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Pilot Test to Evaluate Enhancement of Product Recovery Report
Tow Way Fuel Farm
SWMU 7/8

Naval Station Roosevelt Roads

RCRA/HSWA Permit No. PR2170027203

Ceiba, Puerto Rico

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LIST OF ACRONYMS AND ABBREVIATIONS

Baker	Baker Environmental, Inc.
bgs	below ground surface
ERW	extended radius well
FW	fracture well
ID	inside diameter
IPSI	Inland Pollution Services, Inc.
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
NSRR	Naval Station Roosevelt Roads
pvc	polyvinyl chloride
TWFF	Tow Way Fuel Farm

1.0 INTRODUCTION

This document presents the Pilot Test to Evaluate Enhancement of Product Recovery Report for the Tow Way Fuel Farm (TWFF) located at Naval Station Roosevelt Roads (NSRR), Ceiba, Puerto Rico. This report has been prepared by Baker Environmental, Inc. (Baker) under contract to the Atlantic Division, Naval Facilities Engineering Command (LANTDIV), Contract Number N62470-95-D-6007.

Two Work Plans developed by McLaren/Hart, Inc. (McLaren/Hart) of Warren, New Jersey, Phase I Work Plan (January 13, 2000) and Phase II Work Plan (January 20, 2000) Pilot Test to Evaluate Enhancement of Product Recovery, were followed in the implementation of the pilot test.

The purpose of this report is to provide the results from the implementation of Phase I and Phase II of the Pilot Test to Evaluate Enhancement of Product Recovery. Section 1.0 of this report provides this introduction and a brief discussion on the background, geology, and hydrogeology at the TWFF. A description of the pilot study activities is provided in Section 2.0. Phase I of the pilot test, pre-fracturing activities is discussed in Section 3.0, while Phase II, pneumatic fracturing results are provided in Section 4.0.

1.1 Site Location and Background

The site is an active U.S. Naval Station and is located near the town of Ceiba on the eastern end of Puerto Rico. A regional location map is presented on Figure 1-1. The approximate location of the Naval Station is 18°15’00” latitude and 65°39’30” longitude.

Seven fuel storage tanks constitute the TWFF. Since 1957, spills, leaks, and sludge disposal have resulted in releases of product. This discharge has impacted soil and groundwater at the site.

Free product recovery operations began in 1994 with the installation of a small-scale product recovery system. From 1994 to 1995, approximately 12,600 gallons of product and water were recovered. In April 1997, a larger system was installed, consisting of seven product recovery wells. In July 1998, the system was expanded to include two additional recovery wells. Historically, four of the nine recovery wells were operated at a time. The product recovery system is a skimming system (i.e., single phase). From April 1997 until January 1999, the total

volume of free product recovered by this system was 2,650 gallons. The total amount of product recovered in the 6 years of operations is estimated to be 15,780 gallons.

1.2 Site Geology

The site geology is taken from the Quarterly Summary Progress Report Number 12, dated January 31, 2000. The surficial lithology from 0 to 42 feet below ground surface (bgs) is predominantly clay with varying amounts of weathered volcanic rock fragments. The clays are primarily grayish-green, yellowish-brown, grayish-brown, and olive-brown as based on color matching with the Munsell soil color chart. Intermixed with the primary colors are shades of red, grayish-brown, olive-gray and bluish-gray. The clays are cohesive, stiff, and range from dry to moist. A review of boring logs from several of the recovery wells indicates that much of the near-surface geology consists of silt and clays, and that at one location (RW-4), the bedrock is fairly close to the surface.

1.3 Site Hydrogeology

The site hydrogeology information is taken from the Quarterly Summary Progress Report Number 12, dated February 29, 2000. The hydrogeology is controlled by elevation differences between the Upper and Lower TWFFs. The average hydraulic gradient is 0.012 ft/ft towards the southwest. The dense nature of the volcanic rock and slow recharge rates observed in monitoring wells indicate that the permeability of the rock is very low, causing it to behave as a confining or semi-confining unit.

2.0 DESCRIPTION OF PILOT STUDY ACTIVITIES

The pilot test was conducted at two areas of the TWFF site where product recovery wells are currently being operated. The locations for the pilot test areas are located on Figure 2-1. Fracturing depths ranged from 8 to 25 feet bgs. Both wells in these locations, RW-1 and PW-6, are used for skimming product from a weathered volcanic rock formation which is classified as inorganic clays of low to high plasticity, gravely and sandy clays.

The goals of the pilot test were to evaluate a program to enhance the removal of free product form these two locations. This involved the application of pneumatic fracturing (PF) technology to increase the permeability of the soil formation in the test areas. Product removal was monitored at the recovery wells, and product levels in surrounding wells were monitored.

The objectives of the pilot test were:

1) Establish baseline conditions for the test areas. This was done by conducting short-term product recovery tests.
2) Evaluation of the change in product recovery rates after fracturing in both test plots. This evaluation involved conversion of selected fracture boreholes to recovery wells and repeating the baseline short-term tests.
3) Evaluation of various product recovery well construction techniques.
   - Enhancement of existing recovery wells with PF
   - Enhancement of an existing monitoring well with PF
   - Installation of dry media (proppant) into two PF open boreholes and conversion to recovery wells.
   - Installation of recovery well in a PF open borehole after fracturing has occurred.
4) Obtain site-specific engineering design data necessary for a full-scale system design.

Prior to implementation of the pilot study, operation of the existing Free Product Recovery System was suspended in the pilot test areas. This allowed products levels in the recovery and monitoring wells to stabilize and present a more representative picture of the true subsurface, groundwater and free product conditions at the site.

3.0 PRE-FRACTURING ACTIVITIES

The work plan identified several activities that were accomplished prior to pneumatic fracturing. These activities included geotechnical data collection and analysis, pre-fracturing pump tests, vapor enhanced recovery test, product recovery trench installation, and well installation. These are all discussed in detail in the subsequent paragraphs.

3.1 Geotechnical Data Collection/Analysis

Two pilot test areas were evaluated, RW-1 and PW-6 areas (Figure 2-1). Field efforts began September 1999 with the collection of soil borings for geotechnical analysis in both test plots by McLaren/Hart. The geotechnical evaluation report, which provides a description and analysis of the geotechnical results authored by McLaren/Hart, is included as Appendix A.

3.2 Equipment Layout

McLaren/Hart installed two top-loading pneumatic pumps in RW-1 and PW-6 to collect total fluids from designated recovery wells. One-inch schedule 40 poly-vinyl chloride (PVC) recovery pipe was run from each recovery area to a designated oil/water separator (55-gallon drums). The recovered groundwater and product were kept in separate recovery systems to allow for proper gauging. Product was manually decanted from the drums and placed in the 1500-gallon product storage tank on site. From the oil/water separator, groundwater was gravity fed into a 600-gallon poly tank. The recovered groundwater was subsequently pumped through a meter to a 6000-gallon tanker for storage. Groundwater from both pilot test areas was held for disposal in the 6000-gallon tankers.

The vacuum enhanced recovery system consisted of a liquid ring pump capable of producing 25” Hg vacuum, which is vented to the atmosphere. The VER pump is connected to an air/water separator and subsequently to the recovery well. All connections are 4-inch schedule 40 PVC. A 30” Hg magnahelic gauge is located on the wellhead and inlet to the VER pump. The water that accumulated in the air/water separator was drained periodically from the separator tank and manually conveyed to the 600-gallon poly tanks for storage.

3.3 Pre-Fracture Pump Tests

In January 2000, McLaren/Hart began pre-fracture short and long-term pump tests in RW-1 and PW-6 test plot areas. Well development, background monitoring and short-term tests followed by recovery tests were conducted in the RW-1 and PW-6 areas. The short-term pump tests in RW-1 and PW-6 were 3.5 hours in duration with approximately 16 hours of recovery data collected after completion of the pump test. Long-term tests were also started on the basis of the results of short-term tests. A description and analysis of results authored by McLaren/Hart is included as Appendix B.

It should be noted that the long-term total fluids pump test in the PW-6 area was not completed due to insufficient groundwater storage capability. The work plan called for groundwater treatment and subsequent discharge to the wastewater treatment plant (WWTP) located on base. Analytical results of the treated groundwater showed that organics were below detection limits, however two inorganics, copper and zinc, were above allowable discharge limits. Analysis of the groundwater showed copper to be 0.010 mg/l with a discharge limit of 0.0029 mg/l, while the analysis of zinc showed 0.095 mg/l with a discharge limit of 0.050 mg/l. The WWTP did not have the ability to treat inorganic compounds, therefore the inorganics in the groundwater had to be removed before discharge. An ion exchange unit was brought to the site for this purpose. The groundwater was passed through the ion exchange unit several times but was unable to reduce zinc or copper to an acceptable level.

During this time, the long-term pump test for PW-6 continued to generate groundwater. Storage capacity at the site had increased to 18,000 gallons with the addition of another 6,000-gallon tanker and ten 600-gallon poly tanks. With only 100 gallons of storage capacity remaining on site, it was decided on April 14, 2000 to stop the long-term pump test in PW-6 until groundwater discharge options could be re-evaluated.

In April 2000, a study of alternative discharge options was evaluated. Due to time constraints and inefficiency of the ion exchange unit to remove copper and zinc, it was agreed that Waste Management would collect and treat the recovered groundwater at their approved facility in Puerto Rico. As a result of this decision, the post fracture pumping tests would be “product only” pump tests. The pumps in the recovery wells would be set no more than one foot below the oil/water interface to minimize production of groundwater. Also, subsequent fracturing would be

done at or above the water table to increase product recovery without increasing groundwater recovery.

In May 2000, Waste Management collected 15,600 gallons of recovered groundwater for disposal. Waste Management returned in July and August to collect 6,500 gallons and 3,500 gallons respectively of recovered groundwater for disposal. Total amount of groundwater collected and disposed was 25,600 gallons.

3.4 Vapor Enhanced Recovery (VER) Test

In February 2000, McLaren/Hart performed a VER test on PW-6 to determine the optimal setting for the liquid ring pump. PW-6 was configured with a pneumatic total fluids pump approximately two feet below the oil/water interface. The well was sealed and a vacuum was placed on the well. The test was allowed to run at three different vacuum settings (15" Hg, 20" Hg, and 25" Hg) for three hours per test. The recovered product and groundwater were separated and measured at the end of each test. Results of the test show that product recovery was 0.2, 2.3, and 2.5 gallons for 15" Hg, 20" Hg, and 25" Hg respectively. Even though 25" Hg had the greatest amount of product recovery, it was agreed that a vacuum setting of 20" Hg would be used for future pump tests. It was assumed that fracturing would increase permeability in the unsaturated zone, thus increasing airflow. This setting would allow for a greater airflow increase without significant loss of vacuum pressure.

3.5 Recovery Trench

The work plan called for a recovery trench to be located parallel and adjacent to Forrestal Drive near recovery well RW-8 (Figure 2-1). Excavation started in March 2000 after consulting with base personnel to locate and mark known underground utilities adjacent to Forrestal Drive northwest of RW-8. A backhoe with an 18-inch bucket was used to excavate a 3-foot deep, 50-foot long trench. A fiber optic cable was exposed within this trench. After sufficient cable was exposed, the cable was moved to the side of the excavated area so that the trench could be advanced safely to 12 feet in depth. Trenching continued to a depth of 4.5 feet. At this depth, the side of a 12-inch potable water line was exposed. The water line was located parallel to the trench between the trench and Forrestal Drive. The water line was on top of one to two inches of sand backfill, which was dry and free from hydrocarbon odor. The trenching continued through weathered rock for several hours. The backhoe reached refusal at 5 feet in depth. Two more

attempts were made northwest of RW-8 with negative results. A final attempt was made just north of RW-8. After one day of digging, the final depth of the trench was 12 feet. Moisture was encountered at 11 feet bgs and two inches of water was in the bottom of the trench prior to backfill. The final dimensions of the recovery trench were 6 feet wide, 12 feet long, and 12 feet deep.

A sump was installed at the eastern (down gradient) end of the trench to house product recovery equipment. The sump consisted of a six-inch diameter slotted (0.02-in. opening) PVC standpipe with capped end. A 2-inch diameter PVC piezometer was installed adjacent to the six-inch sump to monitor groundwater and product levels during operations. The sump was backfilled with course gravel to within two feet of grade. Clean fill was placed over the backfill and the sump was fitted with a 3-foot by 3-foot vault. The vault was grouted in place and excavated material was screened for hydrocarbons and removed from the site.

The recovery trench was monitored throughout the remainder of the pilot test for groundwater levels and product thickness. No measurable product was observed in the recovery trench, therefore a discriminating skimmer was not placed in the recovery trench.

3.6 Well Installation

In late February 2000, McLaren/Hart prepared for fracturing by drilling seven pneumatic fracture (PF) wells in the RW-1 pilot test area. All the PF wells were drilled using 3 ½-inch outside diameter (OD) augers to 30-35 feet in depth. Five PF wells were also completed similarly in PW-6 pilot test area. To keep the boreholes free of debris, 35 to 40 feet of 2 ½-inch PVC casing was placed in each open borehole. This left 5 feet or more of 2 ½-inch casing above the ground surface.

In early March 2000, McLaren/Hart mobilized with the fracturing equipment and prepared to fracture the RW-1 pilot test area first. However, the 2 ½-inch casing had become lodged into the boreholes and the trailer mounted drilling rig was unable to remove the casing intact. The apparent cause of the casing sticking in the boreholes was “running silts”. The PF wells had been drilled well into the aquifer, which is under slight pressure. The “running silts” pushed up from the bottom of the boreholes and around the 2 ½-inch casing trapping it in place.

The 2 ½-inch casing was eventually removed and several boreholes in RW-1 area were abandoned. Fracture Well (FW) 2, 6A, and 6B were salvaged and subsequently fractured. The location of these wells is depicted on Figure 2-2.

Inland Pollution Services, Inc. (IPSI) installed all of the FW wells in RW-1 and PW-6 pilot test areas in late February 2000 at the locations shown on Figures 2-2 and 2-3. IPSI also drilled two extended radius wells (ERW) in the PW-6 pilot test area.

In early March 2000, IPSI removed the 2 ½-inch casing from the open boreholes on all the FW wells in both pilot test areas. Four FW wells were abandoned in the RW-1 pilot test area (FW-1, 3, 4, and 5) by removing the 2 ½-inch casing and tremie-grouting the open borehole to the surface with a cement.

In late February 2000, FW-2 was constructed with a 6-foot long by 6-inch diameter steel casing. The casing was installed to a depth of 5 feet bgs to provide stability to the borehole. The remainder of the borehole was drilled with a 3 ½-inch OD solid stem auger to 16.3 feet bgs. The borehole was left open prior to fracturing.

FW-6A, 6B, 7, 8, and 9 were drilled with a 3 ½-inch OD solid stem auger to 19.5, 19.65, 19.2, 23.68, and 19.98 feet bgs, respectively. The boreholes were left open prior to fracturing. These wells were also drilled in late February 2000.

Similarly, ERW-1 and ERW-2 were also drilled with a 3 ½-inch OD solid stem auger to 19.25 and 19.05 feet bgs respectively. The boreholes were left open prior to fracturing. These wells were drilled during the same mobilization in late February 2000.

The borehole for FW-8 was initially drilled to a depth of 15 feet. Continuous split-spoon soil samples were retrieved from 15 feet to 18 feet bgs. At approximately 18 feet bgs, the split-spoon sampler would not advance, so a 300-pound hammer was used to attempt soil recovery. Two three-inch split-spoon samplers were destroyed trying to advance past 18 feet bgs. Therefore, sampling was halted and no further sampling was attempted.

McLaren/Hart returned to the site with Soil Tech in May 2000 to complete the re-drilling of new fracture wells (NFW) in the RW-1 pilot test area. Additionally, existing FW wells in RW-1 pilot test area were also reamed to allow fracturing equipment to fit down the open boreholes. Each

borehole was reamed using a lead auger, which had a welded bead that increased the outside diameter to 3 5/8-inch. Previous attempts to complete the fracture wells had reduced the outside diameter of the auger to 3 ¼-inch. This did not allow for enough space within the borehole to advance the fracturing equipment.

NFW-1, 2, 3, 4, and 5 were drilled with the 3 5/8-inch OD solid stem auger to 23.00, 25.00, 19.62, 19.65, and 24.50 feet bgs respectively. These boreholes were left open prior to fracturing.

Soil Tech brought a B-90 rig to the site, which had the capability to push the 3-inch inside diameter (ID) schedule 40 PVC casing and screen into the 3 5/8-inch OD open borehole. The work plan identified using some open boreholes to set 3-inch ID casing and screen to attempt fracturing from within the screen. Each attempt to set the 3-inch ID screen resulted in failure of the screen due to the tight fit between the screen and borehole. A field decision was made to fracture in open boreholes only.

In July 2000, McLaren/Hart returned to the site with IPSI to ream FW and ERW wells in PW-6 pilot test areas. All five wells were reamed using a 3 5/8-inch OD solid stem auger.

4.0 PNEUMATIC FRACTURING

Pneumatic fracturing was conducted at the RW-1 and PW-6 areas (Figure 2-1) at the TWFF. McLaren/Hart performed all pneumatic fracturing with technical assistance, pneumatic fracturing equipment, and structural monitoring equipment provided by New Jersey Institute of Technology (NJIT).

The fracturing occurred during three different events in the field, March, May, and July. Each event is described in the following subsections. Following the pneumatic fracturing task the fracture wells were developed and pump tests were conducted in each of the two areas. These tasks are discussed in the following subsections, as are the general observations of the pneumatic fracturing.

