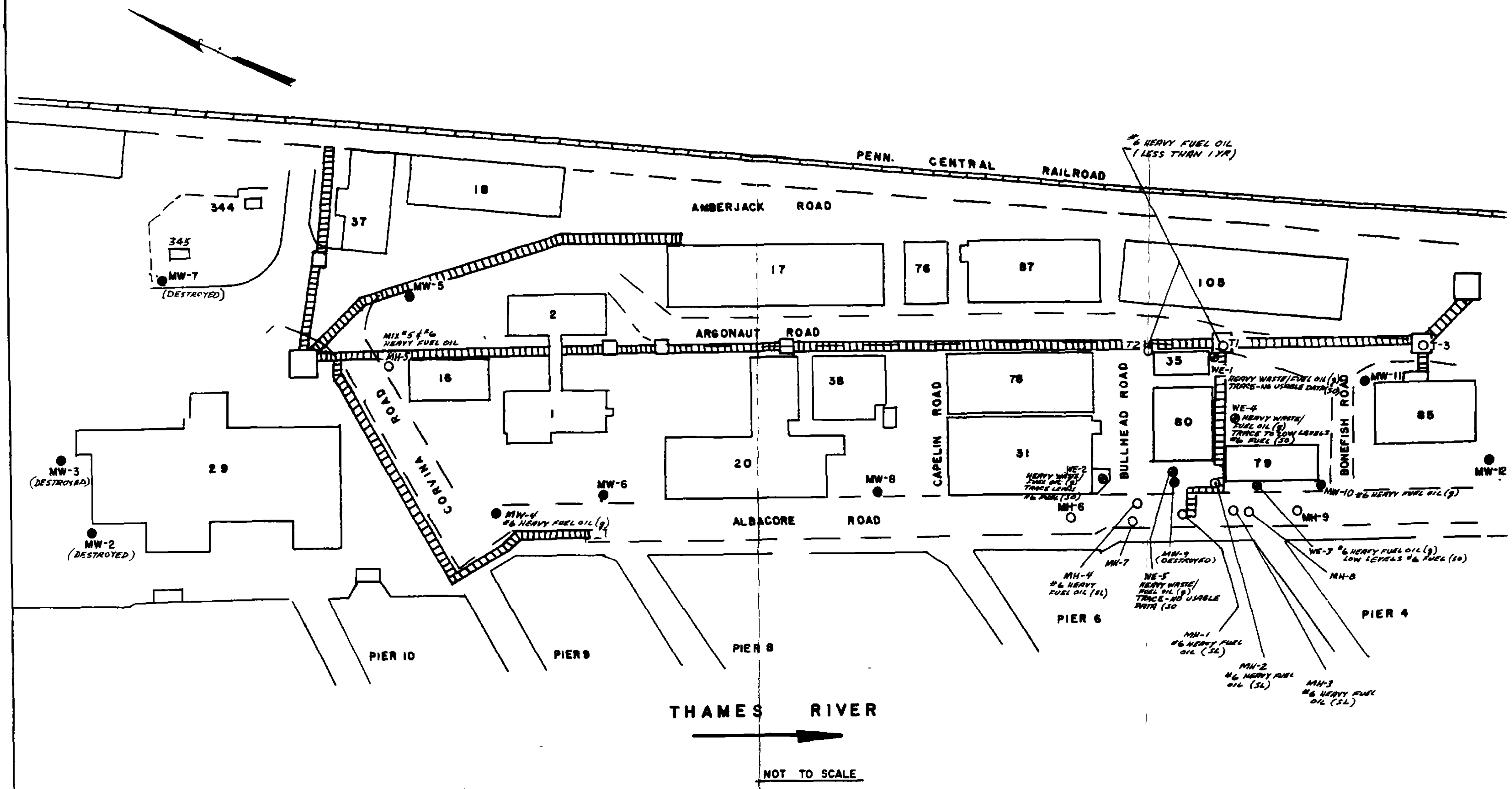
In August of 1986 a complete level run (measure T.O.C. elevations) of the new and old wells was undertaken. Sampling of the oil contaminated manholes and concrete utility trenches was completed.

In September of 1986 groundwater samples were taken and permeability tests were run. A complete cycle of tidal fluctuation measurements were made at nine locations.

A summary of the analytical results follows (see Figure 5.1).

The results of the soil analytical work from the soil borings measured trace to low levels of #6 fuel oil contamination in borings WE-1 through WE-5. The low levels of #6 fuel oil were identified in WE-3 and WE-4 west and east of Building 79.

The results of the sludge analytical work from the manholes and concrete utility trenches identified the oil as a heavy #6 fuel in MH-1 through MH-4 and in T-1, T-2. The oil sampled in MH-1, 2, 3, and 4 was determined to be older than one year. The oil sampled in T-1 and T-2 was determined to be less than one year. The oil from MH-5 was considerably different from the other samples having a mixture of both #5 and #6 oils. FO-1 and FO-2 were standards taken from the Power Plant. FO-1 was a #2 diesel fuel while FO-2 was a #6 heavy fuel oil. T-1, T-2, FO-2 showed spectral similarities suggesting the oil present may have been from the same source. MH-1, MH-3, and MH-4 showed spectral similarities suggesting the oil present may



LEGEND

● MW-10	PRE-EXISTING MONITORING WELL (NESO STUDY)
⊕ WE-3	MONITORING WELL NEWLY INSTALLED
○ T-3	TRENCH
○ MH-1	MANHOLE
(g)	GROUND WATER
(SO)	SOIL
(SL)	SLUDGE

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FIGURE 5.1

SITE SKETCH MAP
W/ SUMMARY OF ANALYTICAL RESULTS
NAVAL SUBMARINE BASE - NEW LONDON
GROTON, CONNECTICUT

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have been from the same source. Samples MH-2 and MH-5 showed spectral differences compared to the other sample, suggesting that the oil present in each was from a different source.

The results of the groundwater analytical work from the monitoring well samples identified spectra typical of heavy waste/fuel oil in wells WE-1, WE-4, and WE-5. The spectra typical of waste oil was located in WE-2. The spectra typical of #6 fuel oil was found in WE-3, MW-4 and MW-10.

The results of the level run from measuring the top of casing elevations are WE-1 (9.45), WE-2 (8.37), WE-3 (8.43), WE-4 (8.62), WE-5 (8.27), MW-4 (8.26), MW-5 (15.79), MW-6 (8.68), MW-8 (7.81), MW-10 (8.32), MW-11 (8.79), PK-1 (7.53), PK-2 (7.70), and PK-3 (7.69).

The results of the permeability testing conducted on the four wells are WE-1 (3.51 ft/day), WE-2 (0.26 ft/day), WE-4 (5.39 ft/day) and WE-5 (15.62 ft/day).

The results of the tidal fluctuation measurements taken at one hour intervals follows: The well location is presented followed by the hourly water elevations (in feet above mean sea level).

WE-1:	2.74, 2.71, 2.73, 2.70, 2.70, 2.70, 2.70, 2.72
WE-2:	2.22, 2.17, 2.12, 2.12, 2.17, 2.27, 2.47, 2.57
WE-3:	1.23, 1.18, 1.18, 1.53, 2.03, 2.46, 2.83, 3,12
WE-4:	2.47, 2.42, 2.39, 2.37, 2.37, 2.39, 2.42, 2.44
WE-5:	2.07, 2.09, 1.94, 1.94, 2.00, 2.12, 2.33, 2.39
MW-4:	2.06, 1.98, 1.96, 2.06, 2.23, 2.26, 2.36, 2.44
MW-10:	2.22, 1.99, 2.00, 2.00, 2.15, 2.42, 2.80, 3.12
PK-1:	1.20, 1.13, 1.48, 1.80, 2.53, 3.07, 3.43, 3.66
PK-2:	1.30, 1.23, 1.42, 1.78, 2.70, 3.04, 3.50, 3.70

6.0 CONCLUSIONS AND RECOMMENDATIONS

The objective of this investigation was to identify and delineate the sources of heavy oil contamination found in the manholes and trenches of the lower SUBASE, including recommendations for further investigations and/or candidate remediation measures would be presented.

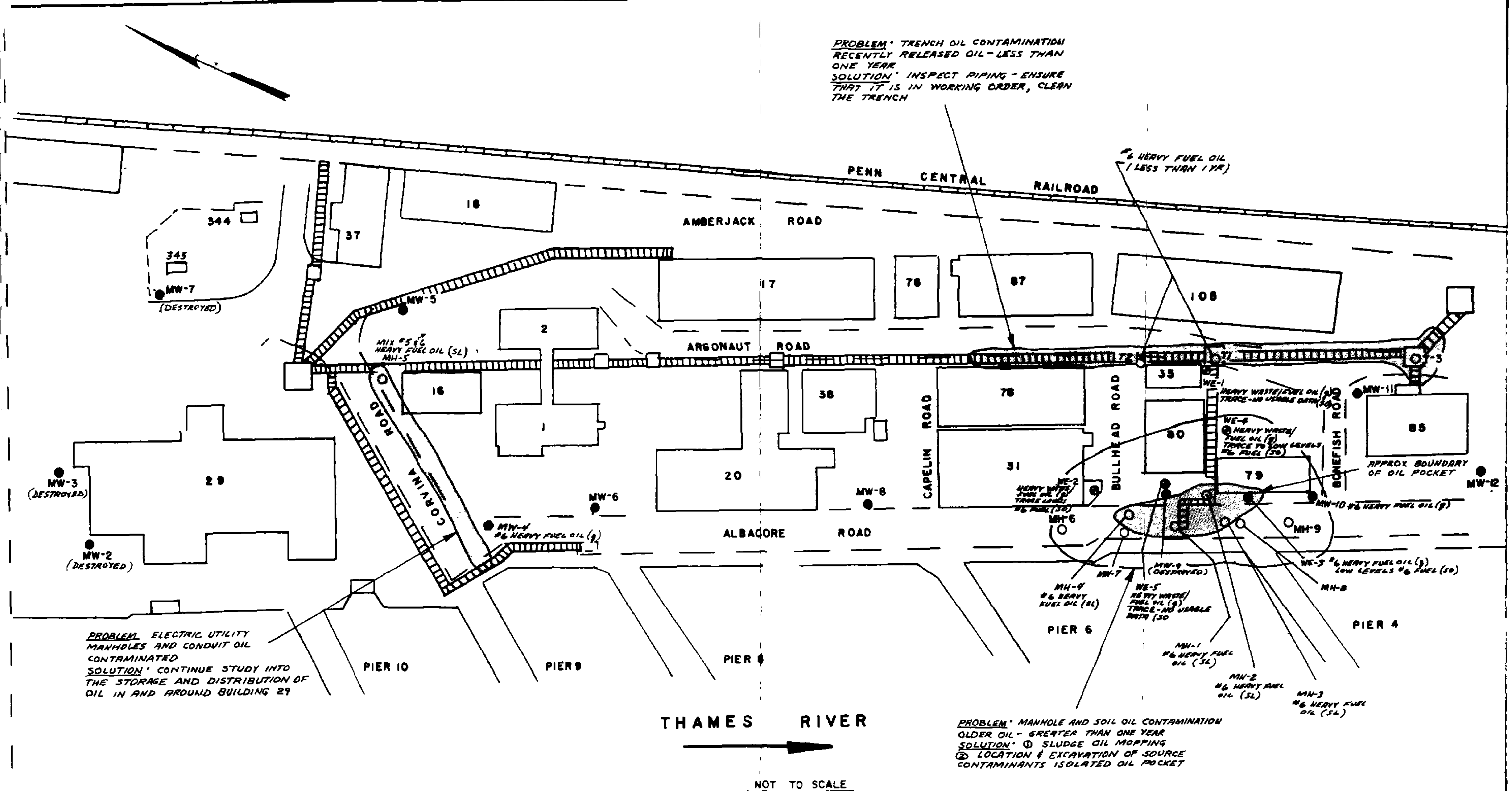
Upon completing the field work and a thorough review of the results, the following conclusions are presented:

Soluble constituents from the oil are present throughout the study area, however, three heavily oil contaminated areas were located (refer to Figure 6.1);

1) The utility trench, starting from Building #85 and going north past Building #78.
2) The manholes and soils north and west of Building #79
3) The electrical conduits and manholes along Corvina Road, from the manhole north of Building 16 and running west to Albacore Road.

The source of oil in area 1 (utility trench) appears to be the result of a recent leak in the #6 fuel line contained within the trench. Wehran's recommendations for a remediation measure would be to inspect the fuel lines within the trench, ensure that no leaks presently exist and then proceed with a trench cleaning operation.

The source of oil in area 2 (area around building 79) appears to be an isolated pocket of oil. There is evidence of contamination from both a heavy #6 fuel oil and a waste oil. This waste oil was most likely deposited during historic train engine repair operations. The source of the #6 fuel oil is unknown, but the analytical results indicate that it is an old release leading us to believe it is an isolated pocket of oil. This oil pocket most likely was generated from an undocumented release from



LEGEND

● MW-10	PRE-EXISTING MONITORING WELL (NESO STUDY)
◐ WE-3	MONITORING WELL NEWLY INSTALLED
○ T-3	TRENCH
○ MH-1	MANHOLE
(g)	GROUND WATER
(SO)	SOIL
(SL)	SLUDGE

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FIGURE 6.1

SITE SKETCH MAP
W/ OIL CONTAMINATION LIMITS
NAVAL SUBMARINE BASE - NEW LONDON
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previous inventory practices. From this study the following conclusions were determined: 1) according to available information a #6 fuel line does not exist within area 2, 2) the heavy #6 fuel was found in a variety of manholes with no pattern or logical distribution, 3) the #6 fuel oil is more than 1 year old, 4) some oil movement under the relieving platform has occurred but it does not appear extensive at the present time, and 5) high specific conductance values were measured in this area which appear to be associated with salt water intrusion from the tidally influenced Thames River. (This can be confirmed in the field using a Cole Palmer Model 1481-50 conductivity/salinity meter.)

Wehran's recommendation for area 2 is to proceed in one of three ways. The first method would require the efforts of a backhoe and cleanup crew. This method calls for the excavation of the oil laden soils. The soils could then be removed for on or off-site disposal/bioremediation. Due to the variability of the oil contaminated zones, Wehran would recommend initiating the excavation adjacent to the oil contaminated manholes and proceeding outwards removing the oil laden material as deemed appropriate. Due to the number and variety of subsurface utilities in this area (Figure 2.2), the excavation process should be closely monitored and performed with extreme caution.

The second method and less disruptive of the two would be the physical removal of the heavy oil from the manholes on a periodic basis. This method would utilize the natural ability of the oil to migrate to specific manholes and calls for a scheduled maintenance program. The oil would be removed and drummed on a scheduled maintenance program using special oil absorbent materials and machinery (e.g. Oil Mop Inc.). The advantages of this method is that it utilizes natural oil migration pathways, requires very little capital, and most importantly the area remains undisturbed and traffic conditions are unchanged. A major disadvantage to this method is the potential for a release of the soluble oil to the environment.