4.1 March 2000 Mobilization

On March 10, 2000 pneumatic fracturing was performed within FW-2 using a triple packer system to increase permeability of the subsurface formation within RW-1 pilot study area (Figure 2-2). Three fracturing events occurred between a depth interval of 17.5 feet and 25 feet bgs. The fracture interval ranged from 2 feet to 5.5 feet. All three fracture events were omni-directional (i.e., 360 degrees). Initial injection pressures were not observed. Influence was observed in MTMW04, which was 10 feet away. Data from the pneumatic fracturing events are summarized in Table 4-1.

Surface monitoring was conducted during the fracturing events by the use of a transit and heave measuring rods. The heave is measured by observing the deflection of a rod located at the fracture well in all cases. Field personnel monitored the pilot study area for any surface heave or possible surface releases. Greatest heave was 3/16 inch.

The packer system was removed from the borehole and cleaned for repositioning into the next borehole. During cleaning, it was noted that the bottom packer of the three-packer configuration had been cut and was leaking air. McLaren/Hart personnel believe the packer was cut by an exposed sharp rock during inflation. This allowed the product to get past the protective Viton coating on the packer and attacked the underlying cord. The cut packer was replaced with a new Viton coated packer.

On March 14, 2000 pneumatic fracturing was performed within FW-6A and FW-6B using a triple packer system in the RW-1 pilot study area (Figure 2-2). Seven fracturing events occurred in FW-6A and FW-6B between a depth interval of 8 feet and 19.2 feet below grade and 8.5 feet and 18.5 feet below grade respectively. The fracture interval ranged from 1 foot to 2 feet. All seven fracture events were omni-directional. Initial injection pressures ranged from 120 to 190 pounds per square inch (psi). Influence was observed in AW-1, which was 14 feet away from FW-6B while influence from the fracturing at FW-6A was not observed. Greatest heave was observed in FW-6A and was 7/16 inch. Data from the pneumatic fracturing events are summarized in Table 4-1.

Three more packers had been compromised during the fracturing of FW-6A and FW-6B. Two of the packers had over inflated due to sloughing bore walls. One packer had been cut by a sharp rock in the borehole after inflation and started to leak air. These packers were replaced and fracturing continued in May 2000.

4.2 May 2000 Mobilization

On May 18, 2000 McLaren/Hart, with assistance from NJIT, returned to the site to complete fracturing in RW-1 area and PW-6 area. Seven wells were fractured five in RW-1 area and two in PW-6 area over the next four days. McLaren/Hart set up to fracture NFW-5 in the RW-1 area first (Figure 2-2). Six fracturing events occurred in NFW-5 between a depth interval of 11 feet and 21 feet bgs. The fracture interval was 2 feet. All six fracture events were omni-directional. Initial injection pressures ranged from 120 to 180 psi. Influence was observed in FW-2, which was 5 feet away from NFW-5. Influence in adjacent wells was determined by either observing a latex glove placed over the riser expanding or physically hearing nitrogen gases escaping from observation well. Greatest heave was 3/8 inch. Data from the pneumatic fracturing events are summarized in Table 4-1.

On May 19, 2000 McLaren/Hart fractured NFW-1, NFW-3, and NFW-4 in the RW-1 area. Four to five fracturing events occurred between the three wells at a depth interval of 9.7 feet to 19 feet below grade. The fracture interval was 2 feet. All fracture events were omni-directional. Initial injection pressures ranged from 135 to 240 psi. Influence was observed in NFW-4 from NFW-1, which was 25 feet away. Influence was observed in AW-1 from NFW-3, which was 10 feet away. Influence was also observed in NFW-5 from NFW-4, which was 10 feet away. Heave was

not observed for these wells. Data from the pneumatic fracturing events are summarized in Table 4-1.

On May 20, 2000 McLaren/Hart fractured two wells, NFW-2 in RW-1 area (Figure 2-2) and ERW-1 in PW-6 area (Figure 2-3). NFW-2 had seven fracturing events between a depth interval of 10.5 feet to 21 feet below grade. The fracture intervals ranged from 1.5 feet to 2 feet. ERW-1 had three fracturing events between a depth interval of 15 feet to 22 feet bgs. The fracture intervals ranged from 1.5 feet to 5.5 feet. All fracture events were omni-directional. Initial injection pressures ranged from 145 to 190 psi for NFW-2 and 150 to 275 psi for ERW-1. Influence was observed in AW-1 from NFW-2, which was 34 feet away. Influence was not observed in the surrounding wells during the fracturing of ERW-1. Heave was not observed for ERW-1, while the greatest heave in NFW-2 was 7/16 inch. Data from the pneumatic fracturing events are summarized in Table 4-1 for RW-1 area fracture wells and Table 4-2 for PW-6 area fracture wells.

Proppant was introduced into ERW-1 while fracturing in the PW-6 area. McLaren/Hart was unable to establish sufficient airflow to successfully push the proppant into the formation. Higher pressures may have helped induce enough airflow to support proppant introduction, however McLaren/Hart believed that the packers might be compromised at greater pressures.

On May 21, 2000 McLaren/Hart fractured FW-8 in the PW-6 area. Three fracturing events occurred between a depth interval of 17 feet to 21 feet below grade. The fracture interval ranged from 2 feet to 4 feet. All fracture events were omni-directional. Injection pressures ranged from 260 to 300 psi. Influence was observed in FW-7, which was 19 feet away from FW-8. Heave was not observed. Data from the pneumatic fracturing events are summarized in Table 4-2.

It should be noted that two additional packers failed during these four days of fracturing. The packers encountered sharp rocks within the boreholes. During inflation, the packers were cut which allowed any product in the borehole to weaken the underlying cord and rubber. McLaren/Hart requested that fracturing stop until new packers could be ordered and coated with Viton. It was agreed that a third mobilization for fracturing in July be arranged.

4.3 July 2000 Mobilization

On July 22, 2000 McLaren/Hart mobilized to the site to complete fracturing on three wells in PW-6 area. FW-7, FW-9, and ERW-2 (Figure 2-3) were fractured. Four fracturing events per well between a depth interval of 11 feet to 17 feet bgs. The fracture interval was 2 feet. All fracture events were omni-directional. All wells were blind fracture, which means the fracture nozzle was placed at this depth without regard to lithology or apparent observed product. Injection pressures ranged from 120 to 180 psi. No heave or influence in surrounding wells was observed. Data from the pneumatic fracturing events are summarized in Table 4-2. Blow by was observed at depths of 15 feet and 17 feet bgs for each well. The packer system was a two-packer system with the injection nozzle between the two packers. It was noted that the top packers had a cut and was leaking after fracturing FW-9. The cut in the top packer was a possible reason for blow by in the wells.

McLaren/Hart made a field decision to use omni-directional fracturing on all wells after demonstration on selected wells showed less than expected radius of influences. Fracture pressures were also reduced thereby avoiding any conflict with surface or subsurface structures. Only blow by was observed in the fracture pilot test areas, which is believed to been caused by packer failure.

4.4 Post Fracture Well Development

After fracturing, a 2 ½-inch screen with plug was placed into each fracture well (FW, NFW, and ERW). The fracture wells were screened from bottom of borehole to 5 feet bgs with 0.020 slot schedule 40 PVC screen. An additional five feet of riser was used to bring the top of the well to surface. A sand pack (00N) was place in the annulus from bottom of borehole to 5 feet bgs. The annulus was backfilled to surface with grout and a cap was placed on top of each well. The wells were then developed with a hand bailer. Five well volumes were removed prior to gauging wells. Recovered groundwater was collected in a 55-gallon drum and transported to a 600-gallon poly tank for storage and subsequent disposal.

After fracturing NFW-2, the well was over drilled with 8 ¼-inch hollow stem auger. A 4-inch schedule 40 PVC well was set in place. The well consisted of 20 feet of 4-inch 0.020 slot schedule 40 PVC screen with plug and 5 feet of 4-inch schedule 40 PVC riser with a metal 8-inch bolt-down well vault. A sand pack (00N) was placed in the annulus from bottom of boring to 5

feet bgs. The remaining annulus was grouted to within 1 foot of surface. A 2-foot by 2-foot concrete pad with 8-inch well vault was formed and poured. The well was then developed by hand using a 2-inch hand bailer. Five well volumes were removed prior to gauging the well. All recovered groundwater was placed in a 55-gallon drum then transported to a 600-gallon poly tank for storage and subsequent disposal.

4.5 Post Fracture Product Only Pump Tests

Since storage capacity was limited at the site and treatment was more costly than previously anticipated, a product only pump test was developed. The purpose of the product only test was to maximize product recovery while minimizing groundwater production. Since the baseline data gathered prior to fracturing was based upon total fluids, any subsequent product recovery data collected after fracturing would be more conservative.

4.5.1 RW-1 Pump Test Results

On May 23, 2000 a post fracturing product only pump test was performed on RW-1. An existing 2-inch top loading pneumatic pump used by McLaren/Hart in the previous tests was placed in RW-1. The top of the pump was placed one foot below the oil/water interface. Baseline readings from all the wells in RW-1 pilot test area were collected prior to initiating the pump test. The pump test was allowed to run for eight days while data was collected. Groundwater and product recovery data is presented in Table 4-3. A graph of product recovery is presented in Figure 4-1.

During this pump test a total of 12.19 gallons of product was recovered. The average product recovery rate was 1.52 gallons per day (gpd).

Upon return to the site in July, 2000, a product only pump test was initiated on NFW-2. This was the well that was fractured, over drilled, and developed into a 4-inch recovery well. Baseline readings from all the wells in RW-1 pilot test area were collected prior to initiating the pump test. The existing 2-inch top loading pneumatic pump was placed one foot below the oil/water interface and allowed to pump for 10 days. Groundwater and product recovery data is presented in Table 4-4. A graph of product recovery is presented in Figure 4-2.

During this pump test a total of 22.72 gallons of product was recovered. The average product recovery rate was 2.27 gpd.

In early August, 2000 a second pump test was performed on NFW-2. The previous test on NFW-2 was stopped when the existing 2-inch top loading pneumatic pump failed. This pump was unable to handle moisture in the air lines, therefore a replacement pump that could handle moisture in the air lines was ordered. Since two consecutive pump tests were running in RW-1 and PW-6 pilot test areas, it was decided to order two pumps. The pumps received at the site were 2-inch top loading pneumatic QED Environmental Systems, Inc. (QED) Hammerhead pumps.

NFW-2 was retrofitted with the new pumps and a new product only pump test was initiated in early August 2000. The top of the pump was placed one foot below the oil/water interface. Baseline readings from all the wells in RW-1 pilot test area were collected prior to initiating the pump test. The pump test was allowed to run for eight days while data was collected. Groundwater and product recovery data is presented in Table 4-5. A graph of product recovery is presented in Figure 4-3.

During this pump test a total of 15.49 gallons of product was recovered. The average product recovery rate was 1.94 gpd, which was slightly less than the previous pump test.

The pump was moved to MTMW-4 to begin a product only pump test. The reason for selecting this well was the unusually high levels of product and baseline data was previously obtained for this well. Baseline readings from all the wells in RW-1 pilot test area were collected prior to initiating the pump test. The pump test was allowed to run for eight days while data was collected. Groundwater and product recovery data is presented in Table 4-5. A graph of product recovery is presented in Figure 4-4.

During this pump test a total of 18.38 gallons of product was recovered. The average recovery rate was 2.30 gpd. Further evaluation of the data reveals that the majority of the product recovery was in the first days of pumping. The rate of product recovery decreased rapidly in the last three days.

4.5.2 PW-6 Pump Test Results

A product only pump test was performed on PW-6 while 20” Hg was applied to the well. The test began in early August 2000 after acquisition of the QED pneumatic pumps. Baseline

readings from all the wells in PW-6 pilot test area were collected prior to initiating the pump test. The pump test was allowed to run for 12 days while data was collected. Groundwater and product recovery data is presented in Table 4-5. A graph of product recovery is presented in Figure 4-5.

During this pump test a total of 8.47 gallons of product was recovered. The average recovery rate was 0.71 gpd. This was significantly lower than the baseline rate prior to fracturing of 1.56 gpd.

The vacuum enhanced recovery system was removed from PW-6 and connected to FW-8. The top loading QED pneumatic pump was located one foot below the oil/water interface and a 20" Hg vacuum was applied. Baseline readings from all the wells in PW-6 pilot test area were collected prior to initiating the pump test. This test was allowed to run for 6 days while data was collected. Groundwater and product recovery data is presented in Table 4-5. A graph of product recovery is presented in Figure 4-6.

During this pump test a total of 8.67 gallons of product was recovered. The average recovery rate was 1.45 gpd. This was a similar recovery rate to PW-6 prior to fracturing.

4.6 General Observations

A total of 25,600 gallons of groundwater was recovered and treated from all activities during the pilot test. Approximately 15,600 gallons was generated prior to pneumatic fracturing activities. The bulk of this groundwater was recovered during the total fluids pumping tests from January to March 2000 in RW-1 and PW-6 areas. After implementing a product only approach to reduce recovered groundwater, the post fracturing activities generated 10,000 gallons. The groundwater recovered after fracturing was from May to August 2000. This was a decrease of 35 percent in groundwater production.

A total of 242 gallons of product was recovered from all activities of the pilot test. Activities prior to pneumatic fracturing collected 146 gallons, while activities after pneumatic fracturing collected 96 gallons. The average rate of product recovery in RW-1 prior to pneumatic fracturing was 1.07 gpd, while PW-6 averaged 1.56 gpd prior to pneumatic fracturing. The average rate of product recovery for RW-1 after pneumatic fracturing was 1.52 gpd, while PW-6 averaged 0.71 gpd after pneumatic fracturing.

TABLES

TABLE 4-1

PNEUAMATIC FRACTURING DATA FOR RW-1 PILOT TEST AREA
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVELT ROADS, CEIBA, PR

Fractured Well #	Fracture Date	Fracture Number	Max Heave (in)	Fracture Depth (ft bgs)	Packer Pressure (psi)	Fracture Duration (sec)	Fracture Pressure (psi)	Max Observed Influence (ft)	Observed Influence Well #
FW-2	10-Mar-00	1	3/16	25	NO	NO	NO	10	FW-1,FW-3
		2	2/16	19.5	NO	NO	NO	10	FW-1,FW-3
		3	1/16	17.5	NO	NO	NO	10	FW-1,FW-3
FW-6A	14-Mar-00	1	4/16	16	300	15	170	NO	NO
		2	6/16	14	295	15	160	NO	NO
		3	7/16	12	295	15	140	NO	NO
		4	NO	10	295	15	130	NO	NO
		5	NO	8	250	15	120	NO	NO
		6	NO	19.2	300	15	190	NO	NO
		7	NO	18	300	15	170	NO	NO
FW-6B	14-Mar-00	1	NO	18.5	300	15	180	14	MTMW-3,AW-1,FW-6
		2	NO	17.5	300	14	170	14	MTMW-3,AW-1,FW-6
		3	2/16	15.5	300	15	160	14	MTMW-3,AW-1,FW-6
		4	3/16	14.5	300	15	150	14	MTMW-3,AW-1,FW-6
		5	1/16	12.5	300	15	150	14	MTMW-3,AW-1,FW-6
		6	3/16	10.5	275	15	150	14	MTMW-3,AW-1,FW-6
		7	4/16	8.5	270	15	150	14	MTMW-3,AW-1,FW-6
NFW-1	19-May-00	1	NO	19	206	15	195	21	NFW-2,RW-1,MTMW-3,NFW-3
		2	NO	17	200	15	160	21	NFW-2,NFW-3,RW-1
		3	NO	15	205	15	150	17	NFW-2,RW-1,MTMW-3
		4	NO	13	180	13	135	25	NFW-2,RW-1,NFW-4,MTMW-3
		5	NO	11	175	15	140	25	NFW-2,NFW-3,NFW-4,FW-6, MTMW-3, RW-1

Notes:
NO - Not Observed

TABLE 4-1

PNEUAMATIC FRACTURING DATA FOR RW-1 PILOT TEST AREA
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVELT ROADS, CEIBA, PR

Fractured Well #	Fracture Date	Fracture Number	Max Heave (in)	Fracture Depth (ft bgs)	Packer Pressure (psi)	Fracture Duration (sec)	Fracture Pressure (psi)	Max Observed Influence (ft)	Observed Influence Well #
NFW-2	20-May-00	1	NO	21	200	<15	175	0	Blow By
		2	NO	20	245	4	195	26	MTMW-4,NFW-4,NFW-5
		3	1/4	18.5	245	20	195	34	MTMW-2,AW-1,FW-6B
		4	3/16	16.5	225	15	180	34	AW-1
		5	1/4	14.5	180	15	150	34	NFW-4,NFW-5,FW-6,AW-1
		6	7/16	12.5	180	14	145	34	NFW-5,AW-1,FW-6
		7	7/16	10.5	180	14	145	NO	NO
NFW-3	19-May-00	1	NO	17.7	275	15	240	10	AW-1,AW-2,MTMW-3
		2	NO	15.7	225	15	170	10	AW-1,AW-2,MTMW-3
		3	NO	13.7	225	15	170	10	FW-6,AW-1,AW-2,MTMW-3
		4	NO	11.7	225	15	150	NO	NO
		5	NO	9.7	225	15	150	NO	NO
NFW-4	19-May-00	1	NO	17	225	15	200	5	FW-2
		2	NO	15	205	15	165	10	FW-2,NFW-5,MTMW-4
		3	NO	13	205	15	155	10	FW-2,NFW-5
		4	NO	11	190	15	150	0	Blow By
NFW-5	18-May-00	1	1/32	21	225	15	130	5	FW-2
		2	1/32	19	200	15	120	5	FW-2
		3	1/32	17	200	15	130	5	FW-2
		4	1/16	15	200	15	130	5	FW-2
		5	3/16	13	200	15	180	NO	NO
		6	3/8	11	200	NO	160	NO	NO

Notes:
NO - Not Observed

TABLE 4-2

PNEUMATIC FRACTURING DATA FOR PW-6 PILOT TEST AREA
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVELT ROADS, CEIBA, PR

Fractured Well #	Fracture Date	Fracture Number	Max Heave (in)	Fracture Depth (ft bgs)	Packer Pressure (psi)	Fracture Duration (sec)	Fracture Pressure (psi)	Max Observed Influence (ft)	Observed Influence Well #
FW-7	22-Jul-00	1	NO	17	250	15	180	0	Blow By
		2	NO	15	220	15	150	0	Blow By
		3	NO	13	200	10	150	>5	None
		4	NO	11	195	5	120	>5	None
FW-8	21-May-00	1	NO	23	390	15	300	0	Did Not Fracture
		2	NO	19	350	15	280	19	PW-6,ERW-1,FW-7
		3	NO	17	350	15	260	19	PW-6,ERW-1,FW-7,ERW-2
FW-9	22-Jul-00	1	NO	17	250	15	180	0	Blow By
		2	NO	15	220	15	150	0	Blow By
		3	NO	13	200	10	150	>6	None
		4	NO	11	195	5	120	>6	None
ERW-1	20-May-00	1	NO	22	285	15	275	NO	NO (Pushed 426 lbs. Ceramic Beads; Low Flow)
		2	NO	15	280	15	150	NO	NO (Pushed 360 lbs. Ceramic Beads; Low Flow)
		3	NO	16.5	230	15	150	NO	NO (Pushed 266 lbs. Ceramic Beads; Low Flow)
ERW-2	22-Jul-00	1	NO	17	250	15	180	0	Blow By
		2	NO	15	220	15	150	0	Blow By
		3	NO	13	200	10	150	>14	None
		4	NO	11	195	5	120	>14	None

Notes:
NO - Not Observed

TABLE 4-3

GROUNDWATER AND PRODUCT RECOVERY DATA - MAY 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well*	5/23/00			5/25/00			5/27/00		
		Depth to		Apparent	Depth to		Apparent	Depth to		Apparent
		Product*	Water*	Product Thickness	Product*	Water*	Product Thickness	Product*	Water*	Product Thickness
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
NFW-001	23.00	11.23	11.83	0.60	NA	NA	NA	10.65	12.38	1.73
NFW-002	25.00	17.2	17.3	0.10	NA	NA	NA	17.58	18.58	1.00
NFW-003	19.62	16.33	18.22	1.89	NA	NA	NA	15.62	18.32	2.70
NFW-004	19.65	18.08	18.54	0.46	NA	NA	NA	17.66	18.15	0.49
NFW-005	24.50	18.95	20.65	1.70	NA	NA	NA	17.5	18.45	0.95
RW-1	28.80	16.5	17.9	1.40	18.95	20.65	1.70	None	21.77	NA
AW-1	34.80	16.95	17.40	0.45	NA	NA	NA	16.84	17.35	0.51
AW-2	29.90	None	20.05	NA	NA	NA	NA	NA	NA	NA
FW-2	16.30	None	None	None	NA	NA	NA	None	None	None
FW-6A	19.65	18.84	19.3	0.46	NA	NA	NA	None	None	None
FW-6B	19.50	17.55	None	1.95	NA	NA	NA	17	17.48	0.48
MTMW-1	30.05	16.95	20.95	4.00	NA	NA	NA	16.9	20.75	3.85
MTMW-2	36.90	18.35	21.20	2.85	NA	NA	NA	18.45	21.85	3.40
MTMW-3	34.75	16.05	19.90	3.85	NA	NA	NA	None	20.1	NA
MTMW-4	34.20	17.98	20.85	2.87	NA	NA	NA	18.15	21.1	2.95
UGW-3	37.50	None	22.68	NA	NA	NA	NA	None	21.60	NA
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-03	26.55	NA	NA	NA	NA	NA	NA	NA	NA	NA
PW-05	26.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
UGW-1	26.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4	26.93	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-9	19.98	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-8	23.68	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-1	19.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-2	19.05	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-3

GROUNDWATER AND PRODUCT RECOVERY DATA - MAY 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well*	5/28/00			5/29/00			5/30/00		
		Depth to		Apparent	Depth to		Apparent	Depth to		Apparent
		Product*	Water*	Product Thickness	Product*	Water*	Product Thickness	Product*	Water*	Product Thickness
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
NFW-001	23.00	10.98	14.43	3.45	11.53	13.28	1.75	10.21	11.58	1.37
NFW-002	25.00	17.55	18.72	1.17	17.55	18.85	1.30	17.54	18.94	1.40
NFW-003	19.62	15.58	18.4	2.82	14.46	17.7	3.24	14.71	17.75	3.04
NFW-004	19.65	17.65	18.18	0.53	17.15	17.65	0.50	17.33	17.82	0.49
NFW-005	24.50	18.97	21.08	2.11	17.98	20.2	2.22	19.04	20.32	1.28
RW-1	28.80	None	21.8	NA	None	21.40	NA	None	21.80	NA
AW-1	34.80	None	16.88	NA	16.84	17.40	0.56	16.71	17.22	0.51
AW-2	29.90	20.9	23.66	2.76	20.86	23.46	2.60	21.38	23.14	1.76
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.85	19.3	0.45	18.9	19.33	0.43	17.20	17.50	0.30
FW-6B	19.50	17.8	None	-15.85	17.65	None	-0.17	17.47	19.10	1.63
MTMW-1	30.05	16.9	20.95	4.05	16.93	21.00	4.07	16.90	20.88	3.98
MTMW-2	36.90	18.45	21.82	3.37	18.50	21.88	3.38	18.48	21.86	3.38
MTMW-3	34.75	15.92	20.18	4.26	15.88	20.44	4.56	15.84	20.37	4.53
MTMW-4	34.20	18.25	21.1	2.85	18.22	21.08	2.86	18.19	21.15	2.96
UGW-3	37.50	None	21.65	NA	None	23.68	NA	None	23.66	NA
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-03	26.55	NA	NA	NA	NA	NA	NA	NA	NA	NA
PW-05	26.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
UGW-1	26.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4	26.93	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-9	19.98	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-8	23.68	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-1	19.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-2	19.05	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-3

GROUNDWATER AND PRODUCT RECOVERY DATA - MAY 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	5/31/00 Depth to Product* (ft)	5/31/00 Depth to Water* (ft)	5/31/00 Apparent Product Thickness (ft)
NFW-001	23.00	13.78	14.83	1.05
NFW-002	25.00	17.00	18.22	1.22
NFW-003	19.62	15.40	18.25	2.85
NFW-004	19.65	17.48	17.92	0.44
NFW-005	24.50	18.73	20.30	1.57
RW-1	28.80	None	20.5	NA
AW-1	34.80	16.7	17.22	0.52
AW-2	29.90	18.58	20.13	1.55
FW-2	16.30	None	None	None
FW-6A	19.65	18.10	18.48	0.38
FW-6B	19.50	18.55	19.22	0.67
MTMW-1	30.05	16.9	20.68	3.78
MTMW-2	36.90	18.42	21.22	2.80
MTMW-3	34.75	15.88	20.1	4.22
MTMW-4	34.20	18.12	20.74	2.62
UGW-3	37.50	None	23.6	NA
PW-06	24.90	NA	NA	NA
FW-7	19.20	NA	NA	NA
MW-03	26.55	NA	NA	NA
PW-05	26.90	NA	NA	NA
UGW-1	26.90	NA	NA	NA
MW-4	26.93	NA	NA	NA
FW-9	19.98	NA	NA	NA
FW-8	23.68	NA	NA	NA
ERW-1	19.25	NA	NA	NA
ERW-2	19.05	NA	NA	NA

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-4

GROUNDWATER AND PRODUCT RECOVERY DATA - JULY 2000
PILOT TEST OT EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVLT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	7/18/00			7/20/00			7/21/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	13.92	15.35	1.43	13.29	14.60	1.31	14.30	15.51	1.21
NFW-002	25.00	16.85	19.65	2.80	NA	NA	NA	None	21.61	NA
NFW-003	19.62	16.37	19.51	3.14	16.32	19.47	3.15	16.38	19.34	2.96
NFW-004	19.65	17.20	19.48	2.28	17.22	19.42	2.20	17.25	19.40	2.15
NFW-005	24.50	16.96	21.03	4.07	17.01	21.08	4.07	17.02	21.10	4.08
RW-1	28.80	16.80	18.05	1.25	16.95	18.25	1.30	17.01	18.38	1.37
AW-1	34.80	16.86	17.18	0.32	16.84	21.26	4.42	16.85	21.28	4.43
AW-2	29.90	17.61	20.78	3.17	17.65	20.95	3.30	17.72	21.01	3.29
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.93	19.33	0.40	18.96	19.31	0.35	18.96	19.31	0.35
FW-6B	19.50	17.62	18.50	0.88	17.68	18.31	0.63	17.69	18.37	0.68
MTMW-1	30.05	17.61	21.72	4.11	17.63	21.68	4.05	17.62	21.63	4.01
MTMW-2	36.90	18.39	22.38	3.99	18.45	22.46	4.01	18.45	22.51	4.06
MTMW-3	34.75	16.50	19.85	3.35	16.50	21.35	4.85	16.51	21.18	4.67
MTMW-4	34.20	17.99	21.94	3.95	18.03	22.01	3.98	18.05	22.1	4.05
UGW-3	37.50	20.31	20.32	0.01	22.35	22.36	0.01	None	20.35	NA
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-03	26.55	NA	NA	NA	NA	NA	NA	NA	NA	NA
PW-05	26.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
UGW-1	26.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4	26.93	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-9	19.98	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-8	23.68	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-1	19.25	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-2	19.05	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-4

GROUNDWATER AND PRODUCT RECOVERY DATA - JULY 2000
PILOT TEST OT EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVLT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	7/22/00			7/24/00			7/25/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	14.54	15.90	1.36	14.83	16.60	1.77	18.94	20.85	1.91
NFW-002	25.00	None	21.60	NA	21.57	21.58	0.01	None	21.60	NA
NFW-003	19.62	16.42	19.42	3.00	16.45	19.35	2.90	16.46	19.36	2.90
NFW-004	19.65	17.29	19.40	2.11	17.33	19.15	1.82	17.36	19.38	2.02
NFW-005	24.50	17.07	21.15	4.08	18.58	22.68	4.10	18.58	22.72	4.14
RW-1	28.80	17.08	18.40	1.32	17.10	18.48	1.38	17.14	18.57	1.43
AW-1	34.80	16.89	21.32	4.43	16.9	21.35	4.45	16.91	21.33	4.42
AW-2	29.90	17.8	21.09	3.29	17.85	21.1	3.25	17.85	21.1	3.25
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.98	19.37	0.39	19.00	19.32	0.32	19.02	19.30	0.28
FW-6B	19.50	18.69	19.38	0.69	18.74	19.35	0.61	18.77	19.37	0.60
MTMW-1	30.05	17.7	21.72	4.02	17.7	21.71	4.01	17.72	21.75	4.03
MTMW-2	36.90	18.48	22.68	4.20	18.5	22.63	4.13	18.48	22.25	3.77
MTMW-3	34.75	16.54	21.4	4.86	16.56	21.5	4.94	16.6	21.5	4.90
MTMW-4	34.20	18.1	22.15	4.05	18.12	22.18	4.06	18.13	22.16	4.03
UGW-3	37.50	None	20.40	NA	None	20.44	NA	None	20.45	NA
PW-06	24.90	NA	NA	NA	12.89	13.82	0.93	12.25	13.20	0.95
FW-7	19.20	NA	NA	NA	12.66	12.71	0.05	12.60	12.62	0.02
MW-03	26.55	NA	NA	NA	14.77	14.90	0.13	14.78	14.84	0.06
PW-05	26.90	NA	NA	NA	13.57	14.30	0.73	13.58	14.3	0.72
UGW-1	26.90	NA	NA	NA	12.70	15.98	3.28	12.70	15.96	3.26
MW-4	26.93	NA	NA	NA	12.17	13.62	1.45	12.17	13.59	1.42
FW-9	19.98	NA	NA	NA	14.57	15.82	1.25	14.54	15.86	1.32
FW-8	23.68	NA	NA	NA	15.79	16.69	0.90	15.62	16.55	0.93
ERW-1	19.25	NA	NA	NA	11.02	11.74	0.72	10.99	11.81	0.82
ERW-2	19.05	NA	NA	NA	11.43	11.70	0.27	11.82	12.05	0.23

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-4

GROUNDWATER AND PRODUCT RECOVERY DATA - JULY 2000
PILOT TEST OT EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVLT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	7/26/00			7/27/00			7/28/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	18.98	21.00	2.02	19.05	21.18	2.13	19.10	21.34	2.24
NFW-002	25.00	None	21.58	NA	None	21.68	NA	None	21.64	NA
NFW-003	19.62	16.48	19.40	2.92	16.53	19.43	2.90	16.52	19.40	2.88
NFW-004	19.65	17.38	19.38	2.00	17.40	19.40	2.00	17.44	19.40	1.96
NFW-005	24.50	18.60	22.73	4.13	18.62	22.70	4.08	18.61	22.85	4.24
RW-1	28.80	17.15	18.55	1.40	17.15	18.60	1.45	17.15	18.60	1.45
AW-1	34.80	16.93	21.35	4.42	16.95	21.4	4.45	16.99	21.35	4.36
AW-2	29.90	17.59	21.1	3.51	17.9	21.12	3.22	17.95	20.1	2.15
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	19.00	19.30	0.30	19.03	19.33	0.30	19.03	19.30	0.27
FW-6B	19.50	18.77	19.40	0.63	18.80	19.42	0.62	18.81	19.40	0.59
MTMW-1	30.05	17.74	21.78	4.04	17.75	21.77	4.02	17.79	21.79	4.00
MTMW-2	36.90	18.54	22.84	4.30	18.52	22.85	4.33	18.52	22.8	4.28
MTMW-3	34.75	16.63	21.52	4.89	16.63	21.53	4.90	16.65	21.55	4.90
MTMW-4	34.20	18.16	22.18	4.02	18.18	22.18	4.00	18.18	22.2	4.02
UGW-3	37.50	None	20.48	NA	None	20.50	NA	None	20.55	NA
PW-06	24.90	12.62	12.78	0.16	12.63	13.05	0.42	11.10	12.68	1.58
FW-7	19.20	12.56	12.63	0.07	12.79	12.89	0.10	12.70	12.79	0.09
MW-03	26.55	14.67	14.77	0.10	14.65	14.73	0.08	14.60	14.72	0.12
PW-05	26.90	13.60	14.31	0.71	13.62	14.33	0.71	13.62	14.33	0.71
UGW-1	26.90	12.77	16.03	3.26	12.62	15.90	3.28	12.63	15.85	3.22
MW-4	26.93	12.12	13.55	1.43	12.12	13.50	1.38	12.13	13.53	1.40
FW-9	19.98	14.56	15.91	1.35	14.96	16.25	1.29	14.88	16.24	1.36
FW-8	23.68	15.46	16.53	1.07	15.43	16.55	1.12	15.40	16.48	1.08
ERW-1	19.25	10.98	11.80	0.82	10.95	11.75	0.80	10.93	11.73	0.80
ERW-2	19.05	12.12	12.36	0.24	12.32	12.50	0.18	12.45	12.72	0.27

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-4

GROUNDWATER AND PRODUCT RECOVERY DATA - JULY 2000
PILOT TEST OT EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVAL STATION ROOSEVLT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	7/29/00			7/30/00			7/31/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	16.38	17.75	1.37	16.37	17.69	1.32	17.45	18.55	1.10
NFW-002	25.00	18.40	18.70	0.30	18.50	18.85	0.35	17.45	17.68	0.23
NFW-003	19.62	16.54	19.41	2.87	16.30	18.53	2.23	16.25	18.18	1.93
NFW-004	19.65	17.45	19.40	1.95	17.46	19.41	1.95	17.45	19.40	1.95
NFW-005	24.50	18.61	22.81	4.20	18.58	22.80	4.22	18.53	22.74	4.21
RW-1	28.80	16.98	18.50	1.52	16.78	18.28	1.50	16.83	18.35	1.52
AW-1	34.80	16.98	21.25	4.27	16.67	21.59	4.92	16.68	21.22	4.54
AW-2	29.90	17.9	21.02	3.12	17.75	20.1	2.35	17.78	20.35	2.57
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	19.03	19.31	0.28	18.08	18.26	0.18	18.38	18.60	0.22
FW-6B	19.50	18.85	19.40	0.55	18.72	19.25	0.53	18.75	19.29	0.54
MTMW-1	30.05	17.8	21.18	3.38	17.82	21.58	3.76	17.8	21.53	3.73
MTMW-2	36.90	18.55	22.8	4.25	18.51	22.64	4.13	18.49	22.52	4.03
MTMW-3	34.75	16.66	21.62	4.96	16.63	21.6	4.97	16.62	21.61	4.99
MTMW-4	34.20	18.18	22.18	4.00	18.18	22.12	3.94	18.1	22.12	4.02
UGW-3	37.50	None	20.55	NA	20.43	20.78	0.35	20.42	20.79	0.37
PW-06	24.90	11.80	12.53	0.73	11.00	11.89	0.89	11.06	12.00	0.94
FW-7	19.20	7.47	7.58	0.11	6.77	6.81	0.04	7.10	7.12	0.02
MW-03	26.55	14.51	14.61	0.10	14.40	14.48	0.08	14.30	14.42	0.12
PW-05	26.90	13.65	14.33	0.68	13.65	14.35	0.70	13.63	14.33	0.70
UGW-1	26.90	12.69	15.92	3.23	12.58	15.82	3.24	12.32	15.52	3.20
MW-4	26.93	12.12	13.55	1.43	7.46	8.10	0.64	7.87	8.60	0.73
FW-9	19.98	12.95	14.70	1.75	13.58	14.80	1.22	14.10	15.25	1.15
FW-8	23.68	12.82	15.12	2.30	12.37	14.56	2.19	13.18	15.38	2.20
ERW-1	19.25	7.66	8.49	0.83	5.45	6.35	0.90	6.16	7.07	0.91
ERW-2	19.05	9.27	9.41	0.14	11.00	11.40	0.40	11.65	12.08	0.43