The source of oil in the third area, electrical conduits and manholes along Corvina Road appears to be from the Building 29 area. The oil sampled in this area was determined to be a mix of #5 and #6 fuel oil. The spectra from this oil was different than all other samples taken. The source of oil could be from the storage tanks and/or from Building 29 itself. This area was originally inspected in January 1986 and no oil was found, but during this study's field activities in August 1986, a worker was observed with oil covered boots. A discussion with the worker revealed that when he first entered the manholes, the electrical conduits were filled with oil and the manholes were clean. To work on the electrical lines he cleaned the oil out of the conduits into the manholes. The oil in the conduits appears to be periodically deposited, possibly during very high water events (flooding). The oil is transported into the conduits while the water level is high and remains there as the water recedes to normal levels. Although no obvious oil contamination was found in the electrical conduits between Buildings 29 and 79, oil was found in the electrical manholes at each location. Wehran recommends further study in this area. This would include a study of the electrical conduits/manholes along Corvina Road, and a thorough review of the oil supply and distribution system of Building 29.

7.0 REFERENCES

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APPENDIX A
Soil Boring Logs

KEY TO NAVY SUBMARINE BASE - GROTON, CT.

BORING LOGS & WELL INSTALLATIONS

1) PVC Riser - 2" OD

2) PVC Screen - 2" OD, 0.10 slot size

3) Bentonite Seal

4) Portland cement grout

5) Roadway Box

6) Ottawa Silica Sand

K = Hydraulic conductivity

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TEST BORING LOG
BORING NO. WE-1

PROJECT: Navy Submarine Base (lower section), Groton, CT	SHEET NO. 1 OF 1
CLIENT: Navy	JOB NO. 04360
BORING CONTRACTOR: New England Boring	ELEVATION 9.45 MSL

GROUND WATER					CAS.	SAMP.	CORE	TUBE	
DATE	TIME	WATER ELEV.	SCREEN INT.	TYPE	Augered	SS			DATE STARTED 7/14/86
7/14/86	Initial	6-7' below grade	15-5' below grade	DIA.	4" ID	2" OD			DATE FINISHED 7/14/86
7/16/86		7.02'		WT.		140 lbs			DRILLER Mike St. John
				FALL		30"			INSPECTOR Barbara Riley
									Drill Rig - Mobile B53

WELL CONSTRUCTION (5)	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS	HNU (ppm)*
(4)	0		AUGERED		Black Macadam	0.5'	
(3) (1)					-FILL- Dark brown, medium to fine SAND, little Gravel, trace Macadam.	DRY	
(6) (2)	5	S-1	SS	2, 2, 3, 4	Loose brown coarse to fine SAND, little sub-angular Gravel, trace Silt	5.0'	0.2
						▼ 7.02' Water Table	
		S-2	SS	2, 2, 2, 2		WET	0.2
	10	S-3	SS	2, 3, 2, 3			0.2
		S-4A	SS	3, 3, 3, 3			0.2
		S-4B	SS	2	-ALLUVIUM- Soft, dark brown fine SAND, some Silt.	12.5' Some organics	0.2
	15	S-5	SS	3, 3, 8			
Bottom of well at 15.0'					-END OF BORING AT 15.0'	15.0' * Background = 0.2 ppm	

ANALYTICAL SAMPLES COLLECTED

Well/Depth	Number	Analysis	Type
WE #1 5.0'-7.0'	NSB-WE1-5-7	Flourescence Spectroscopy	Soil
WE #2 13.0'-15.0'	NSB-WE1-13-15	Flourescence Spectroscopy	Soil

K = Hydraulic Conductivity = 3.46 ft/day

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG
BORING NO. WE-2

PROJECT: Navy Submarine Base (lower section), Groton, CT	SHEET NO. 1 OF 1
CLIENT: Navy	JOB NO. 04360
BORING CONTRACTOR: New England Boring	ELEVATION 8.37 MSL

GROUND WATER					CAS.	SAMP.	CORE	TUBE
DATE	TIME	WATER ELEV.	SCREEN INT.	TYPE	Augered	SS		
7/15/86	Initial	6.0'	12.1' - 2.1'	DIA.	4" ID	2" OD		
7/16/86	2:58 pm	6.5'	Below Grade	WT.		140 lbs		
				FALL		30"		

DATE STARTED 7/15/86
DATE FINISHED 7/15/86
DRILLER Mike St. John
INSPECTOR Barbara Riley
Drill Rig - Mobile B53

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS	HNU* (ppm)
④ ③ ① ⑤	0	S-1	SS	2 / 3 / 8 / 6	- TOPSOIL - Medium dense, dark brown very fine SAND, some Sitl, little rounded gravel, trace Roots.	1.0' DRY	13.0
		S-2	SS	3 / 3 / 5 / 7	-FILL- Loose, brown medium to fine SAND, little Silt and rounded Gravel.	DRY	3.0
						DRY	
	5	S-3	SS	4 / 4 / 3 / 6			4.0
② ⑥		S-4	SS	2 / 1 / 1 / 2	Very Loose, brown coarse to fine SAND, little rounded Gravel, trace Silt.	6.5' Water Table WET; Poor Recovery	20.0
		S-5A	SS	3 / 3	Loose brown coarse to fine SAND, little subangular Gravel, trace Silt	-Gravel lense	2.5
	10	S-5B	SS	2 / 2		8.0'	2.5
		S-6	SS	4 / 3 / 3 / 2	Loose, brown, medium to fine SAND, some Silt.		1.0
		S-7A	SS	3 / 1 / 1	-ALLUVIUM-	13.0'	3.0
		S-7B	SS	4	Very Loose, dark grayish brown very fine SAND and SILT.	Some organics	2.0
Bottom of well at 12.1'	15				END OF BORING AT 14.0'	* Background = 0.2 ppm	
	20						

ANALYTICAL SAMPLES COLLECTED

Well/Depth	Number	Analysis	Type
WE #2 2.0'-4.0'	NSB-WE2-2-4	Flourescence Spectroscopy	Soil
WE #2 12.0'-14.0'	NSB-WE2-12-14	Flourescence Spectroscopy	Soil

K = Hydraulic Conductivity = 0.59 ft/day

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG
BORING NO. WE #3

PROJECT: Navy Submarine Base (lower section), Groton, CT	SHEET NO. 1 OF 1
CLIENT: Navy	JOB NO. 04360
BORING CONTRACTOR: New England Boring	ELEVATION 8.43 MSL

GROUND WATER

DATE	TIME	WATER ELEV.	SCREEN INT.
7/15/86	Initial	6.0' below grade	13.0'-3.0' below grade

	CAS.	SAMP.	CORE	TUBE
TYPE	Augered	SS		
DIA.	4" ID	2" OD		
WT.		140 lbs		
FALL		30"		

DATE STARTED 7 15/86
DATE FINISHED 7 15/86
DRILLER Mike St. John
INSPECTOR Barbara Riley
Drill Rig - Mobile B53

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS	HNU* (ppm)
④ ⑤	0				Black Macadam	0.5' Augered thru first half foot of pavement	
③ ①		S-1	SS	8, 12, 9, 11	-FILL- Medium dense, dark brown fine SAND, little Silt and fine subangler Gravel.	DRY	0.2
				6, 12, 9, 12		No recovery	
⑥ ②	5					6.0' - Water Table WET No recovery 7.0'	
		S-2	SS	6, 5, 7, 6	Medium dense, dark brown and black fine GRAVEL, some coarse to fine Sand, trace Silt.	Thick oily appearance 7'-9'. -Brick fragments-	4.0
	10	S-3	SS	15, 15, 30, 48	Dense brown coarse to fine SAND and GRAVEL, trace Silt.	9.0'	4.0
		S-4	SS	6, 17, 12, 10	Dense brown, coarse to fine SAND, little fine subangular to rounded Gravel, trace Silt.	No oily appearance	1.0
Bottom of well at 13.0'					END OF BORING AT 13.0'	* Background = 0.2 ppm	
	15						
	20						

ANALYTICAL SAMPLES COLLECTED

Well/Depth	Number	Analysis	Type
WE #3 7.0'-9.0'	NSB-WE 3-7-9	Flouresence Spectroscopy	Soil
WE #3 9.0'-11.0'	NSB-WE 3-9-11	Flouresence Spectroscopy	Soil

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO. WE #4

PROJECT: Navy Submarine Base (lower section), Groton, CT	SHEET NO. 1 OF 1
CLIENT: Navy	JOB NO. 04360
BORING CONTRACTOR: New England Boring	ELEVATION 8.62 MSL

GROUND WATER

DATE	TIME	WATER ELEV.	SCREEN INT.
7/16/86	Initial	6.0' below grade	13.3'-3.3' below grade
7/16/86	2:44 pm	6.35'	

	CAS.	SAMP.	CORE	TUBE
TYPE	Augers	SS		
DIA.	4" ID	2"OD		
WT.		140 lbs		
FALL		30"		

DATE STARTED 7/16/86
DATE FINISHED 7/16/86
DRILLER Mike St. John
INSPECTOR Barbara Riley
Drill Rig - Mobile B53

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS	HNU* (ppm)
④ ⑤	0				Black Macadam - pavement	Augered to 1.0'	
③ ①		S-1A	SS	45, 55	Very dense black macadam and angular GRAVEL.	2.0' Broken up boulder from 2.0' - 3.0'	0.4
		S-1B	SS	28, 28	Very dense gray angular GRAVEL.	3.0' Poor recovery	0.2
		S-2	SS	21, 8, 12, 8	-FILL-	DRY	0.2
②	5			7, 1, 1, 1		6.35' Water Table; No recovery	0.2
⑥		S-3	SS	1, 3, 3, 5	Loose brown, medium to fine SAND, some Silt.	WET	0.2
	10	S-4	SS	5, 3, 1/12"		11.0'	0.2
		S-5	SS	1, 1, 1, 1	-ALLUVIUM- Very soft dark brown SILT, little fine Sand.	some organics	0.2
Bottom of well at 13.0'					END OF BORING AT 13.0'	* Background = 0.2 ppm	

ANALYTICAL SAMPLES COLLECTED

Well/Depth	Number	Analysis	Type
WE #4 5.0'-7.0'	NSB-WE 4-7-9	Flourescence Spectroscopy	Soil
WE #4 11.0'-13.0'	NSB-WE 4-11-13	Flourescence Spectroscopy	Soil

K = Hydraulic Conductivity = 5.67 ft/day

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG
BORING NO. WE #5

PROJECT: Navy Submarine Base (lower section), Groton, CT	SHEET NO. 1 OF 1
CLIENT: Navy	JOB NO. 04360
BORING CONTRACTOR: New England Boring	ELEVATION 8.27 MSL

GROUND WATER					CAS.	SAMP.	CORE	TUBE	
DATE	TIME	WATER ELEV.	SCREEN INT.	TYPE	Augers	SS			DATE STARTED 7/16/86
7/16/86	Initial	5.5'	13.9'-3.9' below ground surface	DIA.	4" ID	2" OD			DATE FINISHED 7/16/86
				WT.		140 lbs			DRILLER Mike St. John
				FALL		30"			INSPECTOR Barbara Riley
									Drill Rig - Mobile B53

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS	HNU * (ppm)
roadway box ④ ⑤	0					Augered thru black macadam to 1.0'	
③ ①		S-1A	SS	22 / 18	Dense, black macadam	2.0'	0.2
		S-1B	SS	12 / 12	-FILL- Medium dense, dark brown, medium to fine SAND, some Silt, little fine Gravel.	DRY	0.2
		S-2	SS	12 / 7 / 4 / 10			1.5
	5	S-3	SS	3 / 12 / 1 / 1	Loose brown coarse to fine SAND, some rounded Gravel, trace Silt.	5.0' 5.5'- Water Table WET	0.4
②		S-4	SS	3 / 12 / 7 / 7			0.4
⑥	10	S-5	SS	6 / 4 / 4 / 10	Loose brown, coarse to fine SAND, some Silt, trace Clay.	9.0'	0.2
		S-6	SS	5 / 4 / 3 / 4		Augered to 14.0'	0.2
Bottom of well at 14.0'	15				END OF BORING AT 14.0'	* Background = 0.2 ppm	

ANALYTICAL SAMPLES COLLECTED

Well/Depth	Number	Analysis	Type
WE # 5 5.0'-7.0'	NSB-WE 5-5-7	Flouresence Spectroscopy	Soil
WE #5 11.0'-13.0'	NSB-WE 5-11-13	Flouresence Spectroscopy	Soil

K = Hydraulic Conductivity = 19.19 ft/day

APPENDIX B
Permeability Calculations

WEHRAN ENGINEERING
CONSULTING ENGINEERS

VARIABLE HEAD
PERMEABILITY TEST
PIEZOMETER No. WE # 1

PROJECT: Navy - Lower Sub Base, Groton, CT
CLIENT: Navy
JOB NO: 04360SF
DATE OF TEST: 9/10/86

SCREENED INTERVAL:
Screen interval is from 15.0 to 5.0 feet below the top of PVC casing.

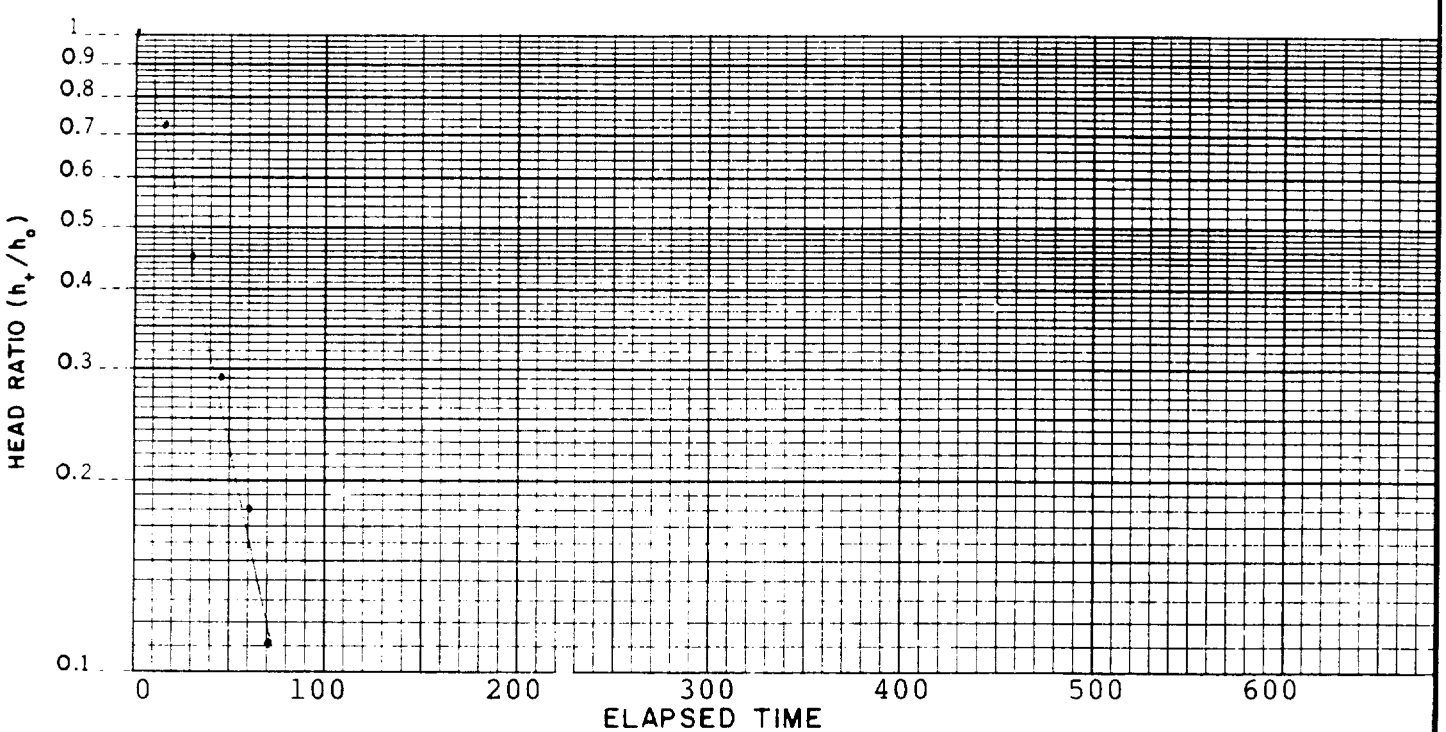
METHOD:
Rising head test

$$K = \frac{r^2 \ \ln \ (h_1/h_2)}{2L \ (t_2 - t_1)} \ .\ln \ \frac{L}{R}$$

Hvorslev (1951)

TEST DATA

ELAPSED TIME (sec)	HEAD RATIO (h_+ / h_o)
0	1.0
15	.72
30	.45
45	.28
60	.18
70	.12
90	.11
105	.08
120	.05
135	.04
150	.03
165	.02
180	.02
195	.02
210	.02



CALCULATIONS:

r = 254 cm
R = 5.08 cm
L = 266
t_1 = 15 sec
t_2 = 90
h_1 = 0.72
h_2 = 0.11

$$K = \frac{(2.54 \text{ cm})^2 \ \ln \ (0.72/0.11)}{2 \ (253) \ \ (90 - 15)} .\ln \frac{253 \text{ cm}}{5.08 \text{ cm}}$$

(.0003194) (3.9) = .00124 cm/sec
= 1.24×10^{-3} cm/sec
= 3.51 feet/day

WEHRAN ENGINEERING
CONSULTING ENGINEERS

VARIABLE HEAD PERMEABILITY TEST
PIEZOMETER No. WE #2

PROJECT:	Navy - Lower Sub Base , Groton, CT
CLIENT:	Navy
JOB NO:	04360SF
DATE OF TEST:	9/±0/86

SCREENED INTERVAL:

Screen interval is from 12.1 to 2.1 feet below the top of PVC casing.

METHOD:

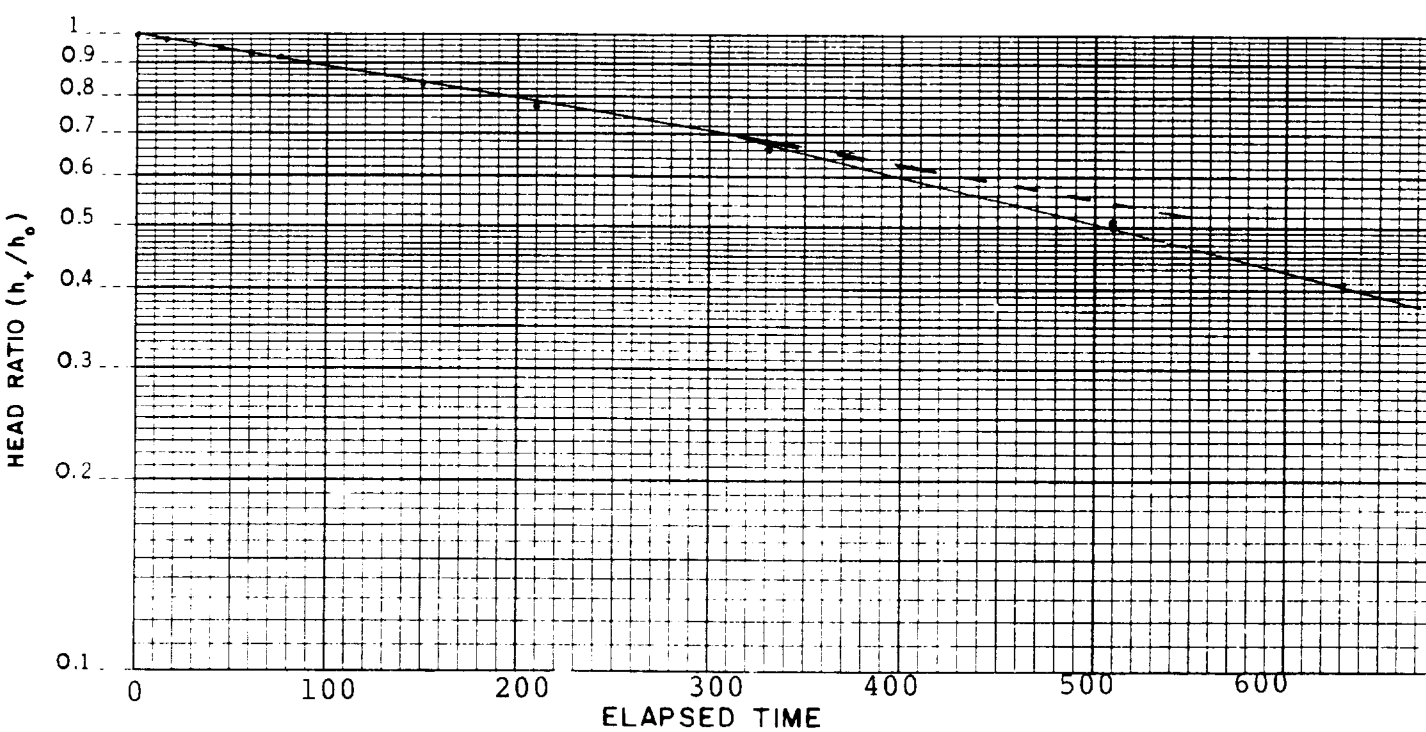
Rising head test

$$K = \frac{r^2 \ln(h_1/h_2)}{2L\ (t_2 - t_1)} \cdot \ln \frac{L}{R}$$

Hvorslev (1951)

TEST DATA

ELAPSED TIME (sec)	HEAD RATIO (h_+ / h_o)
0	1.00
15	.98
30	.96
45	.95
60	.93
75	.92
90	.90
150	.83
210	.77
330	.66
510	.51
630	.42
690	.38



CALCULATIONS:

$r = 2.54$ cm

$R = 5.09$ cm

$L = 179.83$

$t_1 = 330$

$t_2 = 510$

$h_1 = 0.66$

$h_2 = 0.51$

$$K = \frac{(2.54\text{ cm})^2 \ln(0.66/0.51)}{2\ (179.83)\ (510 - 330)} \cdot \ln \frac{179.83}{5.08\text{ cm}}$$

(.0000257) (3.57) = .0000917 cm/sec

= 9.17×10^{-5} cm/sec

= 0.26 feet/day

WEHRAN ENGINEERING
CONSULTING ENGINEERS

VARIABLE HEAD PERMEABILITY TEST
PIEZOMETER No. WE #4

PROJECT: Navy - Lower Sub Base, Groton, CT
CLIENT: Navy
JOB NO: 04360SF
DATE OF TEST: 9/10/86

SCREENED INTERVAL:
Screen interval is from 13.3' to 3.3' below the top of PVC casing.

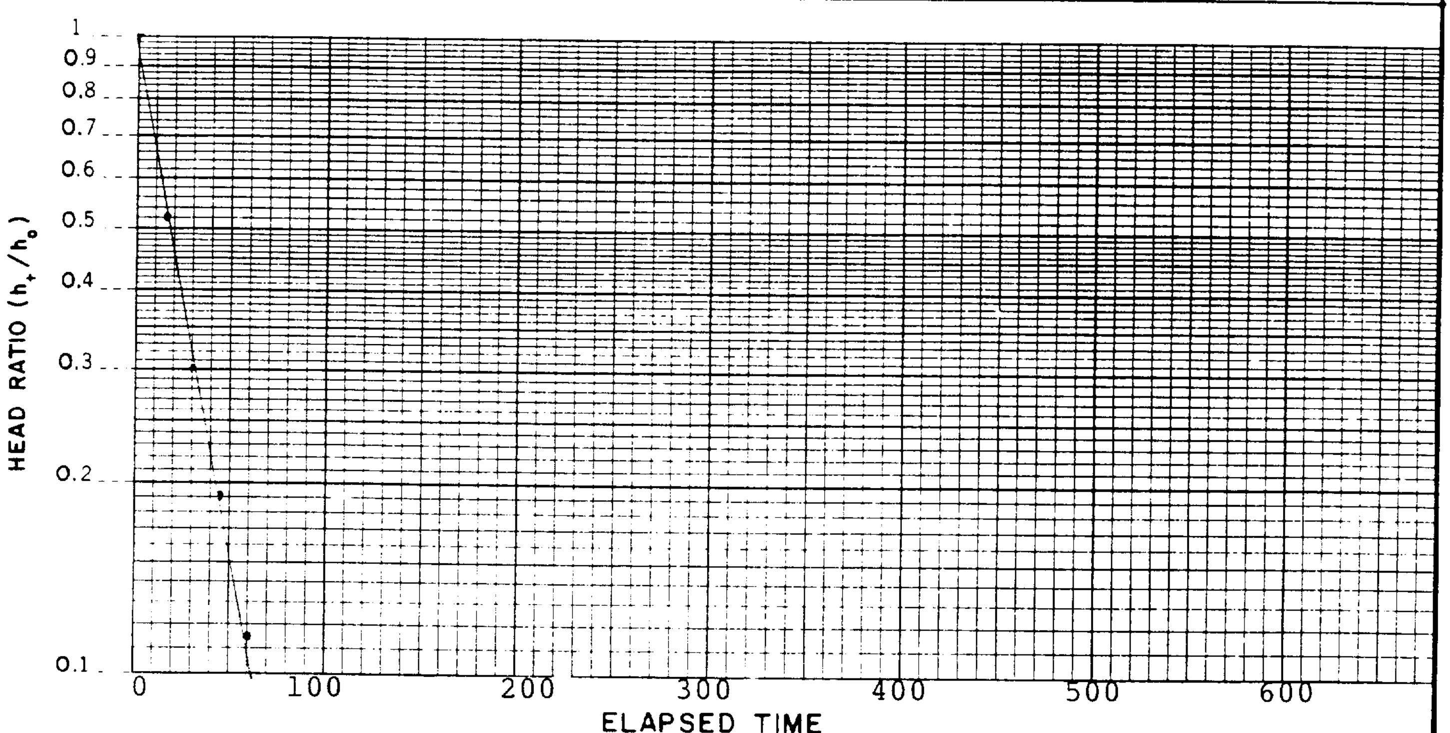
METHOD: Rising head test

$$K = \frac{r^2 \ln (h_1/h_2)}{2L\,(t_2 - t_1)} \cdot \ln \frac{L}{R}$$

Hvorslev (1951)

TEST DATA

ELAPSED TIME (sec)	HEAD RATIO (h_t / h_o)
0	1.00
15	.52
30	.30
45	.18
60	.13
75	.09
105	.07
115	.07
175	.07



CALCULATIONS:

$r = 2.54$ cm
$R = 5.08$ cm
$L = 168.2$ cm
$t_1 = 15$ sec
$t_2 = 45$ sec
$h_1 = 0.52$
$h_2 = 0.18$

$$K = \frac{(2.54\text{ cm})^2 \ln (0.52/0.18)}{2\,(221.89\text{ cm})\,(45-15\text{ sec})} \cdot \ln \frac{221.89\text{ cm}}{5.08\text{ cm}}$$

$(.0005141)\,(3.7) = .0019021$ cm/sec

$= 1.9021 \times 10^{-3}$ cm/sec

$= 5.39$ feet/day

WEHRAN ENGINEERING
CONSULTING ENGINEERS

VARIABLE HEAD PERMEABILITY TEST
PIEZOMETER No. WE #5

PROJECT: Navy - Lower Sub Base, Groton, CT
CLIENT: Navy
JOB NO: 04360SF
DATE OF TEST: 9/10/86
SCREENED INTERVAL:

Screen interval is from 13.9' to 3.9' below the top of PVC casing.