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/1/00			8/2/00			8/3/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	15.67	16.59	0.92	16.52	17.43	0.91	16.75	17.60	0.85
NFW-002	25.00	17.44	17.66	0.22	17.64	17.92	0.28	17.31	17.58	0.27
NFW-003	19.62	16.40	18.27	1.87	16.49	18.35	1.86	16.52	18.45	1.93
NFW-004	19.65	17.45	19.40	1.95	17.43	19.40	1.97	17.45	19.40	1.95
NFW-005	24.50	18.47	22.68	4.21	18.44	22.62	4.18	18.41	22.56	4.15
RW-1	28.80	16.80	18.30	1.50	16.73	18.23	1.50	16.71	18.30	1.59
AW-1	34.80	16.79	21.25	4.46	16.81	21.2	4.39	16.83	21.1	4.27
AW-2	29.90	17.73	20.4	2.67	17.7	21.15	3.45	NA	NA	NA
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.53	18.73	0.20	17.65	17.82	0.17	18.00	18.18	0.18
FW-6B	19.50	18.76	19.27	0.51	18.80	19.08	0.28	18.80	19.30	0.50
MTMW-1	30.05	17.8	21.65	3.85	17.78	21.44	3.66	17.76	21.41	3.65
MTMW-2	36.90	18.48	22.4	3.92	18.45	22.28	3.83	18.4	22.2	3.80
MTMW-3	34.75	16.62	21.64	5.02	16.57	21.52	4.95	16.59	21.46	4.87
MTMW-4	34.20	18.06	21.98	3.92	18.05	21.85	3.80	18.05	21.8	3.75
UGW-3	37.50	20.45	20.78	0.33	20.38	20.73	0.35	20.40	20.75	0.35
PW-06	24.90	11.00	11.92	0.92	10.54	11.45	0.91	NA	NA	NA
FW-7	19.20	6.48	6.50	0.02	6.23	6.24	0.01	10.59	10.62	0.03
MW-03	26.55	14.23	14.35	0.12	14.13	14.24	0.11	15.00	15.14	0.14
PW-05	26.90	13.59	14.29	0.70	13.56	14.23	0.67	13.52	14.2	0.68
UGW-1	26.90	12.20	15.40	3.20	11.74	14.97	3.23	11.21	14.38	3.17
MW-4	26.93	7.28	7.78	0.50	6.22	7.25	1.03	6.79	7.58	0.79
FW-9	19.98	14.08	15.29	1.21	14.15	15.42	1.27	15.45	16.18	0.73
FW-8	23.68	12.89	15.20	2.31	12.25	14.56	2.31	13.23	15.41	2.18
ERW-1	19.25	5.98	6.83	0.85	5.32	6.23	0.91	5.93	6.80	0.87
ERW-2	19.05	11.80	12.28	0.48	11.98	12.36	0.38	12.02	12.42	0.40

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/4/00			8/5/00			8/6/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	17.03	17.87	0.84	17.89	18.21	0.32	18.42	19.08	0.66
NFW-002	25.00	17.40	17.71	0.31	None	19.51	NA	NA	NA	NA
NFW-003	19.62	16.50	18.45	1.95	16.53	18.56	2.03	16.55	18.61	2.06
NFW-004	19.65	17.40	19.42	2.02	17.42	19.42	2.00	17.41	19.42	2.01
NFW-005	24.50	18.42	22.59	4.17	18.43	22.53	4.10	18.41	22.50	4.09
RW-1	28.80	17.81	19.48	1.67	16.76	18.28	1.52	16.75	18.36	1.61
AW-1	34.80	16.84	21.14	4.30	16.88	21.18	4.30	16.9	21.12	4.22
AW-2	29.90	None	22.06	NA	18.01	18.87	0.86	17.99	19.02	1.03
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.16	18.38	0.22	18.37	18.56	0.19	18.46	18.67	0.21
FW-6B	19.50	18.81	19.30	0.49	18.83	19.34	0.51	18.88	19.37	0.49
MTMW-1	30.05	17.78	21.38	3.60	17.82	21.49	3.67	17.81	21.58	3.77
MTMW-2	36.90	18.41	22.3	3.89	18.39	22.17	3.78	18.4	22.2	3.80
MTMW-3	34.75	16.6	21.4	4.80	16.61	21.4	4.79	16.64	21.42	4.78
MTMW-4	34.20	18.08	21.65	3.57	18.08	21.54	3.46	18.01	21.59	3.58
UGW-3	37.50	20.37	20.72	0.35	20.39	20.76	0.37	20.42	20.78	0.36
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	12.51	12.59	0.08	13.38	13.41	0.03	13.60	13.68	0.08
MW-03	26.55	14.98	15.17	0.19	15.02	15.19	0.17	15.18	15.39	0.21
PW-05	26.90	13.51	14.2	0.69	13.60	14.28	0.68	13.63	14.32	0.69
UGW-1	26.90	10.95	14.15	3.20	10.93	14.12	3.19	11.07	14.24	3.17
MW-4	26.93	7.20	8.28	1.08	8.11	9.09	0.98	8.80	9.77	0.97
FW-9	19.98	15.37	16.04	0.67	15.45	16.12	0.67	15.60	16.32	0.72
FW-8	23.68	13.91	16.15	2.24	14.40	16.59	2.19	14.75	16.85	2.10
ERW-1	19.25	6.50	7.40	0.90	7.01	7.92	0.91	7.39	8.29	0.90
ERW-2	19.05	12.08	12.48	0.40	12.17	12.58	0.41	12.21	12.66	0.45

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/7/00 Depth to Product* (ft)	8/7/00 Depth to Water* (ft)	8/7/00 Apparent Product Thickness (ft)	8/8/00 Depth to Product* (ft)	8/8/00 Depth to Water* (ft)	8/8/00 Apparent Product Thickness (ft)	8/9/00 Depth to Product* (ft)	8/9/00 Depth to Water* (ft)	8/9/00 Apparent Product Thickness (ft)
NFW-001	23.00	17.67	18.39	0.72	17.77	18.47	0.70	18.37	19.05	0.68
NFW-002	25.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
NFW-003	19.62	16.57	18.70	2.13	16.58	18.74	2.16	16.60	18.80	2.20
NFW-004	19.65	17.39	19.41	2.02	17.39	19.43	2.04	17.37	19.38	2.01
NFW-005	24.50	18.38	22.46	4.08	18.40	22.47	4.07	18.40	22.45	4.05
RW-1	28.80	16.71	18.36	1.65	16.65	18.35	1.70	16.62	18.33	1.71
AW-1	34.80	16.9	21.23	4.33	16.93	21.3	4.37	16.94	21.26	4.32
AW-2	29.90	17.92	19.11	1.19	17.94	19.2	1.26	17.87	19.2	1.33
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.54	18.76	0.22	18.60	18.82	0.22	18.64	18.87	0.23
FW-6B	19.50	18.88	19.32	0.44	18.89	19.05	0.16	18.90	19.31	0.41
MTMW-1	30.05	17.82	21.6	3.78	17.88	21.62	3.74	17.85	21.6	3.75
MTMW-2	36.90	18.39	22.1	3.71	18.38	22.03	3.65	18.38	22.22	3.84
MTMW-3	34.75	16.65	21.43	4.78	16.69	21.47	4.78	16.7	21.43	4.73
MTMW-4	34.20	18	21.57	3.57	18	21.63	3.63	18.05	21.58	3.53
UGW-3	37.50	20.45	20.80	0.35	20.46	20.83	0.37	20.48	20.85	0.37
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	12.99	13.09	0.10	13.19	13.28	0.09	12.07	12.13	0.06
MW-03	26.55	15.24	15.45	0.21	None	15.25	NA	15.22	15.44	0.22
PW-05	26.90	13.53	14.21	0.68	13.54	14.22	0.68	13.60	14.25	0.65
UGW-1	26.90	11.20	14.35	3.15	11.25	14.40	3.15	11.40	14.55	3.15
MW-4	26.93	9.25	10.22	0.97	9.59	10.58	0.99	9.56	11.00	1.44
FW-9	19.98	15.68	16.34	0.66	15.70	16.32	0.62	15.58	16.19	0.61
FW-8	23.68	15.04	16.97	1.93	15.20	17.09	1.89	16.27	17.08	0.81
ERW-1	19.25	7.74	8.66	0.92	7.90	8.87	0.97	8.09	9.01	0.92
ERW-2	19.05	12.29	12.72	0.43	12.32	12.75	0.43	12.37	12.80	0.43

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/10/00 Depth to Product* (ft)	8/10/00 Depth to Water* (ft)	8/10/00 Apparent Product Thickness (ft)	8/11/00 Depth to Product* (ft)	8/11/00 Depth to Water* (ft)	8/11/00 Apparent Product Thickness (ft)	8/12/00 Depth to Product* (ft)	8/12/00 Depth to Water* (ft)	8/12/00 Apparent Product Thickness (ft)
NFW-001	23.00	18.74	19.57	0.83	18.98	20.00	1.02	19.13	20.25	1.12
NFW-002	25.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
NFW-003	19.62	16.61	18.84	2.23	16.64	18.90	2.26	16.66	18.95	2.29
NFW-004	19.65	17.38	19.41	2.03	17.37	19.42	2.05	17.38	19.42	2.04
NFW-005	24.50	18.40	22.45	4.05	18.41	22.45	4.04	18.42	22.45	4.03
RW-1	28.80	16.57	18.25	1.68	16.35	18.38	2.03	16.72	18.42	1.70
AW-1	34.80	16.95	21.27	4.32	17	21.24	4.24	17.02	21.2	4.18
AW-2	29.90	17.82	19.22	1.40	17.78	19.55	1.77	17.86	19.86	2.00
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.68	18.92	0.24	18.73	18.95	0.22	18.78	19.00	0.22
FW-6B	19.50	18.91	19.35	0.44	18.94	19.35	0.41	18.96	19.33	0.37
MTMW-1	30.05	17.88	20.66	2.78	17.89	21.65	3.76	17.9	21.66	3.76
MTMW-2	36.90	18.38	22.3	3.92	18.4	22.35	3.95	18.4	22.36	3.96
MTMW-3	34.75	16.71	21.45	4.74	16.81	21.5	4.69	16.78	21.45	4.67
MTMW-4	34.20	18.03	21.6	3.57	18.02	21.72	3.70	18.08	21.78	3.70
UGW-3	37.50	20.50	20.89	0.39	20.51	20.90	0.39	20.53	20.90	0.37
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	12.75	12.82	0.07	13.21	13.27	0.06	13.46	13.51	0.05
MW-03	26.55	15.22	15.44	0.22	15.27	15.50	0.23	13.30	13.55	0.25
PW-05	26.90	13.60	14.3	0.70	13.65	14.35	0.70	13.68	14.58	0.90
UGW-1	26.90	11.63	14.90	3.27	11.81	15.15	3.34	12.03	15.35	3.32
MW-4	26.93	10.32	11.38	1.06	10.62	11.80	1.18	10.71	11.81	1.10
FW-9	19.98	15.86	16.41	0.55	15.92	16.43	0.51	16.00	16.45	0.45
FW-8	23.68	15.35	17.13	1.78	15.50	17.25	1.75	15.69	17.30	1.61
ERW-1	19.25	8.32	9.22	0.90	8.50	9.39	0.89	8.68	9.60	0.92
ERW-2	19.05	12.43	12.86	0.43	12.51	12.94	0.43	12.58	13.00	0.42

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/13/00			8/14/00			8/15/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	19.21	20.40	1.19	19.26	20.54	1.28	19.28	20.67	1.39
NFW-002	25.00	NA	NA	NA	NA	NA	NA	NA	NA	NA
NFW-003	19.62	16.68	19.01	2.33	16.67	19.06	2.39	16.71	19.11	2.40
NFW-004	19.65	17.37	19.42	2.05	17.35	19.41	2.06	17.35	19.43	2.08
NFW-005	24.50	18.43	22.47	4.04	18.43	22.50	4.07	18.46	22.50	4.04
RW-1	28.80	16.67	18.40	1.73	16.75	18.48	1.73	16.78	18.48	1.70
AW-1	34.80	17.05	21.19	4.14	17.06	21.18	4.12	17.09	21.18	4.09
AW-2	29.90	17.8	19.9	2.10	17.8	19.97	2.17	17.8	20.08	2.28
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.81	19.02	0.21	18.85	19.08	0.23	18.88	19.11	0.23
FW-6B	19.50	18.98	19.34	0.36	18.98	19.32	0.34	19.00	19.34	0.34
MTMW-1	30.05	17.9	21.65	3.75	17.92	21.68	3.76	17.93	21.68	3.75
MTMW-2	36.90	18.4	22.4	4.00	18.4	22.4	4.00	18.4	22.4	4.00
MTMW-3	34.75	16.8	21.48	4.68	16.77	21.47	4.70	16.79	21.5	4.71
MTMW-4	34.20	18.02	21.81	3.79	18.02	21.84	3.82	18.02	21.9	3.88
UGW-3	37.50	20.55	20.92	0.37	20.54	20.92	0.38	20.56	20.92	0.36
PW-06	24.90	NA	NA	NA	NA	NA	NA	NA	NA	NA
FW-7	19.20	13.66	13.72	0.06	13.74	13.81	0.07	13.85	13.93	0.08
MW-03	26.55	15.40	15.65	0.25	15.42	15.68	0.26	15.52	15.78	0.26
PW-05	26.90	13.72	14.45	0.73	13.80	14.48	0.68	13.83	14.54	0.71
UGW-1	26.90	12.15	15.51	3.36	12.30	15.60	3.30	12.44	15.72	3.28
MW-4	26.93	10.88	11.98	1.10	11.07	12.22	1.15	11.22	12.41	1.19
FW-9	19.98	16.00	16.46	0.46	16.01	16.49	0.48	16.05	16.55	0.50
FW-8	23.68	15.79	17.37	1.58	15.86	17.43	1.57	15.96	17.47	1.51
ERW-1	19.25	8.83	9.75	0.92	8.95	9.86	0.91	9.09	9.91	0.82
ERW-2	19.05	12.61	13.03	0.42	12.63	13.05	0.42	12.65	13.10	0.45

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/16/00			8/17/00			8/18/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	17.71	18.64	0.93	18.38	19.23	0.85	18.18	18.98	0.80
NFW-002	25.00	17.91	17.97	0.06	None	17.74	NA	None	17.61	NA
NFW-003	19.62	16.72	18.98	2.26	16.73	19.22	2.49	16.75	19.22	2.47
NFW-004	19.65	17.44	19.43	1.99	17.50	19.42	1.92	17.51	19.42	1.91
NFW-005	24.50	19.47	23.00	3.53	19.08	22.05	2.97	19.02	21.65	2.63
RW-1	28.80	17.22	19.00	1.78	17.07	18.80	1.73	16.95	18.68	1.73
AW-1	34.80	17.12	21.12	4.00	17.15	21.23	4.08	17.16	21.16	4.00
AW-2	29.90	18.15	21.11	2.96	18.14	20.83	2.69	18.05	20.52	2.47
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	18.93	19.13	0.20	18.96	19.20	0.24	19.00	19.20	0.20
FW-6B	19.50	19.01	19.37	0.36	19.04	19.35	0.31	19.04	19.38	0.34
MTMW-1	30.05	17.95	21.75	3.80	17.96	21.72	3.76	18	21.73	3.73
MTMW-2	36.90	19.55	23.35	3.80	19.01	22.47	3.46	18.88	22.1	3.22
MTMW-3	34.75	16.81	21.55	4.74	16.8	21.53	4.73	16.83	21.56	4.73
MTMW-4	34.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
UGW-3	37.50	20.59	20.95	0.36	20.60	20.96	0.36	20.60	20.98	0.38
PW-06	24.90	12.95	13.18	0.23	12.82	13.13	0.31	12.76	13.12	0.36
FW-7	19.20	13.49	13.56	0.07	13.20	13.24	0.04	12.68	12.69	0.01
MW-03	26.55	15.48	15.72	0.24	15.38	15.61	0.23	15.29	15.48	0.19
PW-05	26.90	13.98	14.7	0.72	14.00	14.70	0.70	14.03	14.72	0.69
UGW-1	26.90	12.61	15.90	3.29	12.77	16.02	3.25	13.01	16.30	3.29
MW-4	26.93	11.55	12.82	1.27	11.62	12.82	1.20	11.67	12.93	1.26
FW-9	19.98	15.86	16.42	0.56	15.91	16.45	0.54	15.79	16.37	0.58
FW-8	23.68	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-1	19.25	9.30	10.10	0.80	9.44	10.30	0.86	9.56	10.40	0.84
ERW-2	19.05	13.00	13.40	0.40	13.30	13.75	0.45	13.40	13.85	0.45