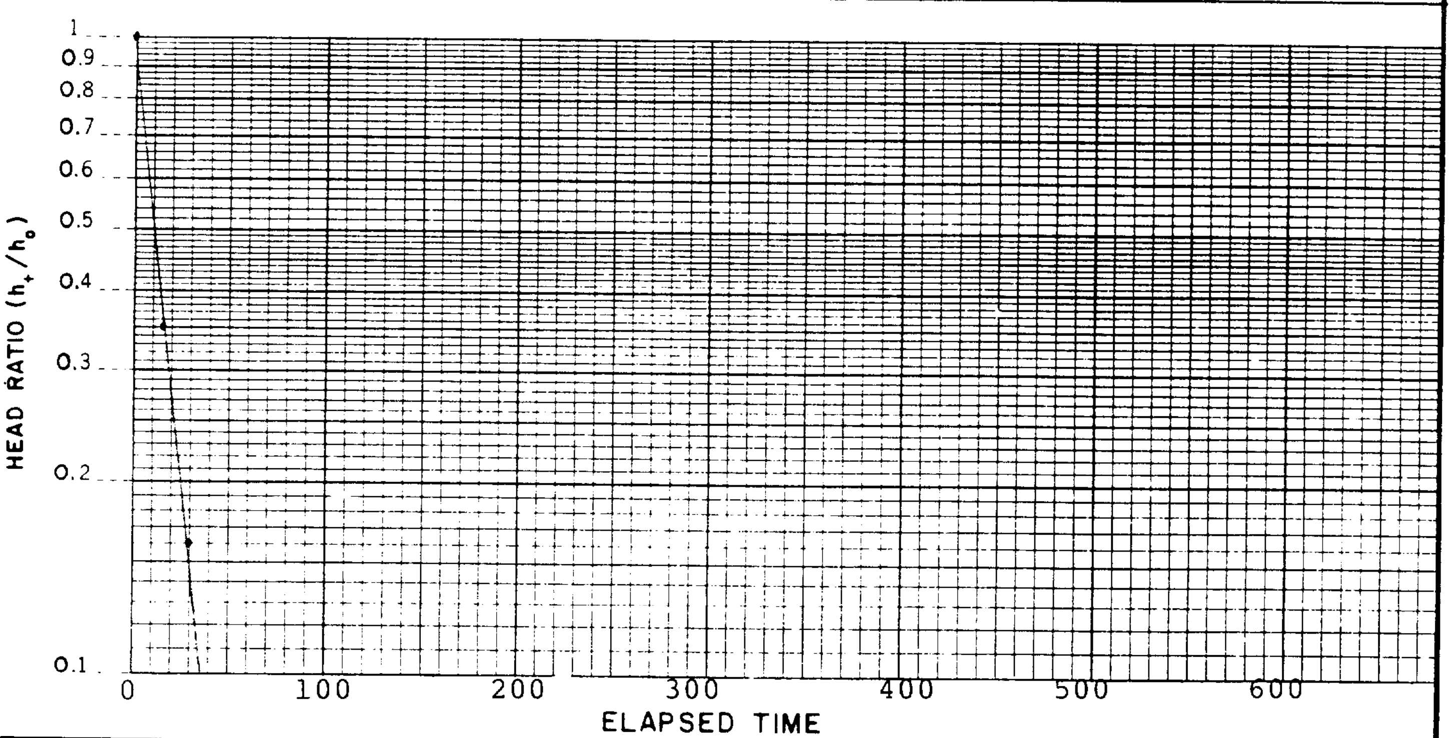
METHOD: Rising head test

$$K = \frac{r^2 \ln (h_1/h_2)}{2L (t_2 - t_1)} . \ln \frac{L}{R}$$

Hvorslev (1951)

TEST DATA

ELAPSED TIME (sec)	HEAD RATIO (h_t / h_o)
0	1.00
15	.35
30	.06
45	.00



CALCULATIONS:

r = 2.54 cm
R = 5.08 cm
L = 236
t_1 = 5 sec
t_2 = 15 sec
h_1 = .58
h_2 = 0.35

$$K = \frac{(2.54 \text{ cm})^2 \ln (1.0/0.35)}{2 (236 \text{ dm}) (10 \text{ sec})} . \ln \frac{(236 \text{ cm})}{5.08 \text{ cm}}$$

(.001435) (3.84) = .0055102 cm/sec
= 5.51×10^{-3} cm/sec
= 15.62 feet/day

APPENDIX C
Water Quality Sampling Field Data Sheets

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: WE #1

LAB SAMPLE No.: NSB-WS-WE1-002

PROJECT: NAVY SUB BASE, Groton, Conn.

CLIENT: NAVY

JOB No: 04360 SF

SAMPLER: B. Riley, P. Croteau

DATE: 9/10/86 TIME: 11:30

WEATHER CONDITIONS: Sunny

AIR TEMPERATURE: ~80°F

TYPE OF SAMPLE: ☑ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 2 in ☑ PVC ☐ STEEL ☐ OTHER:

SCREEN DIAMETER: .01 in ☑ PVC ☐ GALVANIZED STEEL ☐ STAINLESS STEEL ☐ OPEN ROCK

STATIC WATER LEVEL: 6.7' BOTTOM DEPTH: 15.05'

DATUM: ☐ TOP OF PROTECTIVE CASING ☑ TOP OF WELL CASING ☐ OTHER:

GROUND SURFACE TO DATUM: .35' WATER VOLUME IN WELL: 1.36

CONDITION OF WELL: Good - developed clean on 9/9/86 & 9/10/86, secure

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☐ BAILER ☐ OTHER: Tsurumi Engine Pump - Model TE-50-RW

IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO

PUMPING RATE: 1 gal./min ELAPSED TIME: 22 min VOLUME PUMPED: 22 gallons

WAS WELL EVACUATED ? ☐ YES ☑ NO WELL VOLUMES PUMPED: 16+

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☑ BAILER teflon ☐ OTHER:

IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO Decontaminated after each collection

DEPTH OF SAMPLE: 10 to 14 feet

CONTAINERS: NUMBER/TYPE: NSB-WS-WE1-002 1 liter amber glass jar

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☑ CLEAR ☐ TURBID ☐ COLOR: ☑ CONTAINS SEDIMENT: V. little silt ☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:

ODOR: ☐ YES ☑ NO

FIELD DETERMINATIONS:

TEMPERATURE: 35°C pH: 6.5 SPEC. COND: 518 umho

OTHER:

REMARKS:

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: WE #2
LAB SAMPLE No.: NSB-WS-WE2-003

PROJECT: NAVY SUB BASE, Groton Conn.
CLIENT: NAVY
JOB No: 04360 SF
SAMPLER: B. Riley, P. Croteau

DATE: 9/10/86 TIME: 12:35
WEATHER CONDITIONS: Sunny
AIR TEMPERATURE: ~ 80°F
TYPE OF SAMPLE: ☑ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 2in ☑ PVC ☐ STEEL ☐ OTHER:
SCREEN DIAMETER: .01in ☑ PVC ☐ GALVANIZED STEEL ☐ STAINLESS STEEL ☐ OPEN ROCK
STATIC WATER LEVEL: 6.2 BOTTOM DEPTH: 12.1
DATUM: ☐ TOP OF PROTECTIVE CASING ☑ TOP OF WELL CASING ☐ OTHER:
GROUND SURFACE TO DATUM: .35' WATER VOLUME IN WELL: 1.008
CONDITION OF WELL: Good developed - 9/9 and 9/10, secure

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☐ BAILER
☐ OTHER: Tsurumi Engine Pump TE-50 RW
IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO
PUMPING RATE: N/A - Could not measure ELAPSED TIME: 10 min VOLUME PUMPED: ~3+ gallons
WAS WELL EVACUATED ? ☑ YES ☐ NO WELL VOLUMES PUMPED: 3+
Pumped dry twice.

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☑ BAILER Teflon - Deconed after each Collection
☐ OTHER:
IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO
DEPTH OF SAMPLE: 10 to 12 feet
CONTAINERS: NUMBER / TYPE: NSB-WS-WE2-003 - 1 liter amber jar.

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☑ CLEAR ☐ TURBID ☑ COLOR: V. light Gray ☐ CONTAINS SEDIMENT: little silt.
☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:
ODOR: ☐ YES ☑ NO
FIELD DETERMINATIONS:
TEMPERATURE: 31°C pH: 7.12 SPEC. COND: 1688 umhos
OTHER:

REMARKS:

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: WE #4 WS
LAB SAMPLE No.: NSBAWE4-001

PROJECT: Navy Sub Base, Groton, Conn.
CLIENT: NAVY
JOB No: 04360 SF
SAMPLER: B. Riley / P. Croteau

DATE: 9/10/86 TIME: 10:45
WEATHER CONDITIONS: Sunny
AIR TEMPERATURE: ~80°F
TYPE OF SAMPLE: ☒ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 2in ☒ PVC ☐ STEEL ☐ OTHER:
SCREEN DIAMETER: .01in ☒ PVC ☐ GALVANIZED STEEL ☐ STAINLESS STEEL ☐ OPEN ROCK
STATIC WATER LEVEL: 6.02 BOTTOM DEPTH: 13.33
DATUM: ☐ TOP OF PROTECTIVE CASING ☒ TOP OF WELL CASING ☐ OTHER:
GROUND SURFACE TO DATUM: —
WATER VOLUME IN WELL: 1.168 gallons
CONDITION OF WELL: Good, well developed 9/9/86 and 9/10/86, secure

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☐ BAILER
☒ OTHER: Tsurumi Engine Pump – Model TE-50-RW
IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☒ NO
PUMPING RATE: 1gal/minute ELAPSED TIME: 16 min. VOLUME PUMPED: 16 gals
WAS WELL EVACUATED ? ☐ YES ☒ NO WELL VOLUMES PUMPED: 13+

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☒ BAILER
☐ OTHER:
IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☒ NO Decontamination after each location.
DEPTH OF SAMPLE: Approx 10 to 12 feet
CONTAINERS: NUMBER / TYPE: NSB-WS-WE4-001 One liter amber glass jar

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☒ CLEAR ☐ TURBID ☐ COLOR: ☐ CONTAINS SEDIMENT: very little silt
☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:
ODOR: ☐ YES: ☒ NO
FIELD DETERMINATIONS:
TEMPERATURE: 32°F pH: 6.50 SPEC. COND: 502 umho.
OTHER:

REMARKS: Decontaminated bailer after each collection

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: MW #3
LAB SAMPLE No.: DUPLICATE NSB-WS-WE3-006
NSB-WS-WE3-007

PROJECT: NAVY SUB BASE, Groton Conn.
CLIENT: NAVY
JOB No: 04360 SF
SAMPLER: B. Riley P. Croteau

DATE: 9/10/86 TIME: 3:33
WEATHER CONDITIONS: Sunny
AIR TEMPERATURE: ~80°F
TYPE OF SAMPLE: ☑ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 2in ☑ PVC ☐ STEEL ☐ OTHER:
SCREEN DIAMETER: .01in ☑ PVC ☐ GALVANIZED STEEL ☐ STAINLESS STEEL ☐ OPEN ROCK
STATIC WATER LEVEL: 5.4' BOTTOM DEPTH: 13.0
DATUM: ☐ TOP OF PROTECTIVE CASING ☑ TOP OF WELL CASING ☐ OTHER:
GROUND SURFACE TO DATUM: WATER VOLUME IN WELL: 1.216
CONDITION OF WELL: Good, secure except for surface seal which is cracked

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☐ BAILER
☐ OTHER: Tsurumi Engine pump - Model TE-50-RW
IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO
PUMPING RATE: 2 gals/minute ELAPSED TIME: 9 mins. VOLUME PUMPED: ~18 gals
WAS WELL EVACUATED ? ☐ YES ☑ NO WELL VOLUMES PUMPED: 14 +

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☑ BAILER teflon
☐ OTHER:
IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO Decontaminated bailer after each sample collection
DEPTH OF SAMPLE: 10 to 12 ft.
CONTAINERS: NUMBER / TYPE: NSB-WS-WE3-006 — 1 Liter glass amber jar
NSB-WS-WE3-007 — 1 Liter glass amber jar

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☑ CLEAR ☐ TURBID ☐ COLOR: v.v. light brown ☐ CONTAINS SEDIMENT: very little silt
☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:
ODOR: ☐ YES ☑ NO
FIELD DETERMINATIONS
TEMPERATURE: 24°C pH: 6.59 SPEC. COND: ~~[illegible]~~ umho
| 1 ~~~ 0 scale
OTHER:

REMARKS:

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: WE # 5

LAB SAMPLE No.: NSB-WS-WE5-004

PROJECT: NAVY SUB BASE, Groton, Conn.

CLIENT: NAVY

JOB No: 04360 SF

SAMPLER: B. Riley / P. Croteau

DATE: 9/10/86 TIME: 1:20

WEATHER CONDITIONS: Sunny

AIR TEMPERATURE: ~80°F

TYPE OF SAMPLE: ☑ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 2in ☑ PVC ☐ STEEL ☐ OTHER:

SCREEN DIAMETER: .01 in ☑ PVC ☐ GALVANIZED STEEL ☐ STAINLESS STEEL ☐ OPEN ROCK

STATIC WATER LEVEL: 6.15 BOTTOM DEPTH: 13.9

DATUM: ☐ TOP OF PROTECTIVE CASING ☑ TOP OF WELL CASING ☐ OTHER:

GROUND SURFACE TO DATUM: .2 WATER VOLUME IN WELL: 1.24 gals

CONDITION OF WELL: Good, secure, developed 9/8 and 9/10

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☐ BAILER
☐ OTHER: Tsurumi Engine Pump – TE50 RW

IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO

PUMPING RATE: 2 gals/min ELAPSED TIME: 13 min VOLUME PUMPED: 78 gals.

WAS WELL EVACUATED ? ☐ YES ☐ NO WELL VOLUMES PUMPED: 62 +

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☑ BAILER Teflon – Deconed after each collection
☐ OTHER:

IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO

DEPTH OF SAMPLE: 11 to 14 feet

CONTAINERS: NUMBER / TYPE: NSB-WS-WE5-004

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☑ CLEAR ☐ TURBID ☐ COLOR: v.v. light Gray ☐ CONTAINS SEDIMENT V. little silt
☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:

ODOR: ☐ YES ☑ NO

FIELD DETERMINATIONS:

TEMPERATURE: 22°C pH: 6.68 SPEC. COND 500 umho.

OTHER:

REMARKS:

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: MW #10

LAB SAMPLE No.: NSB-WS-MW10-008

PROJECT: NAVY SUB BASE, Groton Conn.

DATE: 9/10/86 TIME: 3:55

CLIENT: NAVY

WEATHER CONDITIONS: Sunny

JOB No: 04360 SF

AIR TEMPERATURE: ~75°F

SAMPLER: B. Riley P. Croteau.

TYPE OF SAMPLE: ☑ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 2.0 ☐ PVC ☑ STEEL ☐ OTHER:

SCREEN DIAMETER: unknown ☐ PVC ☐ GALVANIZED STEEL ☑ STAINLESS STEEL(?) ☐ OPEN ROCK

STATIC WATER LEVEL: 5.3' BOTTOM DEPTH: 8.2'

DATUM: ☐ TOP OF PROTECTIVE CASING ☑ TOP OF WELL CASING ☐ OTHER:

GROUND SURFACE TO DATUM: WATER VOLUME IN WELL: .464'

CONDITION OF WELL: V. Poor - filled with debris (very silty) road box flips up.

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☑ BAILER
☐ OTHER:

IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO Decontaminated before next location.

PUMPING RATE: ~ .5 gallons /min ELAPSED TIME: 3 min VOLUME PUMPED: 1.5 gals

WAS WELL EVACUATED ? ☐ YES ☑ NO WELL VOLUMES PUMPED: 3+.

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☑ BAILER
☐ OTHER:

IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO

DEPTH OF SAMPLE: 6-8 feet

CONTAINERS: NUMBER / TYPE: NSB-WS-MW10-008 1 liter glass jar - amber

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☑ TURBID ☑ COLOR: Dark gray ☑ CONTAINS SEDIMENT: dark gray silt
☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:

ODOR: ☑ YES Slight petroleum odor. ☐ NO

FIELD DETERMINATIONS:

TEMPERATURE: 21°C pH: 6.96. SPEC. COND: 1191. (19,990 scale)

OTHER:

REMARKS:

WEHRAN ENGINEERING
CONSULTING ENGINEERS

WATER QUALITY SAMPLING FIELD DATA SHEET

LOCATION No.: ~~[illegible]~~ mw#4

LAB SAMPLE No.: NSB-WS-mW4-009

PROJECT: NAVY SUB BASE, Groton Conn.

CLIENT: NAVY

JOB No: 04360 SF

SAMPLER: B. Riley / P. Crotean

DATE: 9/10/86 TIME: 4:20

WEATHER CONDITIONS: Sunny

AIR TEMPERATURE: ~85°

TYPE OF SAMPLE: ☑ GROUND-WATER ☐ SURFACE-WATER ☐ OTHER

WELL DATA:

CASING DIAMETER: 3 in ☐ PVC ☑ STEEL ☐ OTHER:

SCREEN DIAMETER: Unknown ☐ PVC ☐ GALVANIZED STEEL ☑ STAINLESS STEEL (?) ☐ OPEN ROCK

STATIC WATER LEVEL: 5.8 BOTTOM DEPTH: 8.5

DATUM: ☐ TOP OF PROTECTIVE CASING ☑ TOP OF WELL CASING ☐ OTHER:

GROUND SURFACE TO DATUM: WATER VOLUME IN WELL: .432

CONDITION OF WELL: V. Poor - V. Silty, filled with debris, guard box flipes up.

PUMPING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☐ DIAPHRAGM PUMP ☑ BAILER

☐ OTHER:

IS PUMPING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO

PUMPING RATE: ~ .5 gals/min ELAPSED TIME: ~ 3 mins. VOLUME PUMPED: 1.5 gals

WAS WELL EVACUATED ? ☐ YES ☑ NO WELL VOLUMES PUMPED: 3+

SAMPLING DATA:

METHOD: ☐ SUBMERSIBLE PUMP ☐ PERISTALTIC PUMP ☑ BAILER

☐ OTHER:

IS SAMPLING EQUIPMENT DEDICATED TO SAMPLE LOCATION ? ☐ YES ☑ NO

DEPTH OF SAMPLE: 6.0 - 8.0

CONTAINERS: NUMBER / TYPE:

PHYSICAL & CHEMICAL DATA:

APPEARANCE: ☐ CLEAR ☑ TURBID ☐ COLOR: ☐ CONTAINS SEDIMENT: dark brown

☐ CONTAINS IMMISCIBLE LIQUID ☐ OTHER:

ODOR: ☑ YES Slight hydrocarbon. ☐ NO

FIELD DETERMINATIONS:

TEMPERATURE: 22 pH: 7.10 SPEC. COND: 697 (19,490 scale)

OTHER:

REMARKS:

APPENDIX D
Chain of Custody Forms

Rf. 2

CHAIN OF CUSTODY RECORD

PROJECT: NAVY - Lower Submarine Base, Groton Conn.

CLIENT: NAVY

JOB No.: 04360

SAMPLE IDENTIFICATION:

LOCATION No.	LAB SAMPLE No.	CONTAINERS: NUMBER/TYPE	CONTAINER CONDITION
WE#1	7	Amber Soil Jar - NSB-WE1-5-7	Clean outside
WE#1		" -NSB-WE1-13-15	"
WE#2		" -NSB-WE2-2-4	"
WE#2		" -NSB-WE2-12-14	"
WE#3		" -NSB-WE3-7-9	"
WE#3		" -NSB-WE3-9-11	"
WE#4		" -NSB-WE4-7-9	"
WE#4		" -NSB-WE4-11-13	"
WE#5		" -NSB-WE5-7-9	"
WE#5		" -NSB-WE5-11-13	"

CHAIN OF CUSTODY CHRONICLE:

COLLECTED BY:

1 NAME: Barbara Riley DATE: WE#1 - Collected on 7/14/86; WE#2,3 - Collected on 7/15/86; WE#4,5 - Collected on 7/16/86

SIGNATURE: Barbara Riley SEALS PLACED ON CONTAINERS? ☐ YES ☐ NO

CUSTODY TRANSFERRED TO:

2 NAME: John Bondos DATE: 7/16/86 TIME: 3:40

SIGNATURE: John A. Bondos Jr. ARE SEALS INTACT? ☐ YES ☐ NO ☒ N/A

CUSTODY TRANSFERRED TO:

3 NAME: DATE: TIME:

SIGNATURE: ARE SEALS INTACT? ☐ YES ☐ NO ☐ N/A

RECEIVED IN LABORATORY BY:

4 NAME: Donald Gonyea DATE: 7/16/86 TIME: 5:35

SIGNATURE: Donald Gonyea ARE SEALS INTACT? ☐ YES ☐ NO ☒ N/A

DISPOSED BY:

5 NAME: DATE:

SIGNATURE:

REFER TO "WATER QUALITY SAMPLING FIELD DATA SHEET" FOR SPECIFIC SAMPLING DETAILS.

WERE ANY SAMPLES SPLIT WITH ANOTHER PARTY? ☐ YES ☐ NO

IF YES, IDENTIFY:

WEHRAN ENVIRONMENTAL LABORATORY

FOR YORK LABS

CHAIN OF CUSTODY RECORD

PROJECT: Navy - Lower Subbase Subsurface Oil Investigation

CLIENT: Naval SuBase Groton CT

JOB No.: 04260

SAMPLE IDENTIFICATION:

LOCATION No.	LAB SAMPLE No.	CONTAINERS: NUMBER/TYPE	CONTAINER CONDITION
T-1		1/ amber glass 1/2 pint	good
T-2		1/ amber glass 1/2 pint	
MH-1		" " " " "	
MH-2		" " " " "	
MH-3		" " " " "	
MH-4		" " " " "	
MH-5		" " " "	
FO-1		" " " " "	
FO-2		" " " " "	good

CHAIN OF CUSTODY CHRONICLE:

COLLECTED BY: Richard Messer & Jennifer Griffith

1 NAME: RICHARD J. MESSER DATE: 8-4-86
SIGNATURE: Richard J. Messer SEALS PLACED ON CONTAINERS? ☐ YES ☒ NO

CUSTODY TRANSFERRED TO:

2 NAME: Ted S. Huggins DATE: 8/5/86 TIME: 12:02
SIGNATURE: Ted S. Huggins rec'd 8 samples ARE SEALS INTACT? ☐ YES ☐ NO ☒ N/A

CUSTODY TRANSFERRED TO:

3 NAME: DATE: TIME:
SIGNATURE: ARE SEALS INTACT? ☐ YES ☐ NO ☐ N/A

RECEIVED IN LABORATORY BY:

4 NAME: PAT McCARTHY DATE: 8-5-86 TIME: 14:24
SIGNATURE: M.P. McCarthy (rec'd 8 samples) ARE SEALS INTACT? ☐ YES ☐ NO ☒ N/A

DISPOSED BY:

5 NAME: DATE:
SIGNATURE:

REFER TO "WATER QUALITY SAMPLING FIELD DATA SHEET" FOR SPECIFIC SAMPLING DETAILS.

WERE ANY SAMPLES SPLIT WITH ANOTHER PARTY? ☐ YES ■ NO
IF YES, IDENTIFY:

REVISED 3/83

Ref 20

WEHRAN ~~ENVIRONMENTAL LABORATORY~~ ENGINEERING

CHAIN OF CUSTODY RECORD

PROJECT: NAVY SUB BASE - Groundwater sampling

CLIENT : NAVY

JOB No. : 04360 SF

SAMPLE IDENTIFICATION:

LOCATION No.	LAB SAMPLE No.	CONTAINERS: NUMBER/TYPE	CONTAINER CONDITION
[illegible]		1 / 1 Liter Amber glass jar	Good
NSB-WS-WE4-001		"	"
NSB-WS-WE1-002		" All samples to be	"
NSB-WS-WE2-003		" ~~collected~~ analyyzed for	"
NSB-WS-WE5-004		" Fluorescence	"
NSB-WS-FB-005		" spectroscopy	"
NSB-WS-WE3-006		"	"
NSB-WS-WE3-007		"	"
NSB-WS-MW10-008		"	"
NSB-WS-MW4-009		"	"

CHAIN OF CUSTODY CHRONICLE:

COLLECTED BY:

1 NAME: Barbara Riley and Peter Croteau DATE: 9/10/86
SIGNATURE: Barbara Riley SEALS PLACED ON CONTAINERS? ☑ YES ☑ NO

CUSTODY TRANSFERRED TO:

2 NAME: Ted S. Huggins DATE: 9/11/86 TIME: 4:21
SIGNATURE: Ted S. Huggins ARE SEALS INTACT? ☐ YES ☐ NO ☑ N/A

CUSTODY TRANSFERRED TO:

3 NAME: DATE: TIME:
SIGNATURE: ARE SEALS INTACT? ☐ YES ☐ NO ☐ N/A

RECEIVED IN LABORATORY BY:

4 NAME: DATE: TIME:
SIGNATURE: ARE SEALS INTACT? ☐ YES ☐ NO ☐ N/A

DISPOSED BY:

5 NAME: K. Crossman DATE: 9/11/86.
SIGNATURE: K. Crossman

REFER TO "WATER QUALITY SAMPLING FIELD DATA SHEET" FOR SPECIFIC SAMPLING DETAILS.

WERE ANY SAMPLES SPLIT WITH ANOTHER PARTY? ☐ YES ☑ NO

IF YES, IDENTIFY:

APPENDIX E
York Laboratories Certified Reports

Rc'd Received Monday December 15, 1986
FILE III 5436C SF
NAVAL ... BASE

YORK LABORATORIES DIVISION

YWC

CERTIFIED REPORT TRANSMITTAL

REPORT NUMBER 30870-1515

DATE December 12, 1986

CLIENT
Wehran Engineering
100 Milk Street
MEthuen, MA 01844

ATTENTION Mr. Richard Messer

The above referenced report is enclosed. Copies of this report and supporting data will be retained in our files in the event they are required for future reference.

If there are any questions concerning this report, please do not hesitate to contact us.

Any samples submitted to our Laboratory will be retained for a maximum of sixty (60) days from receipt of this report, unless other arrangements are desired.

Naturally, as in the past, our staff will be pleased to quote on any future requirements you may have. In addition to the service provided, we also offer the following:

- Hazardous Waste Analyses
- Product Evaluation/R&D
- Water and Wastewater Analyses
- Air and Process Gas Analyses
- Industrial Hygiene Surveys
- Metallurgical Analyses
- Microbiological Analyses
- Mass Spectrometry Services

Very Truly Yours,

Robert Q. Bradley/MD

Robert Q. Bradley
Vice President

December 12, 1986

30860-1515
WEHRAN ENGINEERING
100 Milk Street
Methuen, Massachusetts 01844

Attention: Mr. Richard Messer

Re: Wehran Project 04360, Navy

PURPOSE

Eight (8) liquid samples were submitted to York Laboratories Division of YWC, Inc. by Wehran Engineering. The client requested the type of oil present in each sample be identified using fluorescence spectroscopy. Additionally sample MH-3 was analyzed for polychlorinated biphenyls via GC/ECD. The instrumentation used was a Perkin-Elmer Model Sigma 3 gas chromatograph equipped with an electron capture detector (Ni^{63}).

RESULTS

The results are presented in the following Tables.

Prepared by: [signature]
Jeffrey C. Curran
Laboratory Manager

JCC/md

The liability of YWC, Inc. is limited to the actual dollar value of this project.

TABLE 1.0
30860-1515
WEHRAN ENGINEERING
OIL CHARACTERIZATION RESULTS

Sample Identification	Result
T-1	Analysis of floating material indicated spectra typical of a heavy fuel oil such as #6 oil.
T-2	Analysis of floating material indicated spectra typical of a heavy fuel oil such as #6 oil.
MH-1	Analysis of floating material indicated spectra typical of a heavy fuel oil such as #6 oil.
MW-2	Analysis of floating material indicated spectra typical of a heavy fuel oil such as #6 oil.
MW-3	Analysis of oil sample indicated spectra typical of a heavy fuel oil such as #6 oil.
MH-4	Analysis of oil sample indicated spectra typical of a heavy fuel oil such as #6 oil.
MH-5	Analysis of oil sample indicated spectra typical of a mixed heavy fuel oil such as a mixture of #5 and #6 oil.
FO-2	Analysis of oil resulted in spectra typical of a heavy fuel oil such as #6 oil.

TABLE 2.0
30860-1515
WEHRAN ENGINEERING
PCB RESULTS

Sample Identification: MH-3

PCB Type	Result, mg/Kg
PCB 1016	<0.50
PCB 1221	<0.50
PCB 1232	<0.50
PCB 1242	<0.50
PCB 1248	<0.50
PCB 1254	<0.50
PCB 1260	<0.50

FILE II 04360 5F

YORK LABORATORIES DIVISION

YWC

CERTIFIED REPORT TRANSMITTAL

REPORT NUMBER 30860-1591

DATE October 24, 1986

CLIENT
Wehran Engineering
100 Milk Street
Methuen, MA 01844

ATTENTION Mr. Richard Messer

The above referenced report is enclosed. Copies of this report and supporting data will be retained in our files in the event they are required for future reference.

If there are any questions concerning this report, please do not hesitate to contact us.

Any samples submitted to our Laboratory will be retained for a maximum of sixty (60) days from receipt of this report, unless other arrangements are desired.

Naturally, as in the past, our staff will be pleased to quote on any future requirements you may have. In addition to the service provided, we also offer the following:

- Hazardous Waste Analyses
- Product Evaluation/R&D
- Water and Wastewater Analyses
- Air and Process Gas Analyses
- Industrial Hygiene Surveys
- Metallurgical Analyses
- Microbiological Analyses
- Mass Spectrometry Services

Very Truly Yours,

Robert Q. Bradley

Robert Q. Bradley
Vice President

October 24, 1986

30860-1591
WEHRAN ENGINEERING
100 Milk Street
Methuen, Massachusetts 01844

Attention: Mr. Richard Messer

PURPOSE

One sample dated 08/04/86 was submitted to York Laboratories Division of YWC, Inc. for analysis. The client requested that the sample be analyzed for "oil fingerprinting" by fluorescence spectroscopy.

RESULTS

The results are reported below:

Sample Identification	Fluorescence Spectra Data
FO-1, 08/04/86	Spectra typical of #2 fuel oil.

Prepared by: ____________________
Jeffrey C. Curran
Laboratory Manager

JCC/md

The liability of YWC, Inc. is limited to the actual dollar value of this project.

SUBSURFACE OIL INVESTIGATION

RECEIVED
By________
MAR - 6 1987
WEHRAN ENGINEERING
METHUEN, MA

YORK LABORATORIES DIVISION

YWC

CERTIFIED REPORT TRANSMITTAL

REPORT NUMBER 30860-1515 Addendum

DATE February 27, 1987

CLIENT Wehran Engineering
100 Milk Street
Methuen, MA 01844

ATTENTION Ms. Jennifer Griffith

The above referenced report is enclosed. Copies of this report and supporting data will be retained in our files in the event they are required for future reference.

If there are any questions concerning this report, please do not hesitate to contact us.