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/19/00			8/20/00			8/21/00		
		Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)	Depth to Product* (ft)	Depth to Water* (ft)	Apparent Product Thickness (ft)
NFW-001	23.00	17.89	18.72	0.83	18.28	19.11	0.83	18.68	19.75	1.07
NFW-002	25.00	None	17.61	NA	None	17.60	NA	17.61	17.62	0.01
NFW-003	19.62	16.75	19.32	2.57	16.78	19.35	2.57	16.77	19.40	2.63
NFW-004	19.65	17.52	19.42	1.90	17.54	19.44	1.90	17.53	19.42	1.89
NFW-005	24.50	19.00	21.70	2.70	19.00	21.73	2.73	19.00	21.77	2.77
RW-1	28.80	16.92	18.65	1.73	16.94	18.68	1.74	17.92	18.70	0.78
AW-1	34.80	17.17	21.16	3.99	17.17	21.17	4.00	17.21	21.19	3.98
AW-2	29.90	18.01	20.42	2.41	18.02	20.45	2.43	18	20.48	2.48
FW-2	16.30	None	None	None	None	None	None	None	None	None
FW-6A	19.65	19.01	19.22	0.21	19.02	19.25	0.23	19.03	19.23	0.20
FW-6B	19.50	19.06	19.38	0.32	19.06	19.37	0.31	19.09	19.38	0.29
MTMW-1	30.05	17.99	21.76	3.77	18.02	21.78	3.76	18.02	21.77	3.75
MTMW-2	36.90	18.85	22.1	3.25	18.85	22.1	3.25	18.85	22.12	3.27
MTMW-3	34.75	16.85	21.56	4.71	16.87	21.6	4.73	16.87	21.6	4.73
MTMW-4	34.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
UGW-3	37.50	20.62	21.00	0.38	20.62	21.00	0.38	20.65	21.00	0.35
PW-06	24.90	12.83	13.23	0.40	12.80	13.24	0.44	12.80	13.22	0.42
FW-7	19.20	11.77	11.80	0.03	11.37	11.39	0.02	11.07	11.09	0.02
MW-03	26.55	15.18	15.37	0.19	15.10	15.26	0.16	15.00	15.16	0.16
PW-05	26.90	14.03	14.75	0.72	14.05	14.75	0.70	14.05	14.75	0.70
UGW-1	26.90	12.97	16.21	3.24	12.90	16.15	3.25	12.88	16.12	3.24
MW-4	26.93	11.78	13.03	1.25	11.70	12.92	1.22	11.79	13.02	1.23
FW-9	19.98	15.79	16.23	0.44	15.77	16.23	0.46	15.73	16.25	0.52
FW-8	23.68	NA	NA	NA	NA	NA	NA	NA	NA	NA
ERW-1	19.25	9.65	10.47	0.82	9.75	10.55	0.80	9.83	10.67	0.84
ERW-2	19.05	13.46	13.92	0.46	13.57	13.94	0.37	13.54	14.00	0.46

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

TABLE 4-5

GROUNDWATER AND PRODUCT RECOVERY DATA - AUGUST 2000
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY
TOW WAY FUEL FARM - SWMU 7/8
NAVLA STATION ROOSEVELT ROADS, CEIBA, PR

Well ID	Depth of well* (ft)	8/23/00 Depth to Product* (ft)	8/23/00 Depth to Water* (ft)	8/23/00 Apparent Product Thickness (ft)	8/24/00 Depth to Product* (ft)	8/24/00 Depth to Water* (ft)	8/24/00 Apparent Product Thickness (ft)
NFW-001	23.00	14.41	15.45	1.04	16.90	17.81	0.91
NFW-002	25.00	None	17.29	NA	17.43	17.49	0.06
NFW-003	19.62	16.73	19.30	2.57	16.67	19.06	2.39
NFW-004	19.65	17.52	19.42	1.90	17.50	19.42	1.92
NFW-005	24.50	18.66	21.53	2.87	18.90	21.75	2.85
RW-1	28.80	14.67	16.13	1.46	16.64	18.00	1.36
AW-1	34.80	17	20.62	3.62	16.95	20.55	3.60
AW-2	29.90	16.18	17	0.82	17.6	19.45	1.85
FW-2	16.30	None	None	None	None	None	None
FW-6A	19.65	17.91	18.01	0.10	18.00	18.06	0.06
FW-6B	19.50	18.46	18.76	0.30	18.13	18.39	0.26
MTMW-1	30.05	18	21.4	3.40	17.84	20.75	2.91
MTMW-2	36.90	18.71	21.33	2.62	18.8	21.95	3.15
MTMW-3	34.75	16.7	21.9	5.20	16.6	21.05	4.45
MTMW-4	34.20	NA	NA	NA	NA	NA	NA
UGW-3	37.50	20.55	20.92	0.37	20.30	20.67	0.37
PW-06	24.90	12.79	13.27	0.48	12.40	12.90	0.50
FW-7	19.20	None	4.72	NA	None	5.31	NA
MW-03	26.55	14.52	14.66	0.14	14.27	14.44	0.17
PW-05	26.90	14.03	14.75	0.72	14.00	14.68	0.68
UGW-1	26.90	12.45	15.67	3.22	11.50	14.73	3.23
MW-4	26.93	5.08	6.61	1.53	5.63	7.22	1.59
FW-9	19.98	14.46	14.91	0.45	14.76	15.10	0.34
FW-8	23.68	NA	NA	NA	NA	NA	NA
ERW-1	19.25	4.18	5.05	0.87	4.86	5.73	0.87
ERW-2	19.05	13.50	13.97	0.47	13.48	13.92	0.44

Notes:
*- Level measured from top of casing
UGW- Monitor well
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitor well
AW- Mantech chemical oxidation pilot test delivery well
FW- Fractured Wells
NFW- New Fracture Wells
ERW- Extended Radius Wells
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

FIGURES

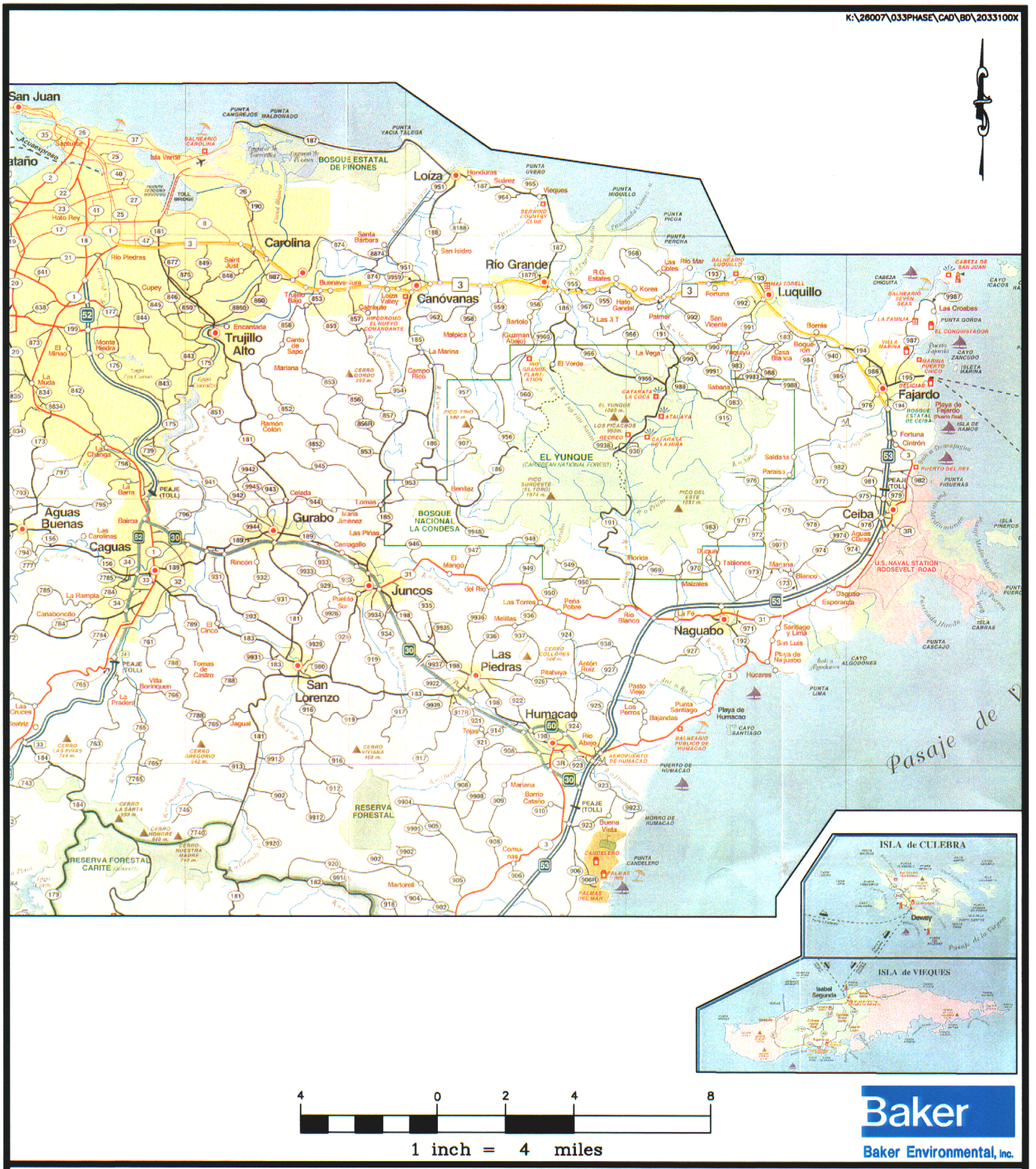


FIGURE 1-1
REGIONAL LOCATION MAP

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

SOURCE: METRODATA, INC., 1999.

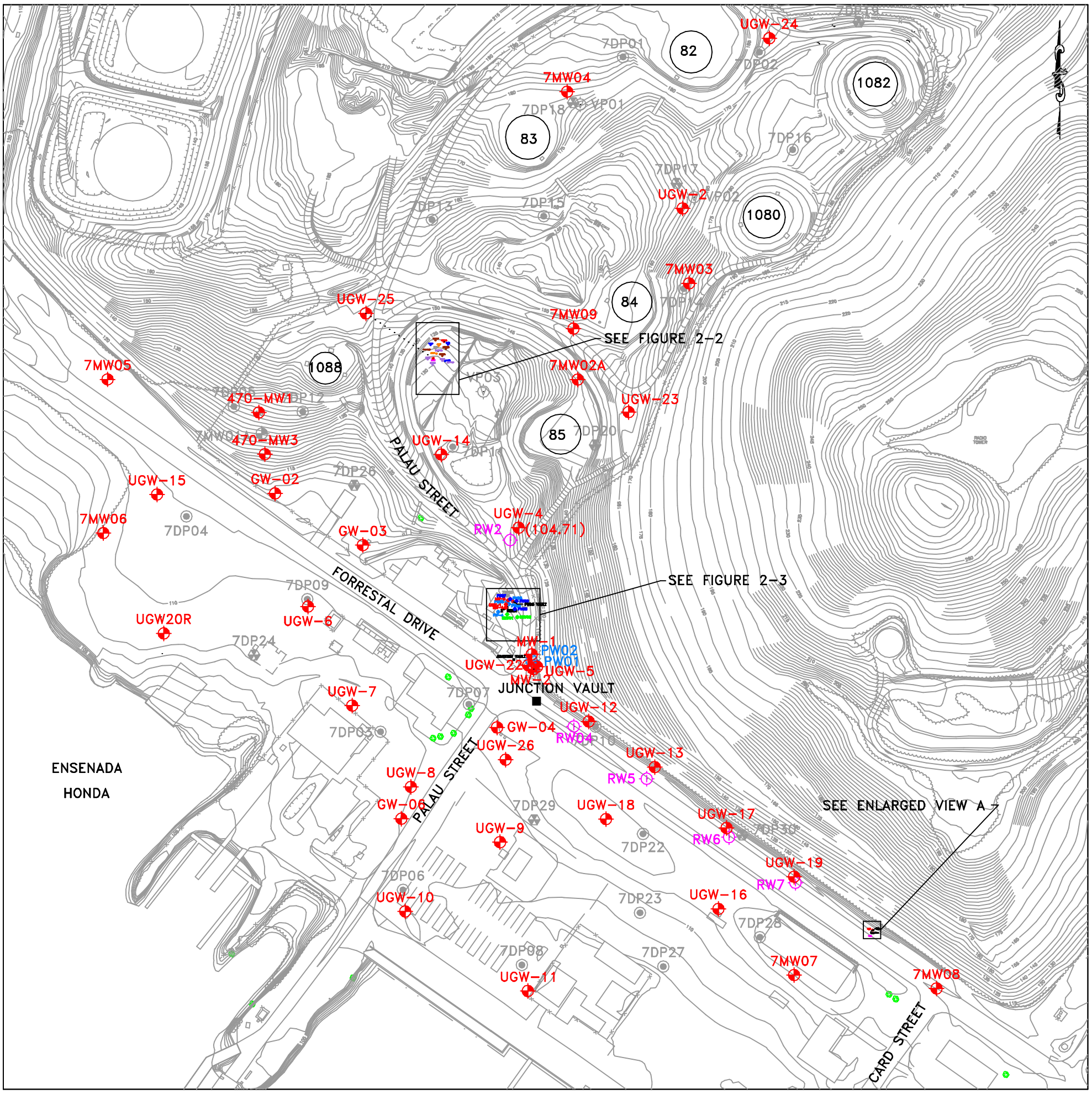
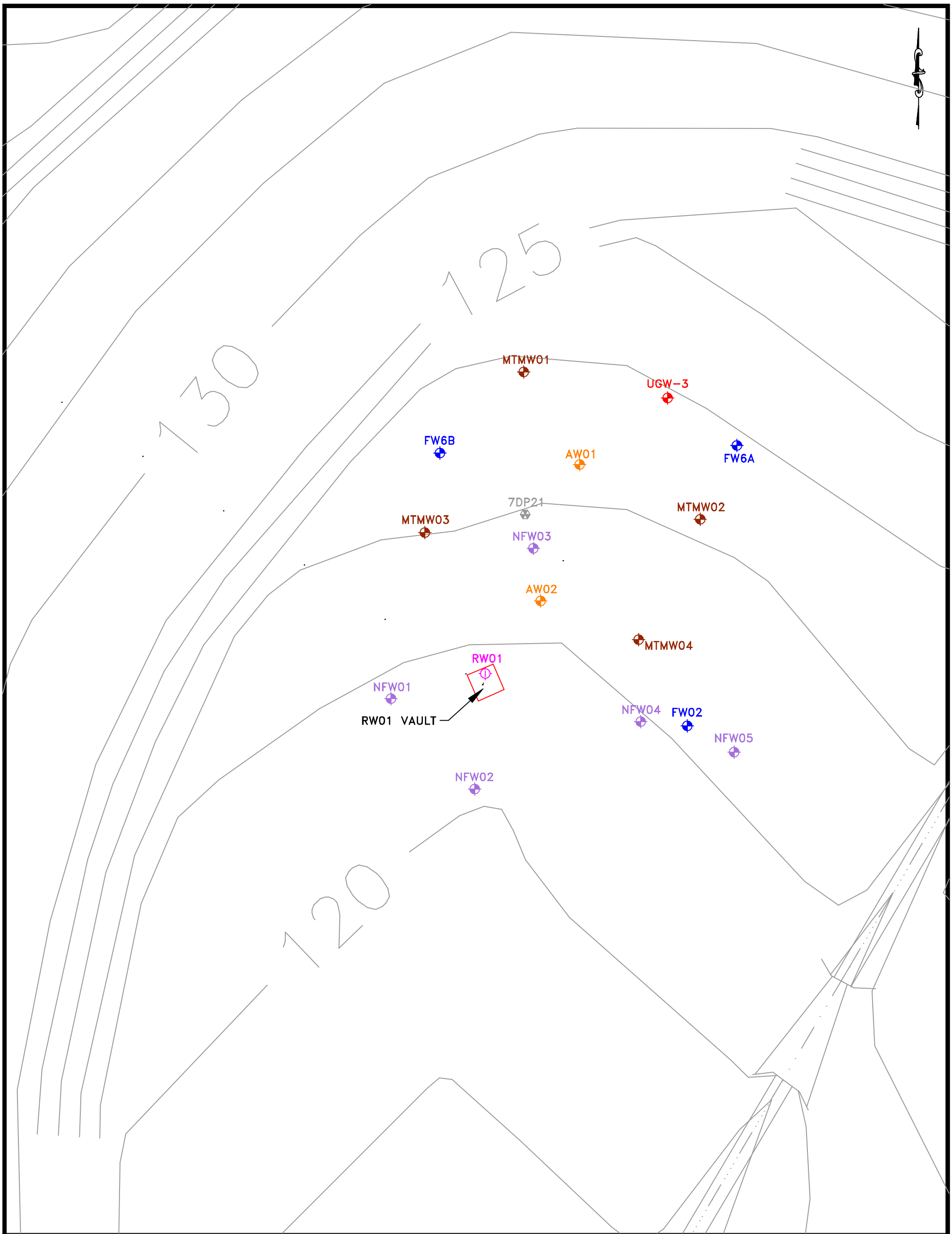


FIGURE 2-1
PILOT TEST
LOCATION MAP
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



10 0 5 10

1 inch = 10 ft.