Any samples submitted to our Laboratory will be retained for a maximum of sixty (60) days from receipt of this report, unless other arrangements are desired.

Naturally, as in the past, our staff will be pleased to quote on any future requirements you may have. In addition to the service provided, we also offer the following:

- Hazardous Waste Analyses
- Product Evaluation/R&D
- Water and Wastewater Analyses
- Air and Process Gas Analyses
- Industrial Hygiene Surveys
- Metallurgical Analyses
- Microbiological Analyses
- Mass Spectrometry Services

Very Truly Yours,

Robert Q. Bradley
Vice President

February 27, 1987

30860-1515 Addendum
WEHRAN ENGINEERING, INC.
100 Milk Street
Methuen, Massachusetts 01844

Attention: Ms. Jennifer Griffith

PURPOSE

Eight (8) previously submitted samples were examined for hydrocarbon weathering characteristics using fluorescence spectroscopy. The results are discussed below:

RESULTS

Samples T-1, T-2, FO-2 showed spectral similarities suggesting the oil present may have been from the same source.

Samples MH-1, MH-3 and MH-4 showed spectral similarities suggesting the oil present may have been from the same source.

Samples MH-2 and MH-5 showed spectral differences from the others suggesting the oil present in each was from a different source.

Prepared by: Jeffrey C. Curran
Jeffrey C. Curran
Laboratory Manager

JCC/md

The liability of YWC, Inc. is limited to the actual dollar value of this project.

SUBSURFACE OIL INVESTIGATION

YORK LABORATORIES DIVISION

RECEIVED
By [signature]
JAN 2? 1987
WEHRAN ENGINEERING
METHUEN, MA

Fed-Xpress

CERTIFIED REPORT TRANSMITTAL

REPORT NUMBER 30860-1515-Addendum

DATE January 21, 1987

CLIENT Wehran Engineering
100 Milk Street
Methuen, MA 01844

ATTENTION Mr. Richard Messer

The above referenced report is enclosed. Copies of this report and supporting data will be retained in our files in the event they are required for future reference.

If there are any questions concerning this report, please do not hesitate to contact us.

Any samples submitted to our Laboratory will be retained for a maximum of sixty (60) days from receipt of this report, unless other arrangements are desired.

Naturally, as in the past, our staff will be pleased to quote on any future requirements you may have. In addition to the service provided, we also offer the following:

- Hazardous Waste Analyses
- Product Evaluation/R&D
- Water and Wastewater Analyses
- Air and Process Gas Analyses
- Industrial Hygiene Surveys
- Metallurgical Analyses
- Microbiological Analyses
- Mass Spectrometry Services

Very Truly Yours,

[signature]

Robert Q. Bradley
Vice President

January 21, 1986

30860-1515-Addendum
WEHRAN ENGINEERING, INC.
100 Milk Street
Methuen, Massachusetts 01844

Attention: Mr. Richard Messer

PURPOSE

Eight (8) previously submitted samples were examined for hydrocarbon weathering characteristics using fluorescence spectroscopy. The results are discussed in the following paragraphs.

RESULTS AND DISCUSSION

Initially the samples were determined to contain a heavy fuel oil such as #6 oil. Sample MH-5 was determined to be a mixture of #5 and #6 oil. Spectral variations in several of the samples indicated the source of the oil present was different than the sample (FO-2) used as a standard.

SAMPLES T-1 AND T-2

These two (2) samples were the least weathered of the samples submitted. Estimated time of weathering is less than one year.

SAMPLES MH-1, MH-2, MH-3 AND MH-4

These samples were the most weathered of the set. Data indicated characteristics of oil weathered for one year or more.

SAMPLE MH-5

As the spectra of this sample was considerably different from the other samples and standard no weathering characteristics could be determined from the data.

It is noted that the weathering of these samples appears to be very slow. It is not possible to determine any more accurate weathering information without further data.

Prepared by: Jeffrey C. Curran
Jeffrey C. Curran
Laboratory Manager

JCC/md

The liability of YWC, Inc. is limited to the actual dollar value of this project.

File I ... F
... case

YORK LABORATORIES DIVISION

YWC

RECEIVED
BY
DEC 1 1986
... ...RING
METHUEN, MA

CERTIFIED REPORT TRANSMITTAL

REPORT NUMBER 30860-1391

DATE October 24, 1986

CLIENT Wehran Engineering/Navy
100 Milk Street
Methuen, MA 01844

ATTENTION Mr. Richard Messer

The above referenced report is enclosed. Copies of this report and supporting data will be retained in our files in the event they are required for future reference.

If there are any questions concerning this report, please do not hesitate to contact us.

Any samples submitted to our Laboratory will be retained for a maximum of sixty (60) days from receipt of this report, unless other arrangements are desired.

Naturally, as in the past, our staff will be pleased to quote on any future requirements you may have. In addition to the service provided, we also offer the following:

- Hazardous Waste Analyses
- Product Evaluation/R&D
- Water and Wastewater Analyses
- Air and Process Gas Analyses
- Industrial Hygiene Surveys
- Metallurgical Analyses
- Microbiological Analyses
- Mass Spectrometry Services

Very Truly Yours,

Robert Q. Bradley

Robert Q. Bradley
Vice President

... Connecticut 06468 • (203) 2..-..58

October 24, 1986

30860-1391
WEHRAN ENGINEERING/NAVY
100 Milk Street
Methuen, Massachusetts 01844

Attention: Mr. Richard Messer

Wehran Job #04360

PURPOSE

Ten (10) soil samples were submitted to York Laboratories Division of YWC, Inc. by Ms. Barbara Riley of Wehran Engineering, Inc. The client requested that the samples be analyzed for petroleum hydrocarbon (oil) fingerprinting by fluorescence spectroscopy.

RESULTS

The spectroscopy results are presented in the Table 1.0. In addition, the samples were also analyzed for typical "weathering" characteristics, in which none of the samples submitted exhibited any apparent "weathering".

Prepared by: ______________________
Jeffrey C. Curran
Laboratory Manager

JCC/md

The liability of YWC, Inc. is limited to the actual dollar value of this project.

TABLE 1.0
30860-1391
WEHRAN ENGINEERING/NAVY

Sample Identification	Fluorescence Spectra Results
NSB-WE1-5-7	Trace concentration levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
NSB-WE1-13-15	Trace concentration levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
NSB-WE2-2-4	Trace levels of a heavy fuel oil (No. 6 fuel oil) detected.
NSB-WE2-12-14	Trace levels of a heavy fuel oil (No. 6 fuel oil) detected.
NSB-WE3-7-9	Low levels of a heavy fuel oil (No. 6 fuel oil) detected.
NSB-WE3-9-11	Low levels of a heavy fuel oil (No. 6 fuel oil) detected.
NSB-WE4-7-9	Low levels of a heavy fuel oil (No. 6 fuel oil) detected.
NSB-WE4-11-13	Trace concentration levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
NSB-WE5-7-9	Trace concentration levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.
NSB-WE5-11-13	Trace concentration levels of petroleum hydrocarbons resulted in poor resolution spectra. No usable data obtained.

YORK LABORATORIES DIVISION

RECEIVED
By

DEC 1 1986

CERTIFIED REPORT TRANSMITTAL

REPORT NUMBER 30860-1772

DATE October 24, 1986

CLIENT
Wehran Engineering/Navy
100 Milk Street
Methuen, MA 01844

ATTENTION Ms. Barbara Riley

The above referenced report is enclosed. Copies of this report and supporting data will be retained in our files in the event they are required for future reference.

If there are any questions concerning this report, please do not hesitate to contact us.

Any samples submitted to our Laboratory will be retained for a maximum of sixty (60) days from receipt of this report, unless other arrangements are desired.

Naturally, as in the past, our staff will be pleased to quote on any future requirements you may have. In addition to the service provided, we also offer the following:

- Hazardous Waste Analyses
- Product Evaluation R&D
- Water and Wastewater Analyses
- Air and Process Gas Analyses
- Industrial Hygiene Surveys
- Metallurgical Analyses
- Microbiological Analyses
- Mass Spectrometry Services

Very Truly Yours,

Robert Q. Bradley
Vice President

October 24, 1986

30860-1772
WEHRAN ENGINEERING/NAVY
100 Milk Street
Methuen, Massachusetts 01844

Attention: Ms. Barbara Riley

PURPOSE

Nine (9) samples dated 09/10/86 were submitted to York Laboratories Division of YWC, Inc. for analysis. The client requested that the samples be analyzed for "oil fingerprinting" by fluorescence spectroscopy.

RESULTS

The results are presented in Table 1.0.

Prepared by: ______________________
Jeffrey C. Curran
Laboratory Manager

JCC/md

The liability of YWC, Inc. is limited to the actual dollar value of this project.

TABLE 1.0
30860-1772
WEHRAN ENGINEERING, INC.

Sample Identification	Fluorescence Spectra Data
NSB-WS-WE4-001	Spectra typical of a heavy waste/fuel oil.
NSB-WS-WE1-002	Spectra typical of a heavy waste/fuel oil.
NSB-WS-WE2-003	Spectra typical of a waste oil.
NSB-WS-WE5-004	Spectra typical of a heavy waste/fuel oil.
NSB-WS-FB-005	No petroleum hydrocarbons detected.
NSB-WE3-006	Spectra typical of #6 fuel oil.
NSB-WS-WE3-007	Results unavailable-sample lost during processing.
NSB-WS-MW10-008	Spectra typical of #6 fuel oil.
NSB-WS-MW4-009	Spectra typical of #6 fuel oil.

APPENDIX F

Fluorescence Spectroscopy Analysis Method

OIL SPILL IDENTIFICATION BY FLUORESCENCE SPECTROSCOPY

1. Scope

1.1 The recommended fluorescence method provides a means of fingerprinting oil by spectral characteristics and thereby matching a waterborne crude or refined petroleum oil sample to a suspect source oil sample.

1.2 This method can be applied to any neat oil, waterborne oil, or sample of oil-soaked material whether the sample is weathered (environmentally or artificially) or unweathered.

2. Summary of Method

The neat, weathered or unweathered, petroleum crude or refined oil sample is prepared for fluorescence analysis by diluting a known weight of oil in a low-actinic glass volumetric flask to volume using spectroquality cyclohexane as the solvent. It is recommended that the initial oil concentration by 100 ppm by weight. This is an acceptable working concentration at 254 nm (nanometers) excitation for all light distillate fuel oils, light crudes, and lubricating oils. For heavy crude oils, cut or residual number four, five and six fuel oils, the concentration should be adjusted to 20 ppm by weight through a serial dilution.

The prepared sample is then transferred to a 1 cm square fluorescence-free quartz cell using a disposable Pasteur pipet. The fluorescence emission monochromator is then manually scanned over the emission spectrum of the oil at a fixed excitation wavelength of 254 nm to locate the major fluorescence emission response. The major fluorescence peak is then adjusted to 95$\pm$2% of full-scale by adjusting instrument amplifier gain settings. The solution is then replaced with a fresh solution of the same sample (see NOTE 1) and the fluorescence emission spectrum of the oil is recorded from 280 nm to 500 nm.

Identification of the waterborne oil sample is made by direct comparison of the sample's spectrum with the spectra from suspected source samples over the spectral range from 280 nm to 500 nm.

NOTE 1: The solution is replaced with a fresh solution to prevent the possibility of errors in the recorded spectrum of the oil through photodecomposition of the sample by prolonged exposure of the sample to high intensity ultraviolet light.

YORK LABORATORIES DIVISION
YWC

May 30, 1986

Sample container/size
Soil ~50 grams /150 cc glass
water ~500 ml glass w/ sulfuric acid preservative

Ms. Jennifer Griffith
Wehran Engineering
100 Milk Street
Methuen, MA 01844

Dear Ms. Griffith:

The article I have enclosed will give you a brief overview of the "fluorescence" method for hydrocarbon analysis. This is meant to be a generic response rather than specific to the methods actually used. The actual procedure used does not employ the 3-D effect outlined in the article. It is usual for environmental samples to be more complex than those cited in the article. With that limitation it is better to use more traditional fluorescence techniques.

As I had mentioned to you, the methodology has been around for a while. It is within the last few years that a sufficient vocabulary of typical signatures or fingerprints of hydrocarbons has been developed. Using the available instrumentation and coupled with the broad range of experience of the analyst, we feel that the interpretation of the data will be excellent. Furthermore it is that technique referred to which is now being reviewed by the USEPA, the D.O.D., the D.O.T. and various state agencies.

We are confident that the subcontractual arrangement which we employ is one which will assure you, the client, that the work has been performed correctly and that the data is the best that can be available. In addition the analysis is far more effective on a dollar-for-dollar comparison with more traditional GLC procedures.

If you have any further questions, feel free to contact Kathy Scrimenti or me here in our Monroe offices (203/261-4458).

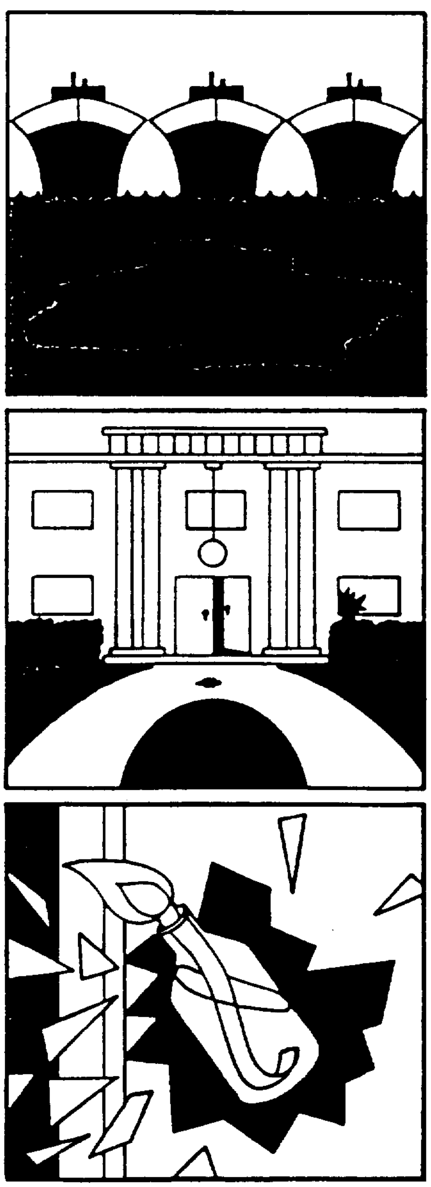
Very truly yours,

Robert Ueberbacher

Robert Ueberbacher
Field Representative

RU/md
Enclosure
cc: K. Scrimenti

SOLVING CRIMES WITH 3-D FLUORESCENCE SPECTROSCOPY



The Santa Barbara channel off the coast of California is choked with oil tankers waiting to unload their cargoes of crude oil for refining. Suddenly the water becomes fouled with crude leaking from one of the vessels. But which one?

An old car pulls into the driveway of an expensive home. The driver of the car commits a burglary in the home and leaves the scene, but his car leaves a deposit of motor oil that has leaked from the crankcase. Can the oil spill be matched to the oil of the car?

An arsonist is hired by the owner of a failing business to torch the building. He shows up at the building in the middle of the night and tosses a Molotov cocktail, a bottle containing gasoline and a cloth wick that is ignited, through the window. After the fire is put out, an investigator finds the broken bottle still containing a small amount of gasoline. Did the gasoline come from a five-gallon can of gasoline found in the suspect's car?

These incidents have certain aspects in common. They occur frequently in the United States today, and they involve a petroleum-based hydrocarbon product as a critical piece of evidence. These cases require comparisons of a hydrocarbon whose source is known (such as the crude oil in the tankers, the engine oil in the crankcase, and the gasoline in the five-gallon can) with one whose source is not known and which is found at the scene of the incident (the oil slick on the water, the motor oil spill on the driveway, and the remains of the Molotov cocktail). The goal of the chemical analysis in each case is to determine to a standard of reasonable scientific certainty whether the known samples and the scene samples could have had a common source. The similarities among various types and brands of hydrocarbon products create formidable analytical problems that may call for unconventional methodologies.

Present methods of analysis

The conventional methods used to analyze petroleum products in forensic cases are usually some variation of gas–liquid chromatography (GLC). The more volatile products such as gasoline are usually analyzed by headspace techniques, perhaps after concentration by a purge-and-trap method. The less volatile oils and lubricants are solvent extracted and/or directly injected. Although GLC can easily determine what type of petroleum product is present, i.e., gasoline vs. motor oil vs. petroleum jelly, it is not discriminating enough to determine reliably what brand or type of a particular hydrocarbon product is present. Thus, GLC cannot, by itself, be used to determine if two samples could have had a common source. Although capillary column GLC has improved resolution significantly and uses smaller samples, it still cannot overcome the fundamental weakness of this method.

Fluorescence spectroscopy in hydrocarbon analysis

In recent times, the possibility of using fluorescence spectroscopy in the analysis of petroleum products has received increased attention. Virtually

The Analytical Approach

Jay A. Siegel
Michigan State University
School of Criminal Justice
East Lansing, Mich. 48824-1118

all of the fuels and lubricants derived from petroleum exhibit significant fluorescence because of the presence of various types of polynuclear aromatic hydrocarbons (PAHs). The simple excitation fluorescence spectrum of a gasoline or motor oil sample contains three distinct regions of fluorescence (Figure 1). The relative amounts of the various PAHs in these products are instrumental in determining their particular physical and chemical properties and would be expected to vary within the same type of products made by different manufacturers and perhaps within different lots from the same manufacturer.

Thus, the potential exists to use the fluorescence of a particular sample as a unique marker for that product. This, in theory, would make it possible to determine whether or not two different samples could have had a common source. To be able to use fluorescence as a tool in this type of comparative analysis, however, it is necessary to obtain something more than the conventional excitation–emission–synchronous fluorescence spectra generated from a fluorescence experiment. These "simple" spectra reveal the fluorescence of a sample within only one area and do not provide nearly enough data to distinguish between two closely related samples. This type of fluorescence allows us to study only one of the three major areas of fluorescence of the petroleum products of interest at a time. For this reason, we decided to evaluate 3-D fluorescence to determine if it could provide enough spectral information to distinguish between two closely related samples to the standard of reasonable scientific certainty.

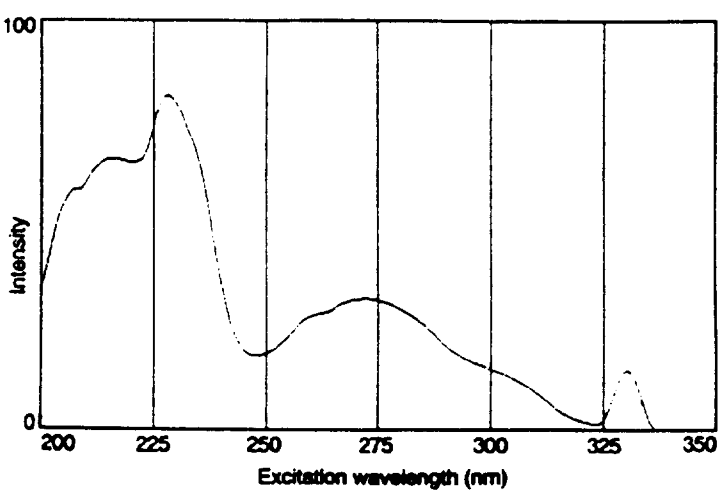


Figure 1. Excitation fluorescence spectrum of Quaker State Super Blend Motor Oil

3-D fluorescence

Three-dimensional fluorescence spectroscopy involves the collection of data encompassing the *total* fluorescence of a sample. This involves obtaining not one, but a whole series of either excitation or emission spectra in which the nonscanning monochromator is stepped up by a fixed interval through a whole range of wavelengths while the scanning monochromator scans a fixed wavelength range. Or, in the case of synchronous fluorescence, a series of spectra is obtained in which the difference in wavelength between the two monochromators is increased systematically. The instrument used in this study permits the collection of up to 30 such spectra in a series. The spectra are stored on a floppy disk and then plotted on a Cartesian system with the wavelengths of the scanning monochromator, the nonscanning monochromator (or the wavelength difference in synchronous fluorescence), and the fluorescence intensity as the x-, y-, and z-axes, respectively. The plotting program can also plot the spectra starting with either the highest or lowest wavelength of the nonscanning monochromator (y-axis). This can generate two plots that view the fluorescence profile from either the "front" (Figure 2a) or "back" (Figure 2b). If 3-D plots are taken of the excitation, emission, and synchronous fluorescence, one can obtain a total of

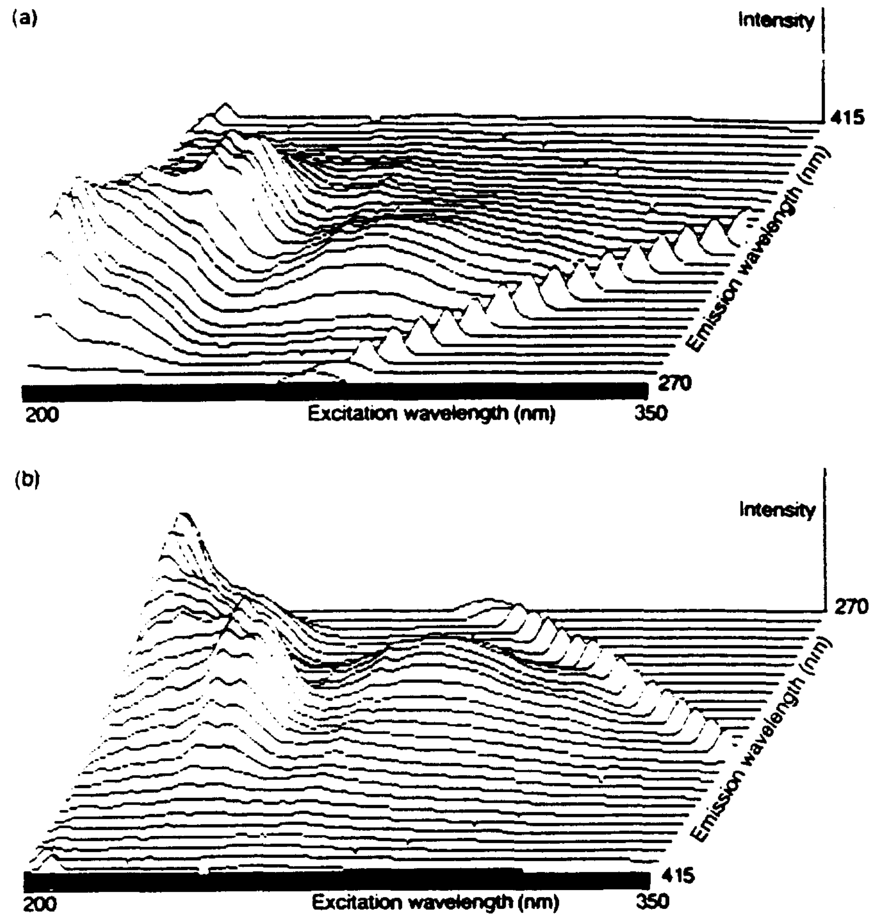


Figure 2. (a) Front and (b) back view of the 3-D excitation fluorescence spectrum of Quaker State Super Blend Motor Oil

six distinct views of the fluorescence profile.

Gasoline samples

In certain incendiary fires, some of the gasoline used to accelerate the fire may be recovered unburned as in the case of the Molotov cocktail that is recovered partially intact. This constitutes the crime scene evidence. If a suspect is apprehended and has in his possession a container that contains some gasoline that is suspected to be the source of the gasoline from the crime scene, then the technique of 3-D fluorescence can be used to determine if the two gasoline samples could have had a common source.

In such cases the two gasoline samples to be compared are dissolved in spectro-grade hexane and diluted to a final concentration of 25 ppm. All of the spectra are obtained on a Perkin-Elmer Model Lambda 5 spectrofluorimeter with a Model 3600 data station controlling the generation and storage of the spectra. Perkin-Elmer's PLOT program is used to generate the 3-D plots. Prescans are first performed on each sample, and then simple excitation and emission spectra are obtained to identify the important areas of fluorescence and to make a preliminary determination of the likelihood that the two samples could have had a common source. If the simple spectra are markedly different at this point, we can immediately conclude that the samples had different sources. If the spectra are similar then 3-D analysis is performed.

Examination of 3-D spectral plots of many gasoline samples in our laboratory has shown that the 3-D emission plot is more effective at differentiating between two samples of gasoline than are the excitation or synchronous excitation plots. Therefore, 3-D emission plots are obtained for each sample. The architecture of the disk operating system and the capacity of the disks permit storage of three 3-D spectra stacked plots on one disk. The 3-D emission plots of the two samples of gasoline are put on the same disk, which leaves room on that disk for the resultant plot obtained by computer comparison of the two plots.

Hard copies of the front and back views of the emission plots are obtained and visually compared to determine if they are obviously different, although experience dictates that if the simple emission spectra are very similar, the stacked plots will be also. Because these stacked plots are quite

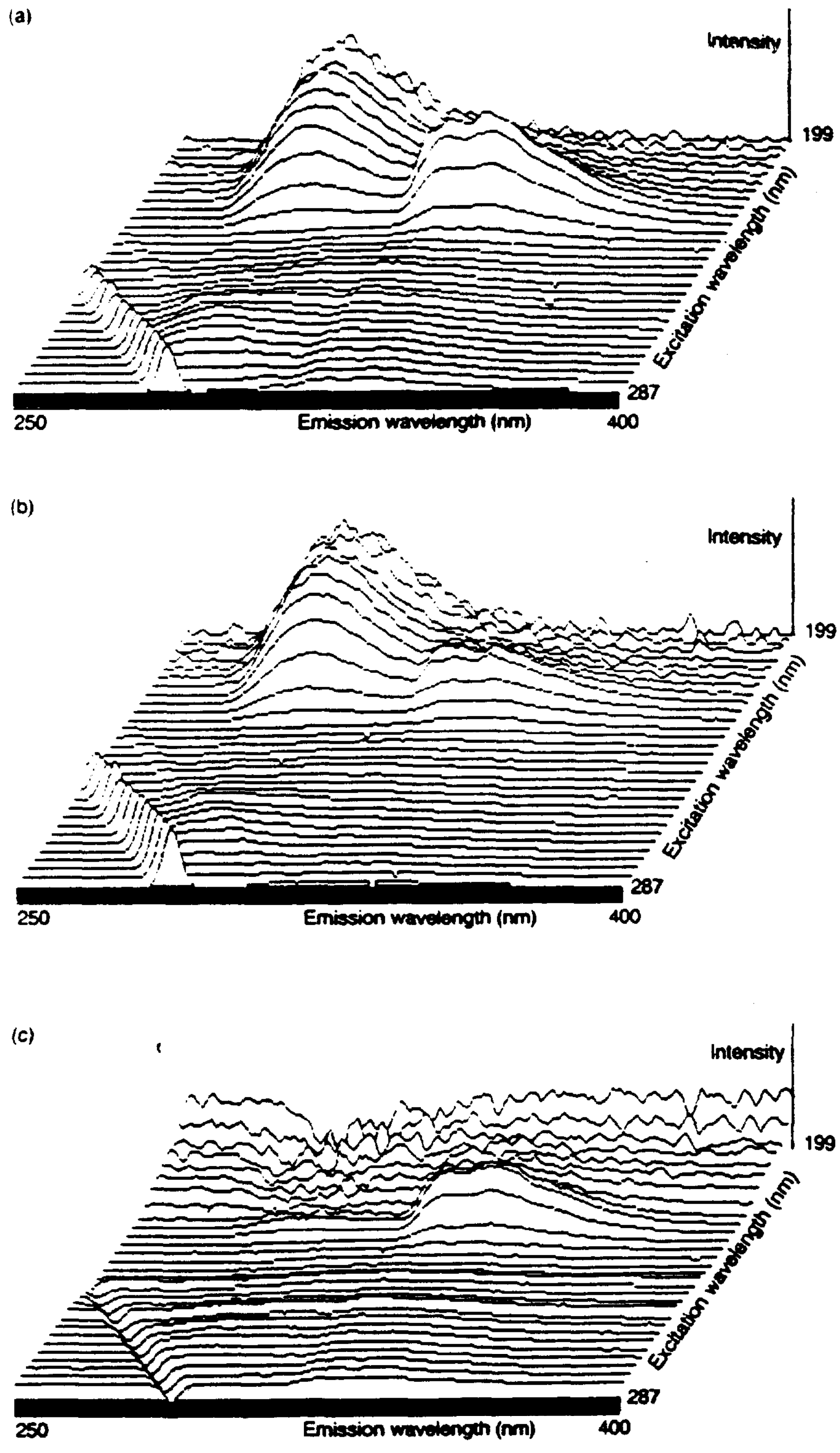


Figure 3. Three-dimensional stacked plots of (a) unknown and (b) known gasoline samples of different origin and (c) the result of subtracting the two stacked plots

complex, however, visual comparison may not be sufficient to make a definitive determination. Thus we wrote a program that would permit computerized comparison of two plots by subtracting one from the other, spectrum by spectrum, and then prepare a stacked plot of the resultant spectra. If the 3-D emission plots of the crime scene gasoline sample and the sample of known origin do have a common source then the resultant spectra obtained by subtracting one plot from the other should have essentially zero intensity at any point in the plot. If, on the other hand, the two samples being compared have different sources, then the subtracted plot should have some regions of net fluorescence. This program also accounts for "negative fluorescence" obtained from subtraction by adding a factor equal to the highest negative intensity to the whole plot.