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NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

Baker

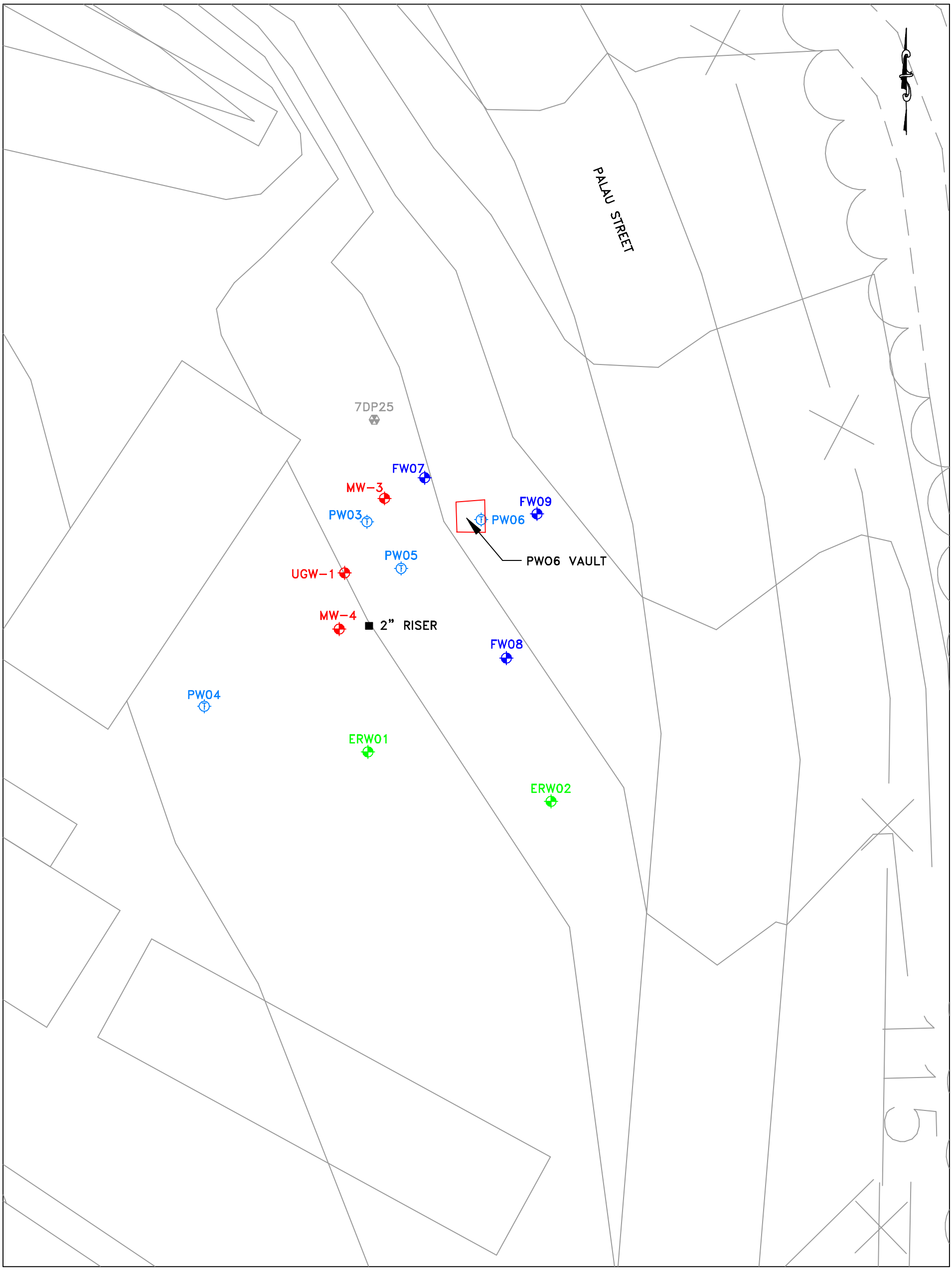
LEGEND

- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- ICHOR PRODUCT RECOVERY WELL LOCATION
- FRACTURE WELL FROM PNEUMATIC FRACTURE PILOT STUDY
- MANTECH MONITORING WELL FROM THE CLEAN OX® PILOT STUDY
- NEW FRACTURE WELL FROM PNEUMATIC FRACTURE PILOT STUDY
- APPLICATION WELL FROM THE CLEAN OX® PILOT STUDY

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-2
RW-1 AREA LOCATION MAP
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO



10 0 5 10

1 inch = 10 ft.

NOTE:
DATUM PLAN USED IS MEAN LOW WATER = 100.00 FT. AS ESTABLISHED BY U.S. NAVY SURVEY SECTION AS OF NOVEMBER 1941.

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LEGEND

- MONITORING WELL LOCATION
- SOIL BORING AND SOIL GAS SAMPLE LOCATION
- TERRAVAC PRODUCT RECOVERY WELL LOCATION
- FRACTURE WELL FROM PNEUMATIC FRACTURE PILOT STUDY
- EXTENDED RADIUS WELL FROM PNEUMATIC FRACTURE PILOT STUDY

SOURCE: LANTDIV, FEB. 1992/1997

FIGURE 2-3
PW-6 AREA LOCATION MAP
TOW WAY FUEL FARM

NAVAL STATION ROOSEVELT ROADS
PUERTO RICO

FIGURE 4-1
POST FRACTURE PRODUCT RECOVERY RW-1

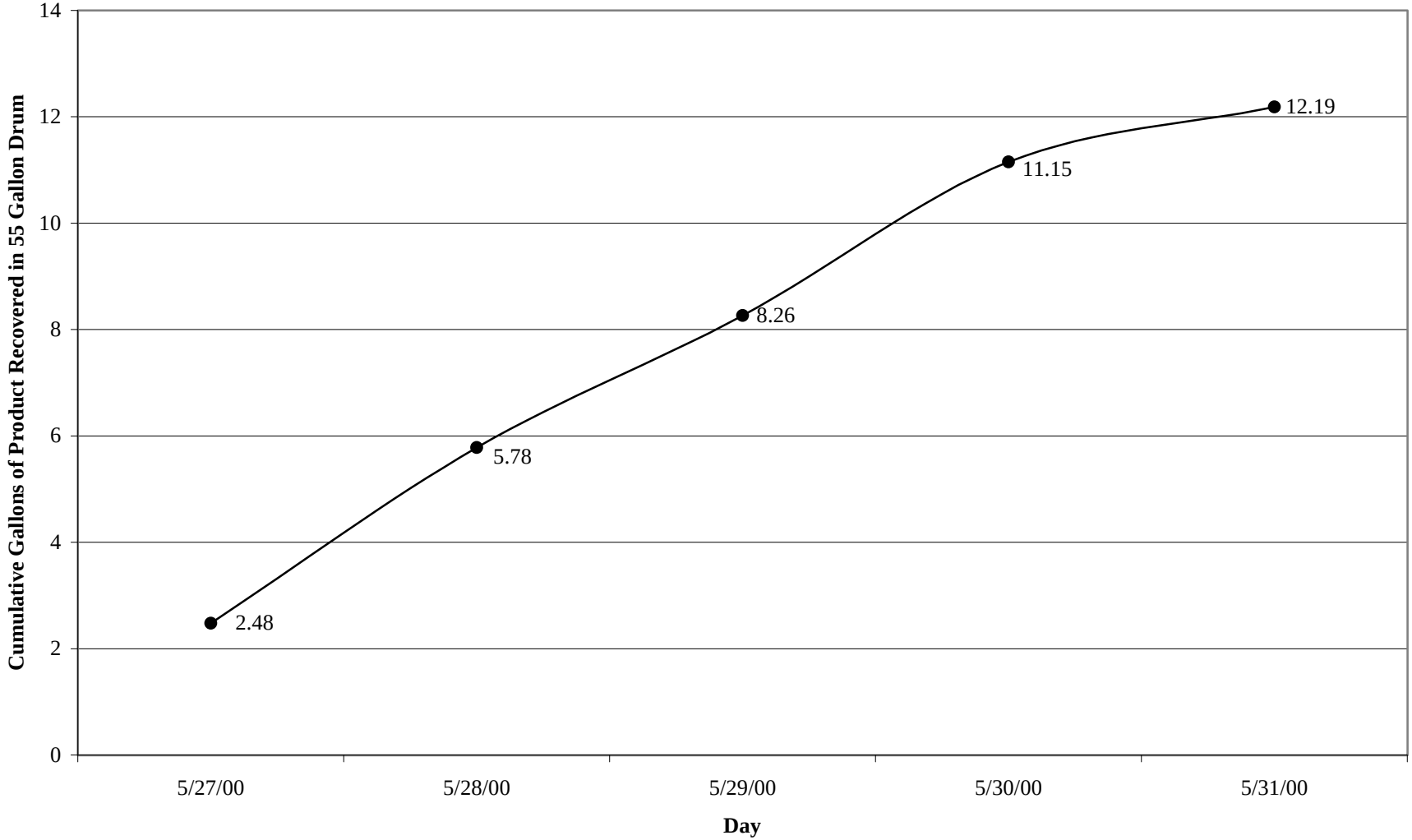


FIGURE 4-2
POST FRACTURE PRODUCT RECOVERY NFW-2

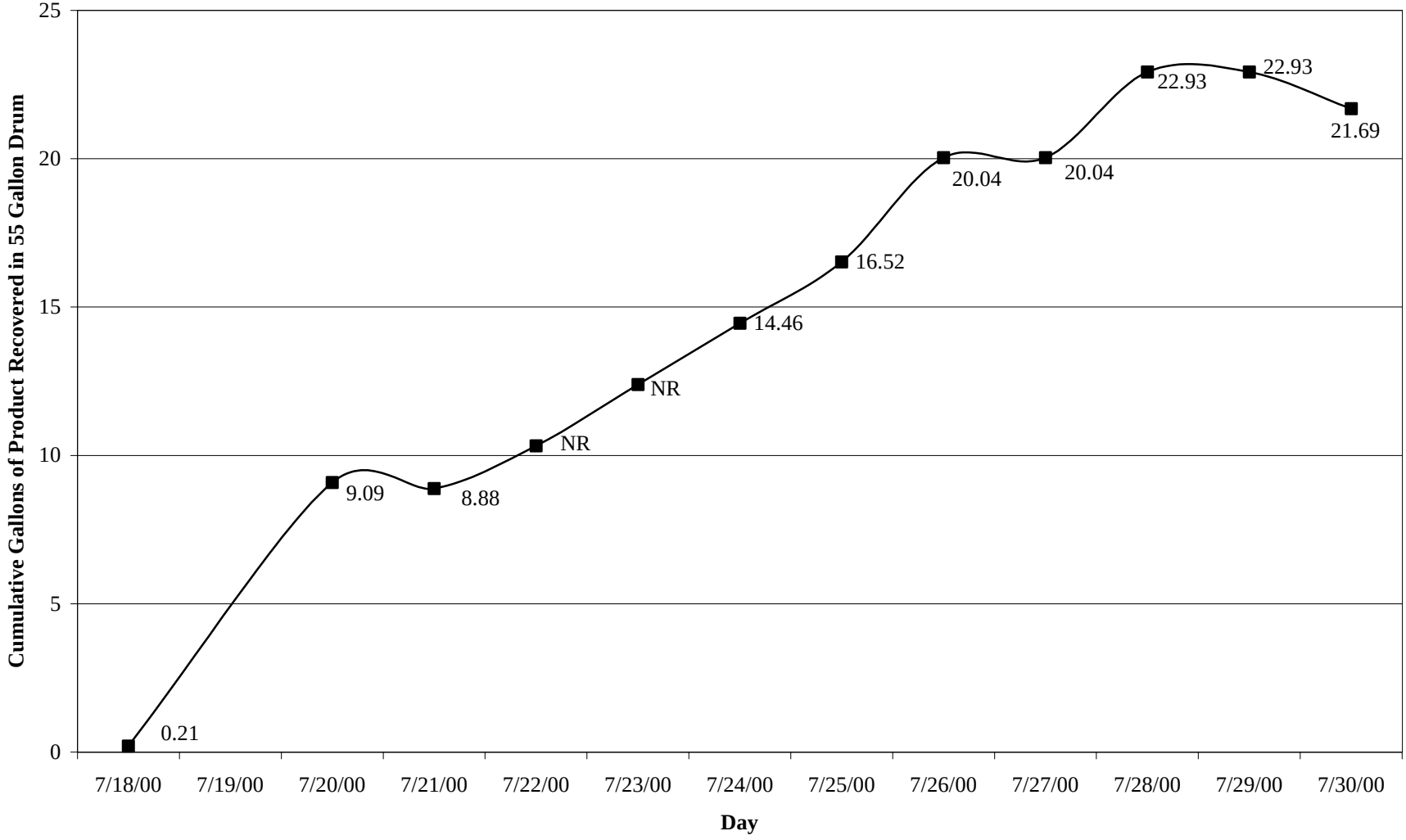


FIGURE 4-3
POST FRACTURE PRODUCT RECOVERY NFW-2

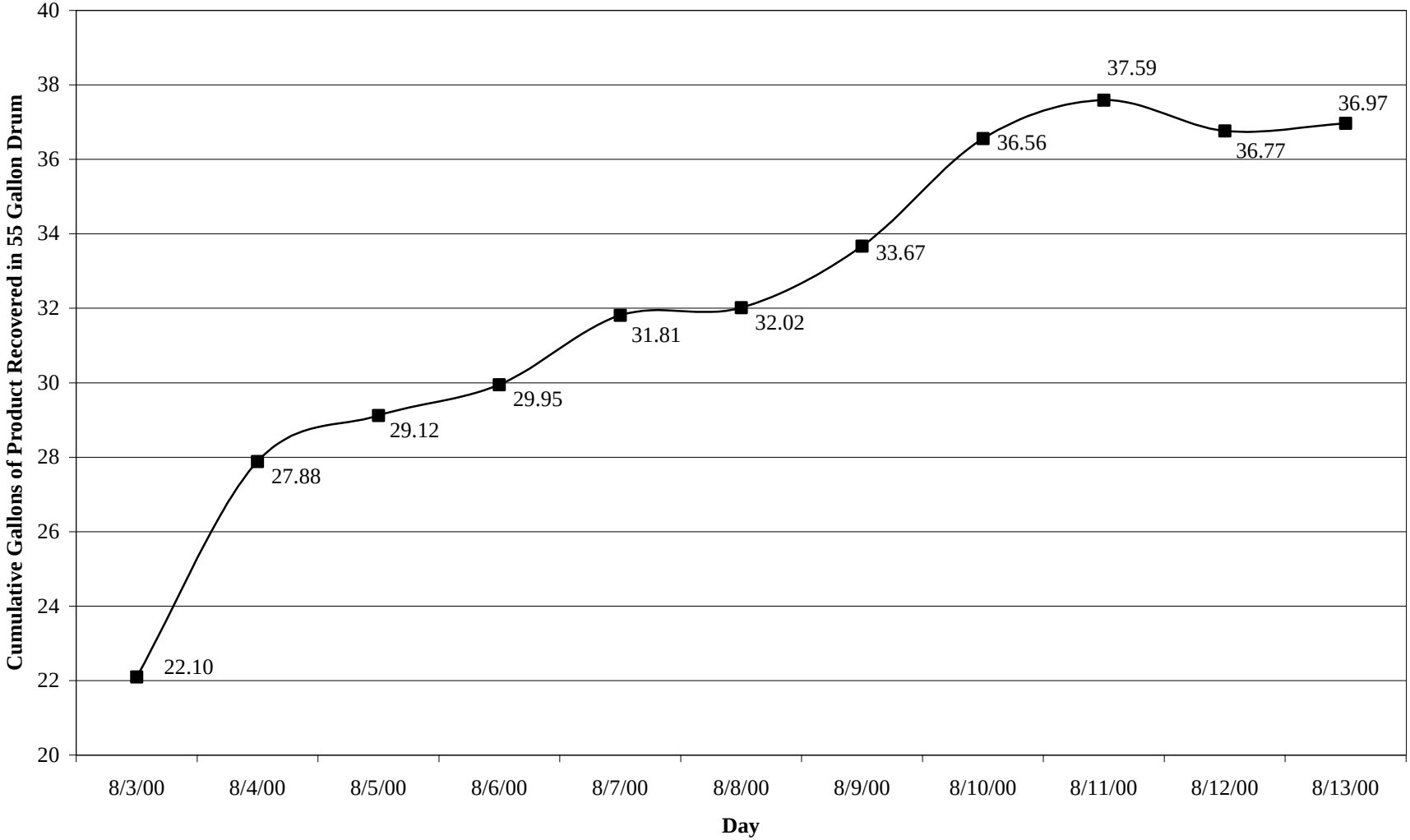


FIGURE 4-4
POST FRACTURE PRODUCT RECOVERY MTMW-4

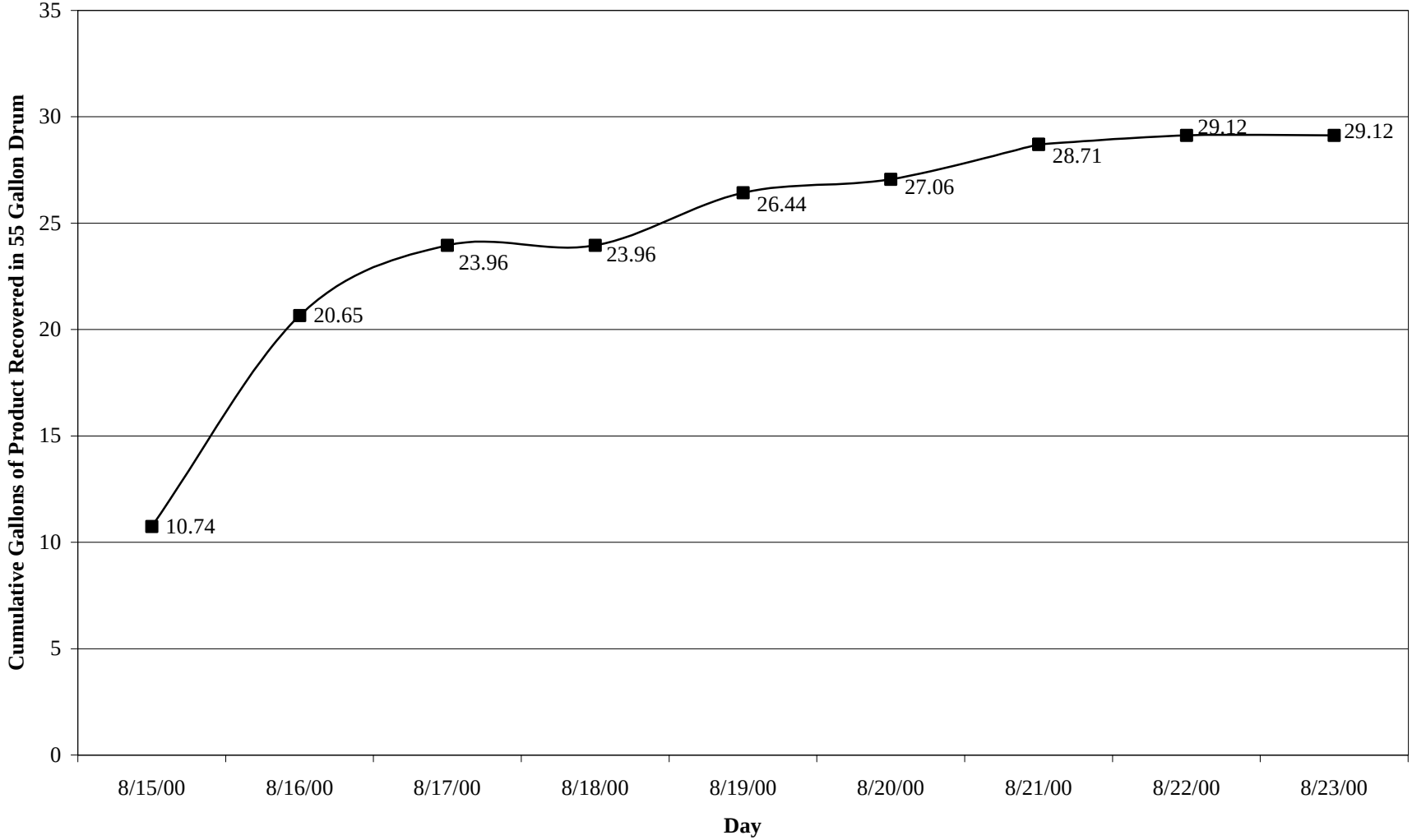


FIGURE 4-5
POST FRACTURE PRODUCT RECOVERY PW-6 (w/20" Hg Vacuum)

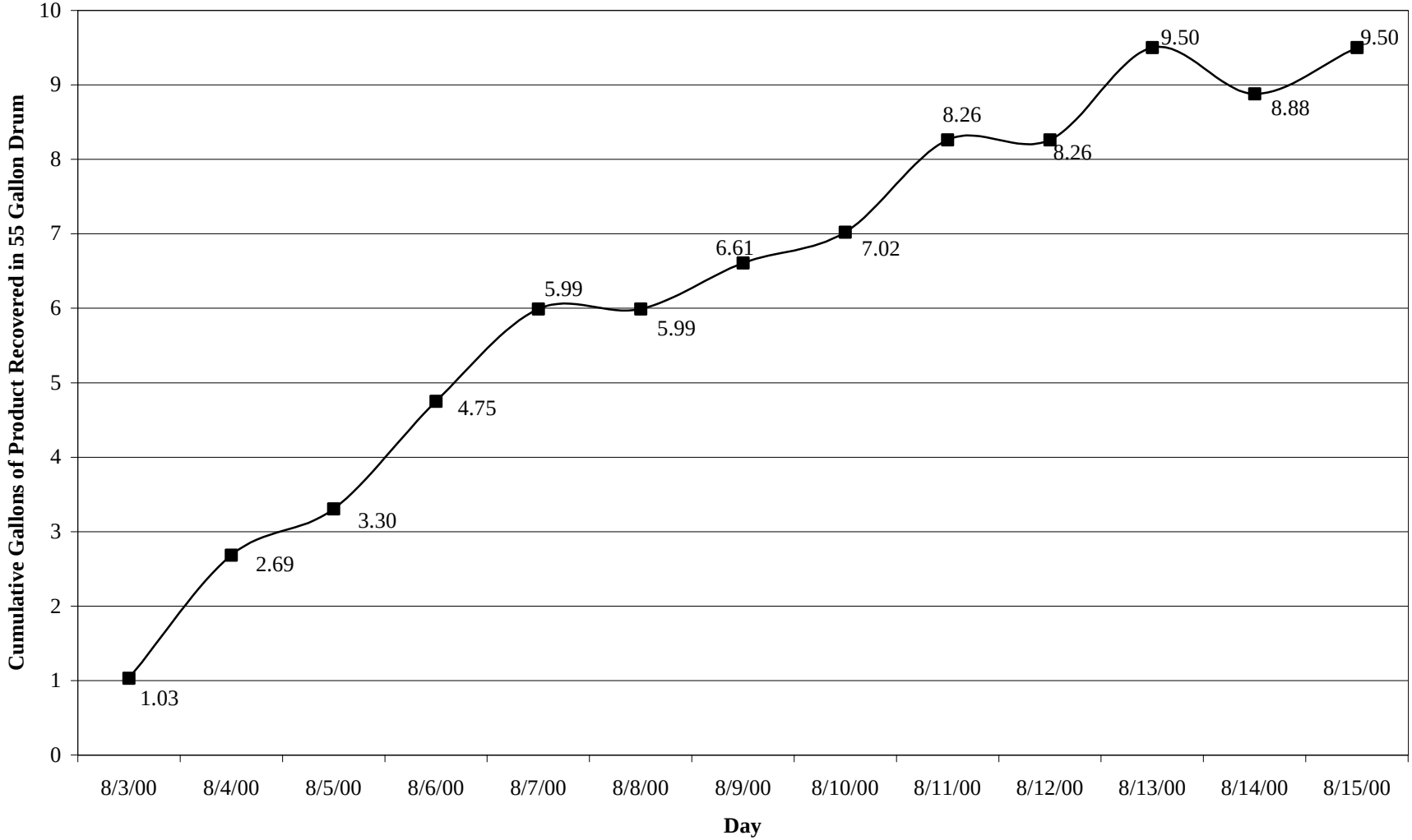
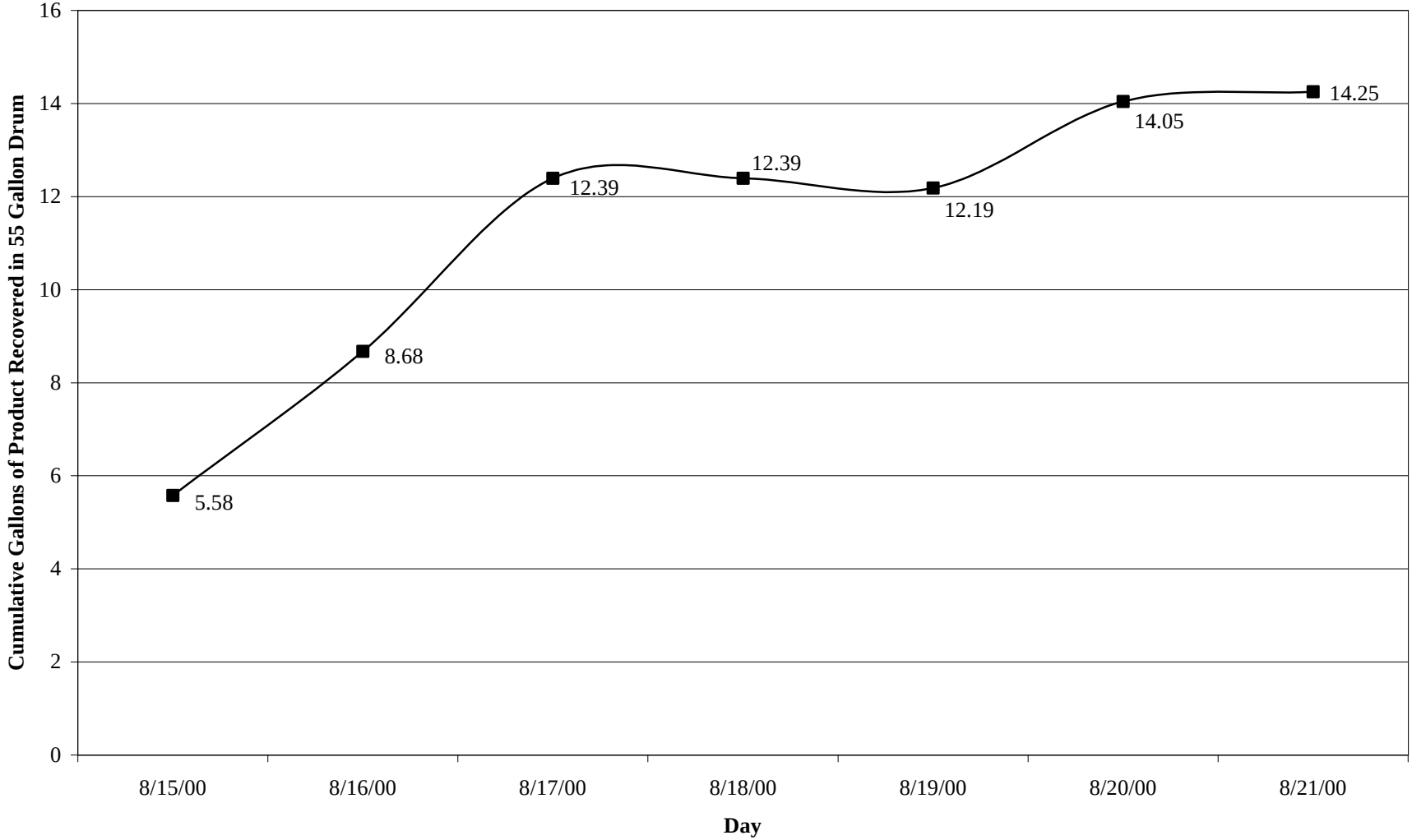


FIGURE 4-6
POST FRACTURE PRODUCT RECOVERY FW-8 (w/20" Hg Vacuum)



APPENDIX A
MCLAREN HART GEOTECHNICAL EVALUATION REPORT

1.0 PRE-PILOT TEST PREPARATION ACTIVITIES

The objective of the pre-pilot test preparation activities is to ensure that the design of the pilot test will be efficient and cost effective. Test preparation activities include the following: 1) site visit by a pneumatic fracture engineer, 2) implementation of a reconnaissance soil boring program, 3) conducting a product assessment in the proposed pilot test area, 4) conducting a geotechnical analysis on selected samples, and 5) determining permit and health and safety issues.

1.1 SITE VISIT

In September 1999, the McLaren/Hart project manager and a pneumatic fracture engineer conducted a site visit to obtain first hand knowledge of the site and pilot test area. They saw the layout of the site; selected two potential pilot test areas; located a soil boring grid for split spoon sample collection; looked at soil samples from the two areas; evaluated free product levels in existing monitoring wells; determined drilling requirements and performance; and identified general pilot test requirements.

During this visit they also met with representatives from the U.S. Naval station environmental staff and field staff of J.A. Jones Management Services Company which is currently monitoring the product recovery system at the site. Information on permit requirements, access requirements by pilot test personnel, utility requirements and general site protocol was also obtained.

1.2 SOIL SAMPLING PROGRAM AND RESULTS

The location of the proposed pilot test areas RW-1 and PW-6 as shown on Figure 4. Both areas are located in the Upper TWFF and are approximately 250 feet apart. A reconnaissance soil-boring program was performed to evaluate the soil conditions at the site and to identify product zones to a depth of 30-ft bgs. This program involved the

collection of 101 split spoon samples from eight soil boring locations within the two pilot test areas.

Samples were collected by driving a 2-ft. by 2-in. diameter split spoon sampler into the undisturbed formation with a 140-pound drop hammer. Once the sample was retrieved, a 2.5-in. hollow stem auger was advanced to the sample depth and the sampling process repeated.

Samples were visually inspected for the evidence of product and were lithologically described using the Burmister Soil Classification System. Shear strengths of the samples were determined using a pocket penetrometer or from the hammer blow counts. On completion of soil classifications, the samples were carefully packed and shipped to the New Jersey Institute of Technology (NJIT), in New Jersey, USA for further inspection and for the determination of selected geotechnical parameters.

1.2.1 RW-1 Area

In September 1999, sixty-five split spoon soil samples were collected from five soil boring locations. Figure 5 shows the soil boring locations in the RW-1 pilot test area. The boring identifications were: MH-SB-2, MH-SB-5, MH-SB-6, MH-SB-7, MH-SB-8 and DP-31A, and the sample identifications were S-#s. Copies of the soil boring logs are included in Appendix C.

Figure 6 shows a geologic cross-section location map and Figure 7 shows two stratigraphic cross sections which are representative of the geology in RW-1 pilot test area. These cross-sections were developed using boring logs from the Mantech Environmental well installation program, the McLaren/Hart reconnaissance soil boring program and the RW-1 well installation log.

Cross-section AA’ is a north to south trend of the area and cross-section BB’ is a northwest to southeast trend of the area. The figure highlights the following:

- From the land surface to a depth of approximately 30-ft, the geologic materials consist of silt and clay with some sand and gravel.
- The geologic material consists of dry to damp clay and sand.
- Lenses or zones of sand and gravel are more evident in the northeast location of the pilot test plot.
- The potentiometric surface in the area of this test plot varies from 3-ft. bgs at RW-1 to 13-ft. bgs at the MTMW-4 location.

1.2.2 PW-6 Area

In September 1999, thirty-six split spoon soil samples were collected from three soil boring locations within this pilot test area. Figure 8 shows the soil boring locations in the PW-6 pilot test area. The boring identifications were: MH-SB-1, MH-SB-3, and MH-SB-4, and the sample identifications were S-#s. Copies of the soil boring logs are also included in Appendix C.

Figure 9 shows one stratigraphic cross-section for this area. This cross-section was developed using the three McLaren/Hart borings. This cross-section was developed to gain a conceptual understanding of the subsurface conditions in the pilot test plot and should not be considered representative of the site-wide geologic conclusions. Cross-section CC' is a northwest to southeast rend of the area. Based on the limited number of soil boring locations, the figure highlights the following:

- From the land surface to a depth of approximately 30-ft, the geologic materials consist of silt and clay with some sand and gravel.
- The geologic material consists of dry to damp clay and sand.
- In the area of MH-SB-4 there is a saprolite zone of weathered gabbro, which is classified texturally as sand and gravel, and occurs from grade to a depth of approximately 20-ft.
- The potentiometric surface in the area of the test plot is approximately 8-ft bgs.

1.3 GEOTECHNICAL TEST PROGRAM

To determine if pneumatic fracturing could be applied to enhance the permeability of the soil formation at the site, samples were shipped to the research laboratory at the Center of Environmental Engineering and Science (CEES), located at NJIT in New Jersey, USA. These samples were reviewed by McLaren/Hart personnel and the NJIT pneumatic fracture technical team.

Five samples from zones identified for product recovery enhancement were analyzed for several geotechnical-engineering parameters. Table 1 shows a summary of the geotechnical test program. It includes: boring ID, type of analysis, American Society of Testing and Materials (ASTM) methods, etc. These boring locations have been prioritized based on field screening of soil samples and the evidence of product in these boring locations. The main geotechnical parameters evaluated were: Atterberg Plastic and Liquid limits by ASTM D2217 and D4318; and Atterberg Shrinkage Limit by ASTM D427. These soils have been classified using the Unified Soil Classification System (ASTM D2487).

1.4 GEOTECHNICAL ANALYTICAL RESULTS

The results of the geotechnical analysis, performed on selected soil samples by NJIT, are presented in Tables 2, 3, and 4. A discussion of the results and recommendations (based on the samples analyzed) for the pneumatic fracture strategy at the site are presented below.

Five soils from NSRR were selected and tested for Atterberg limits [liquid limit (LL), plastic limit (PL), and shrinkage limit (SL)]. This selection was based on a review of the boring logs (i.e., reference to potential product zones and logged PID readings) and odor from the samples. The results, including calculations of plasticity index (PI) and

shrinkage index (SI), are presented in Table 2. Grain size data associated with the wash are shown in Table 3. The data suggest the following:

- The soil passing the No. 40 sieve are highly variable, ranging from silts to clays of both low and high plasticity. This is consistent with the saprolitic nature of the soil, where the residual clay mineralogy is expected to vary according to lithology and weathering conditions.
- The grain size data show that there is 10-50% medium to course sand and gravel. Because the sand and gravel are completely coated with fines, it is expected that the fines will dominate the soil behavior.

An analysis of the potential expansivity of the soil passing the No. 40 sieve was also performed according to empirical relationships show in Table 2.8 of Hall [Hall, H.A. 1995. "Investigation into Fracture Behavior and Longevity of Pneumatically Fractured Fine-Grained Formations," M.S. Thesis, New Jersey Institute of Technology, Newark, NJ]. Results are presented in Table 4 and are summarized below.

- There is some potential for swelling to occur. Sample SB-6 12'-14' shows the greatest potential, with both a high PI (46.2) and a high SI (20.5). It is expected to contain the clay mineral montmorillonite. The sample SB-4 18'-18'10" appears to be of secondary concern.
- It will be difficult to predict swelling zones given the geologic history of the deposit. While lithology is one component which may be traced, clay mineral formation also depends on leaching history, pore water constituents, pH, and temperature. It is recommended that Atterberg limit testing be performed on samples at the screened interval, or, at the very least, that the samples be observed with a trained eye.

The degree of contamination was also monitored on the five samples tested for Atterberg limits. The samples were prioritized from most contaminated to least contaminated based on odor and oil sheen on the wash water as shown below:

SB-4 cuttings

SB-8 18’-20’

SB-4 18’-18’10”

SB-6 12’-14’

SB-6 24’-26’

The two samples which appear to be most contaminated (SB-4 cuttings and SB-8 18’-20’) do not exhibit a great degree of swelling behavior. The samples SB-4 18’-18’10” and SB-6 12’-14’ appeared to be contaminated to a lesser degree, but are both selling soils. Sample SB-6 24’-26’ seemed to be clean and exhibit relatively little swelling.

The results of this testing suggest that the soils must be monitored closely at the site, and that the consideration of proppant use is warranted. The fines are selling and are expected to control soil behavior, contamination was found in the swelling soils, and the degree of potential swelling is believed to be great enough to influence fracture geometry and longevity.