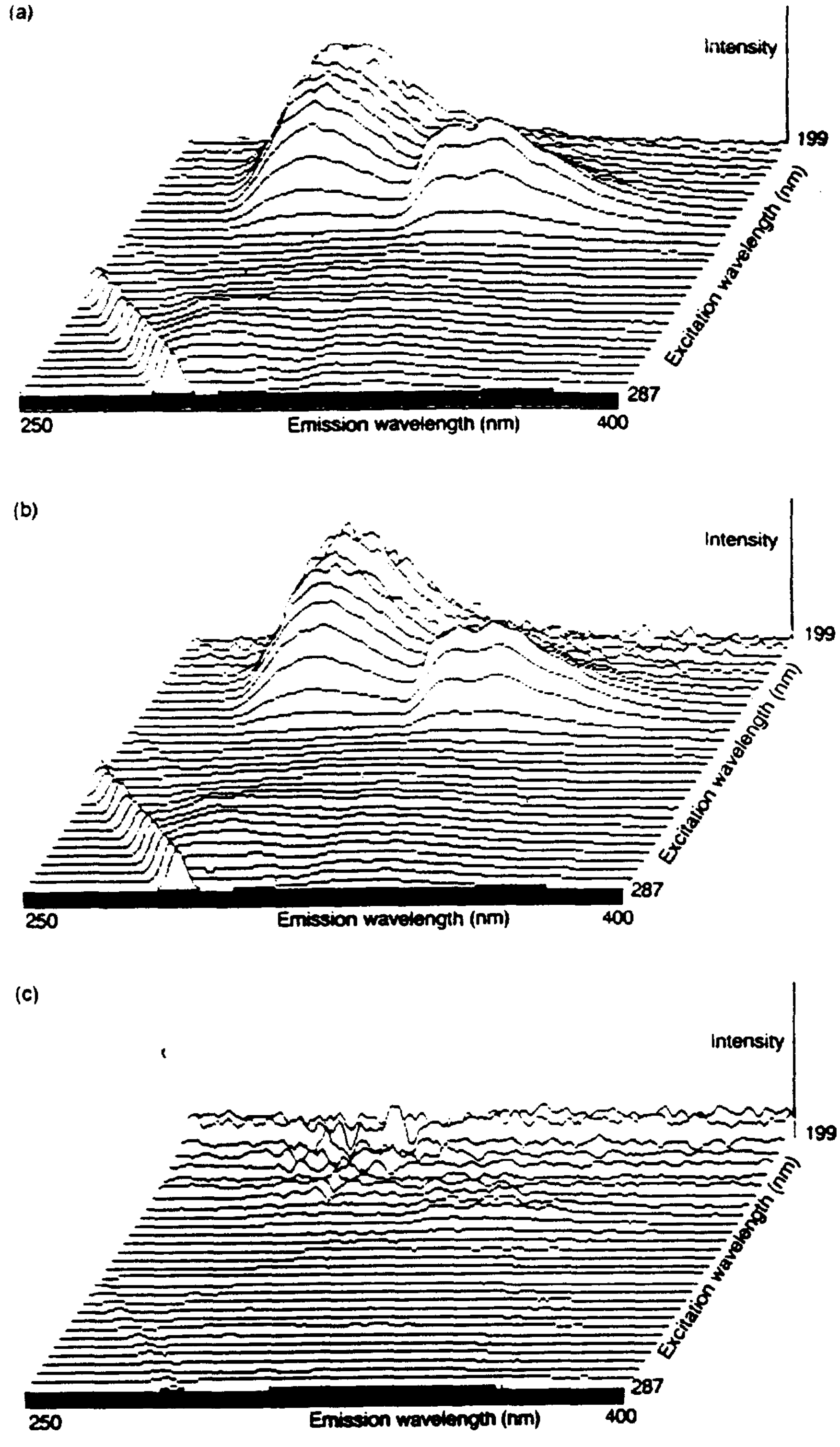


Figure 4. Three-dimensional stacked plots of (a) unknown and (b) known gasoline samples of common origin and (c) the result of subtracting the two stacked plots

Figures 3a and 3b are the 3-D emission spectral plots of an unknown sample of gasoline and a sample of known origin, respectively. The resultant stacked plot in Figure 3c indicates that the samples had different sources, which is in fact the case. Likewise, Figures 4a and 4b are emission stacked plots of different known and unknown gasoline samples. The flat-plane appearance of Figure 4c, the result of subtracting the two stacked plots, suggests that the two samples have a common source, which was the case in this instance.

The results of these examples of 3-D fluorescence as well as other experimental work suggest that this technique has great potential as a test that allows the analyst to determine, with reasonable certainty, if two petroleum product samples in a criminal or civil case could or could not have had a common source.

YORK LABORATORIES DIVISION

November 13, 1987

Mr. Rich Messer
Wehran Engineering
100 Milk Street
Methuen, MA 01844

Dear Rich:

Attached is a copy of the information you requested from us on your samples which were analyzed for oil fingerprinting by fluorescence spectroscopy.

Your sample NSB-WS-WE3-007 could not be analyzed as the sample bottle was broken in transport from York Laboratories to our subcontractor.

I hope this information will serve your needs. If I can be of any further assistance please do not hesitate to call me at (203) 261-4458.

Very truly yours,

Johanna L. Dubauskas

Johanna L. Dubauskas
Client Services Representative

JLD/md

Attachment

[illegible] Monroe, Connecticut [illegible] • (203) 261-4458

niantic
envirolab incorporated
249 boston post road
east lyme, ct 06333

(203) 739-4080

RWC
200 Monroe Turnpike
Monroe, CT 06468 November 5, 1987.

Johanna Dubauskas:

Please find below a short description of our fluorescence spectroscopic technique which you recently requested.

****

Various fluorescence spectroscopic techniques have been successfully used to detect, identify, and quantify specific pollutants in municipal watersheds and industrial effluent discharges. These techniques evolved into a very effective method for the identification and "fingerprinting" of petroleum oils in the marine environment. A logical extension of these earlier studies is in the application of fluorescence spectroscopic techniques as a rapid and reliable screening method in the analysis of groundwater and soil samples for the presence of petroleum oils.

During the past five years, Niantic EnviroLab, Inc. has developed a fluorescence technique and "library" representing over 750 spectra of petroleum oils each having a distinct "fingerprint". With these data we can successfully identify many petroleum oils. Also, with the simple sample preparation, the nondestructive nature of fluorescence, and the inherent sensitivity of fluorescence spectroscopy, we can identify petroleum products with more confidence than with conventional gas chromatographic techniques.

Please find attached 3 (three) spectra representing a) #2 Fuel Oil; b) #6 Fuel Oil; c) your sample #1772009. Notice the visual ease of comparison and the extreme difference between the #2 and #6 fuel oil spectra.

****

If we can offer any additional assistance, please contact us.

Sincerely,
William S. Georgian
William S. Georgian,
Director

antic
envirolab, incorporated
249 boston post road
east lyme, ct 06333

(203) 739-4080

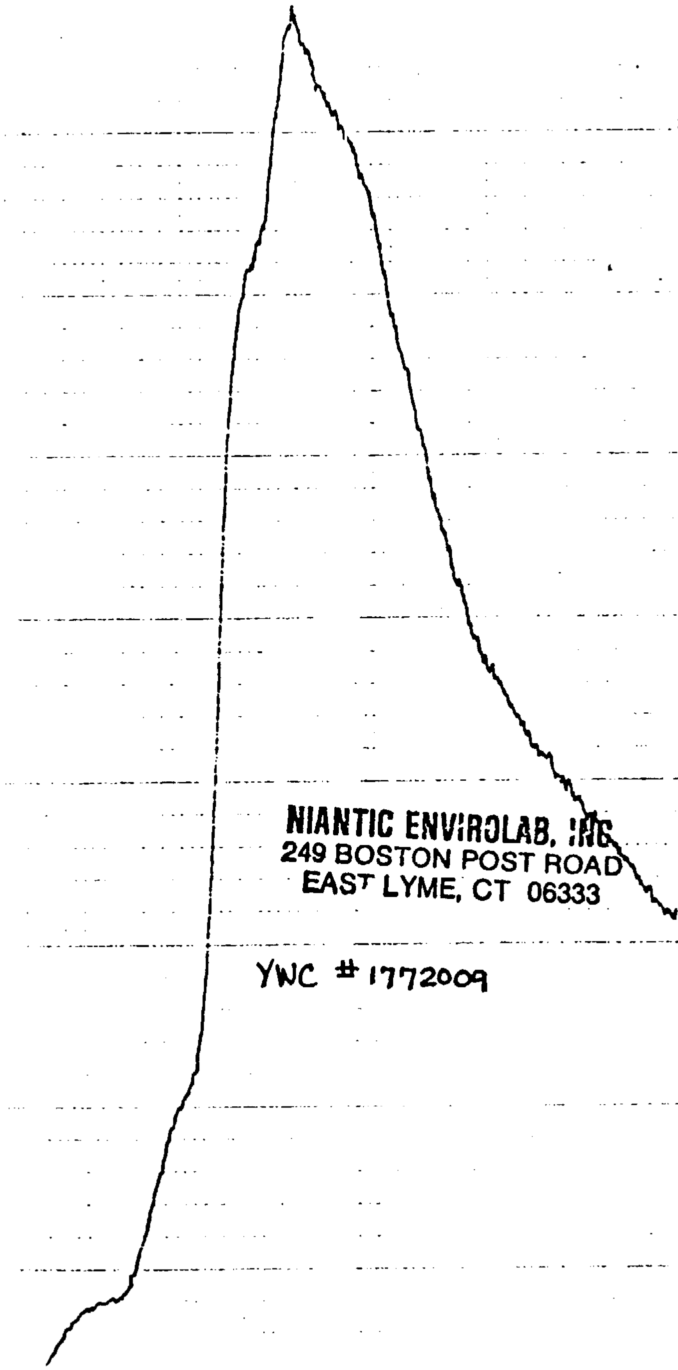
YWC
200 Monroe Turnpike
Monroe, CT 06468

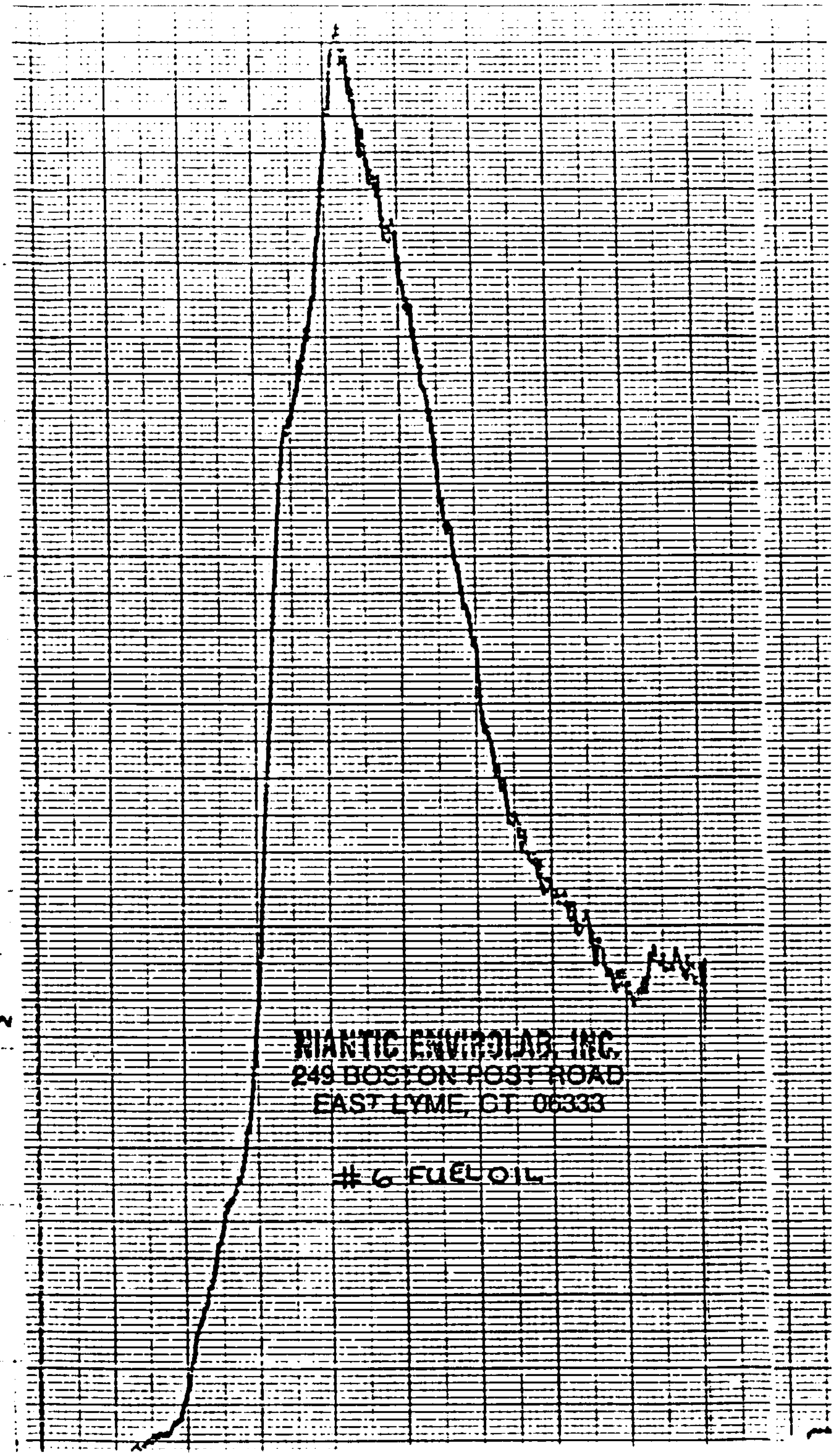
Log number: C 1377

Eight samples submitted for "oil fingerprinting" by fluorescence spectroscopy.

Sample identification	Fluorescence spectra data
1772001	Spectra typical of a heavy waste/fuel oil.
1772002	Spectra typical of a heavy waste/fuel oil.
1772003	Spectra typical of waste oil.
1772004	Spectra typical of a heavy waste/fuel oil.
1772005	No petroleum hydrocarbons detected.
1772006	Spectra typical of #6 fuel oil
1772007	Sample received broken.
1772008	Sample typical of #6 fuel oil.
1772009	Sample typical of #6 fuel oil.

Authorization: *William S. Georgian*
William S. Georgian,
Director


NIANTIC ENVIROLAB, INC
249 BOSTON POST ROAD
EAST LYME, CT 06333
YWC # 1772009


NIANTIC ENVIROLAB, INC.
249 BOSTON POST ROAD
EAST LYME, CT 06333
#6 FUEL OIL