1.5 PNEUMATIC FRACTURING MODEL EVALUATION

Originally when McLaren/Hart began evaluating the use of pneumatic fracturing at the TWFF, two possible application of pneumatic fracturing to enhance product recovery were considered:

1) Using pneumatic fracturing technology (which employs pressurized gases to create fractures) as a method to develop a network of interconnecting fractures that would vastly improve soil permeability and free product recovery.
2) Installing Extended Radius Wells (ERW) at strategic locations associated with product zones. This would be accomplished by using a variation of the pneumatic fracturing technology to inject thin layers of ceramic beads (proppant) which would form highly conductive lenses in and immediately

within the vicinity of product zones. This would improve product recovery well performance by extending well's radius of influence.

Initially, based upon field observations that the soil appeared to be dense and brittle, it was believed that the soil could be fractured without the need to maintain fracture apertures with proppants. However, as discussed above, when certain geotechnical tests were performed, some of the samples exhibited swelling behavior. Therefore, in a portion of this pilot test, ERWs will be installed to create thin conductive lenses adjacent to the product zones.

In association with technology applicability review, further evaluation of the application of pneumatic fracture and ERWs was performed using the windows-based pneumatic fracture Model. This program, developed at the CEES provided guidelines for optimum and safe field implementation of the technology (e.g., injection pressures, expected radius of influence and fracture aperture dimensions).

The model consists of three major components: site screening, system design, and calibration components. The site-screening component was used to determine a technology recommendation rating for permeability enhancement, dry media injection and liquid media injection. The system design component provided information of fracture aperture, radius of influence, maintenance pressures and the effect of various injection flow rates. The calibration component allowed data from site pilot tests to be inserted into the model so that the model could be calibrated to sit-specific conditions.

The following conclusions were made using the pneumatic fracture Model in conjunction with geotechnical analyses:

1) The soils will benefit from a permeability enhancement program.
2) Injection of a dry media (proppant) is recommended in select locations.
3) Depending on treatment depth, injection pressures would be in the range of 250 to 600 psi.

4) Maintenance pressures will vary between 81 to 87 psi.
5) Injection flow rates will vary between 1000 – 3000 SCFM.
6) Fracture apertures will vary from 0.02 – 0.04 inches.
7) Radius of influence will vary from 10 – 16 feet.

1.6 PRODUCT EVALUATION

An evaluation of free product in the two pilot test areas was performed based on a review of soil geologic logs, evaluation of soil samples from a reconnaissance soil boring program and measurement of Light Non-Aqueous Phase Liquid (LNAPL) in pumping and monitoring (existing and M/H temporary) wells. The following summarizes the findings for each pilot test area.

1.6.1 RW-1 Area Soils

Six existing boring logs and soil samples from six McLaren/Hart soil borings were reviewed for this area. This existing soil boring logs are: RW-1, AW-1, AW-2, MTMW-1, MTMW-3, and MTMW-4. Except for RW-1, the logs were prepared by Mantech Environmental during their Chemical Oxidation Pilot test. The McLaren/Hart soil boring locations are: DP-31A, MH-SB-2, MH-SB-5, MH-SB-6, MH-SB-7 and MH-SB-8. All logs are included in Appendix C.

A review of the Mantech Environmental boring logs show that product zones vary between a quarter of an inch and two feet. These thicknesses were observed at various elevations in the borings and were all above the water-saturated zone for that location. A two foot saturated product zone was observed at MTMW-4 at a depth of 18 to 20 ft. bgs. The deepest zone where product was identified was 29 to 29.5 ft. bgs at MTMW-1. There is no documented evidence of free product in the boring log of RW-1.

During the McLaren/Hart reconnaissance soil-boring program, samples from six soil borings were evaluated. Except for MH-SB-8 sample location (at a depth of 18 to 20 ft.

bgs) there was no clear evidence of product saturated zones in any of the remaining soil samples. At some sample depths, where no product was visible, but a strong odor was obvious, the locations were logged as damp.

During sampling at MH-SB-6, a damp sample, retrieved from a depth of 20 to 22 ft. bgs had a diesel odor. A measurement for product was made inside of the auger at this depth, and 22 inches of diesel fuel was measured. The first evidence of water was observed at 24 ft. bgs. This boring was completed to 29 ft. bgs, and no further evidence of product was observed in the soil samples. A check of the open borehole approximately 30 minutes after the final depth of 29 ft. was achieved showed no evidence of free product. There was less than 4 inches of water in the well at the time of the measurement.

1.6.2 RW-1 Area LNAPL

A survey of existing wells and the new temporary monitoring wells installed by McLaren/Hart shows that there is free product in some areas of the site. The results of several rounds of monitoring for free product and groundwater is summarized in Table 5. The distribution of free product is also shown on the geologic cross-section AA' and BB' on Figure 7.

In the Mantech Environmental wells on 9/25/99, product thickness varied from 3.7 feet at MTMW-4 to 5.0 feet at MTMW-2. On the same day, 1.9 feet of product was measured at the temporary McLaren/Hart monitoring well location MH-SB-6. There was no measurable product thickness in the RW-1 well on 9/25/99. Based on the groundwater data collected, the potentiometric level is approximately 16 to 18 ft. bgs (see Table 5).

This evidence from the soil and groundwater evaluation shows that there is a free product plum in the zone 15 to 25 ft. bgs. This plume is above a semi-confining layer, which varies between 24 and 38 ft. bgs based on the soil boring logs for this area.

3.6.3 PW-6 Area Soils

No soil borings or wells construction logs for existing wells were available for review. Evaluation of soils in this are was based on samples from three McLaren/Hart soil borings: MH-SB-1, MH-SB-3 and MH-SB-4. These logs are include in Appendix C.

During sampling at the MH-SB-1 location, evidence of product was observed in a moist zone 10 to 12 ft. bgs. There was also a petroleum odor at this zone. Samples collected above and below this zone were dry. At the MH-SB-3 location, a damp to moist zone was observed 16 to 18 ft. bgs on 9/20/99. Before continuing the borings on 9/21/99, one foot of product was measured in the borehole. Continued sampling at this location showed a moist zone of product at approximately 22.5 to 24 ft. bgs. There was no further evidence of product in samples collected from this location. At the MH-SB-4 location, product was observed at 16.5 to 17 ft. bgs on 9/21/99. Prior to sampling, on the following day (9/22/99), 2 feet of product was measured in this borehole. During split spoon sampling, the 20 to 22 foot zone was observed to be saturated with product.

1.6.4 PW-6 Area LNAPL

A survey of existing wells and the temporary wells installed by McLaren/Hart shows that there is some evidence of free product in this area. The results of several rounds of monitoring for free product and groundwater are summarized in Table 5. The distribution of free product is also shown on the geologic cross-section CC' on Figure 9.

In existing wells, product thickness varies form 0.3 to 0.2 feet at PW-06 and PW-05 respectively. In the temporary McLaren/Hart monitoring wells product was observed in all wells, with product thickness varying form 1 to 10 feet at MH-SB-3 and MH-SB-1 respectively. It should be noted that the thickness at MH-SB-1 might be an anomaly based on well construction technique. Based on the groundwater measurements, the potentiometric level is approximately 14 ft. bgs (see Table 5).

This evidence shows that there is a free product plume in the zone 10 to 25 ft. bgs. This plume is above a semi-confining layer.

1.7 PERMIT ACQUISITION

Based on conversations with the U.S. Naval Station Environmental Management team in Puerto Rico, no permit for the performance of a pilot test at the TWFF is required. However, since the injection process involves the injection of an inert gas (e.g., industrial grade nitrogen) and an inert media (ceramic beads), approval from EQB is required.

Table 1. Summary of Geotechnical Test Program
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Pilot Test Location	Sample Media	Boring ID	Laboratory Analysis	ASTM Designation	Number of Samples	Field Sample Collection
RW-1	Soil	• MH-SB-6 • MH-SB-8	• USCS Classification • Grain Size • Liquid Limit • Plastic Limit • Shrinkage Limit	• D2487-93 • D422-63 • D2217-85 • D4318-84 • D427	3 3 3 3 3	• Auger/ Drill Rig • Split spoon
PW-6	Soil	• MH-SB-4	• USCS Classification • Grain Size • Liquid Limit • Plastic Limit • Shrinkage Limit	• D2487-93 • D422-63 • D2217-85 • D4318-84 • D427	2 2 2 2 2	• Auger/ Drill Rig • Split spoon

RW- Recovery well location
PW- Pumping well location
USCS- Unified Soil Classification System
MH-SB-#- McLaren/Hart - soil boring- number

Table 2. **Atterberg Limit Test Results**
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Sample ID	Sample Depth	Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit (%)	Plasticity Index (%)	Shrinkage Index (%)	Classification**
MH-SB-8	18' - 20'	36.9 37.4	20.8 20.8	16.8	16.4	4	CL
MH-SB-4	18' - 18'10"	59.9	38.6	21.7	21.7	21.2	MH
MH-SB-4 cuttings*		40.6	21.4	19.2	19.2	8.3	CL
MH-SB-6	24' - 26'	45.8	29.4	17.9	16.4	11.5	ML
MH-SB-6	12' - 14'	80.9	34.7	14.2	46.2	20.5	CH

* Soil cuttings collected from a depth of 21' below grade surface using augers.

Represents plasticity chart classification for soil passing the No. 40 sieve, **not total soil sample.

MH-SB-# - McLaren/Hart soil boring number
CL - Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
MH - Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
ML - Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
CH - Inorganic clays of high plasticity, fat clays

Table 3. **Grain Size Data**
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Sample ID	Sample Depth	>No. 40 Sieve (%)	<No. 40 Sieve (%)
MH-SB-8	18' - 20'	23.8	76.2
MH-SB-4	18' - 18'10"	50.1	49.9
MH-SB-4 cuttings*		36.3	63.7
MH-SB-6	24' - 26'	53.1	46.9
MH-SB-6	12' - 14'	10.5	89.5

* Soil cuttings collected from a depth of 21' below grade surface using augers.

MH-SB-# - McLaren/Hart soil boring number

Table 4. **Volume Change Potential**
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Investigator*	MH-SB-8 18'-20'	MH-SB-4 18'-18'10"	MH-SB-4 cuttings**	MH-SB-6 24'-26'	MH-SB-6 12'-14'
Chen (1988)	M	M	M	M	H
Ranganatham and Satyanarayana (1965)	L	M	L	L-M	M
Raman (1967)	L-M	M	L-M	L-M	M-VH
Altmeyer (1955)	L	L	L	L	L
Holtz and Gibbs (1956)	L	L-M	M	L-M	M-VH
Chen (1965)	M	VH	H	H	VH
Snethen et al. (1977)	L	L-H	L	L	H

* Hall, H.A. "Investigation into fracture behavior and longevity of pneumatically fractured fine-grained formations", Master's Thesis, NJIT, Table 2.8, pg. 44, October 1995.
** Soil cuttings collected from a depth of 21' below grade surface using augers.

MH-SB-# - McLaren/Hart soil boring number
L- Low
M- Moderate
H- High
V- Very

Table 5. **Groundwater and Product Recovery Data**
September 1999
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Well ID	Depth of well*	9/22/99			9/23/99			9/25/99			9/30/99		
		Depth to		Apparent	Depth to		Apparent	Depth to		Apparent	Depth to		Apparent
		Product*	Water*	Product Thickness	Product*	Water*	Product Thickness	Product*	Water*	Product Thickness	Product*	Water*	Product Thickness
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
MH-SB-1	18	NA	NA	NA	NA	NA	NA	7.70-18.00	0.00	10.40	7.70	18.05	10.35
MH-SB-3S	25	14.90	15.60	0.70	NA	NA	NA	11.50	12.50	1.00	5.20	8.00	2.80
MH-SB-3D	30	0.00	13.30	0.00	NA	NA	NA	0.00	11.60	0.00	10.90	11.05	0.15
MH-SB-3 Hole	25	NA	NA	NA	NA	NA	NA	10.90	14.10	3.20	NA	NA	NA
MH-SB-4	21.5	NA	NA	NA	6.63	12.03	5.40	9.43	15.63	6.20	9.44	15.36	5.92
MH-SB-4 Hole	21.5	NA	NA	NA	12.60	15.70	3.10	9.50	13.30	3.80	7.20	13.00	5.80
PW-06	NA	11.37	11.52	0.15	NA	NA	NA	11.40	11.52	0.03	NA	NA	NA
PW-05	26.9	9.15	9.30	0.15	NA	NA	NA	9.20	9.40	0.20	NA	NA	NA
PW-03	26.3	NA	NA	NA	NA	NA	NA	9.83	9.98	0.15	NA	NA	NA
UGW-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4	27.7	NA	NA	NA	NA	NA	NA	3.87	3.97	0.10	NA	NA	NA
MW-3	22.2	NA	NA	NA	NA	NA	NA	10.27	10.35	0.08	NA	NA	NA
RW-1	35	0.00	16.25	0.00	0.00	16.59	0.08	0.00	16.50	0.00	NA	NA	NA
UGW-3	NA	17.57	18.2	0.63	17.55	18.17	0.62	0.00	17.62	0.00	NA	NA	NA
AW-1	36	16.95	21.1	4.15	16.95	21.20	4.25	16.95	21.15	4.20	NA	NA	NA
AW-2	31	16.14	19.81	3.67	16.26	19.69	3.43	16.24	19.64	3.40	NA	NA	NA
MTMW-1	40	17.83	21.68	3.85	17.91	21.65	3.74	17.93	21.68	3.75	NA	NA	NA
MTMW-2	NA	19.08	21.98	2.90	17.1	22.03	4.93	17.13	22.13	5.00	NA	NA	NA
MTMW-3	35	16.89	20.59	3.70	16.86	20.59	3.73	16.34	20.38	4.04	NA	NA	NA
MTMW-4	36	18.29	21.09	2.80	16.35	21.13	3.78	16.89	20.59	3.70	NA	NA	NA
DP-31A	18	NA	NA	NA	NA	NA	NA	0.00	13.00	0.00	NA	NA	NA
MH-SB-2	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-5	29	NA	NA	NA	NA	NA	NA	0.00	15.68	0.00	0.00	15.25	0.00
MH-SB-5 Hole	29	NA	NA	NA	0.00	19.80	0.00	0.00	16.70	0.00	NA	NA	NA
MH-SB-6 S	19	NA	NA	NA	NA	NA	NA	15.70	15.90	0.20	13.60	15.50	1.90
MH-SB-6 D	29	NA	NA	NA	NA	NA	NA	0.00	15.50	0.00	0.00	16.25	0.00
MH-SB-6 Hole	19	NA	NA	NA	16.01	16.31	0.30	14.91	15.91	1.00	12.51	14.21	1.70
MH-SB-7	13.5	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00	NA	NA	NA
MH-SB-8	26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

*- Level measured from grade
MH-SB-#, S,D- McLaren/Hart soil boring number, shallow well or deep well.
MH-SB-#, Hole- McLaren/Hart soil boring number, borehole common with shallow well.
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitoring well
AW- Mantech chemical oxidation pilot test delivery well
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

Table 5. (cont.) **Groundwater and Product Recovery Data**
October 1999
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Well ID	Depth of well*	10/6/99			10/13/99			10/27/99		
		Depth to		Apparent	Depth to		Apparent	Depth to		Apparent
		Product*	Water*	Product Thickness	Product*	Water*	Product Thickness	Product*	Water*	Product Thickness
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
MH-SB-1	18	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-3S	25	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-3D	30	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-3 Hole	25	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-4	21.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-4 Hole	21.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
PW-06	NA	15.02	15.52	0.50	10.87	11.62	0.75	9.12	9.92	0.80
PW-05	26.9	8.80	8.95	0.15	7.45	7.52	0.07	7.22	7.3	0.08
PW-03	26.3	9.38	9.48	0.10	7.83	7.93	0.10	4.03	4.13	0.10
UGW-1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-3	22.2	9.82	9.92	0.10	9.17	9.22	0.05	11.80	11.83	0.03
RW-1	35	14.86	14.88	0.02	14.16	14.17	0.01	13.45	13.68	0.23
UGW-3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
AW-1	36	NA	NA	NA	NA	NA	NA	NA	NA	NA
AW-2	31	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTMW-1	40	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTMW-2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTMW-3	35	NA	NA	NA	NA	NA	NA	NA	NA	NA
MTMW-4	36	NA	NA	NA	NA	NA	NA	NA	NA	NA
DP-31A	18	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-2	30	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-5	29	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-5 Hole	29	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-6 S	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-6 D	29	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-6 Hole	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-7	13.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-8	26	NA	NA	NA	NA	NA	NA	NA	NA	NA

*- Level measured from grade
MH-SB-#, S,D- McLaren/Hart soil boring number, shallow well or deep well.
MH-SB-#, Hole- McLaren/Hart soil boring number, borehole common with shallow well.
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitoring well
AW- Mantech chemical oxidation pilot test delivery well
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

Table 5. (cont.) **Groundwater and Product Recovery Data**
November 1999
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Well ID	Depth of well*	11/3/99			11/10/99			12/1/99		
		Depth to		Apparent	Depth to		Apparent	Depth to		Apparent
		Product*	Water*	Product Thickness	Product*	Water*	Product Thickness	Product*	Water*	Product Thickness
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
MH-SB-1	18	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-3S	25	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-3D	30	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-3 Hole	25	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-4	21.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-4 Hole	21.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
PW-06	NA	9.32	10.12	0.80	9.42	10.22	0.80	4.92	4.92	Sheen
PW-05	26.9	7.20	7.31	0.11	7.13	7.25	0.12	4.10	4.15	0.05
PW-03	26.3	7.37	7.37	0.00	7.46	7.46	0.00	3.43	3.43	0.00
UGW-1	NA	NA	NA	NA	NA	NA	NA	6.10	6.20	0.10
MW-4	NA	NA	NA	NA	NA	NA	NA	0.52	0.77	0.25
MW-3	22.2	8.27	8.27	0.00	8.45	8.45	0.00	2.97	2.97	0.00
RW-1	35	12.45	12.63	0.18	12.15	12.4	0.25	6.35	6.50	0.15
UGW-3	NA	NA	NA	NA	15.32	15.97	0.65	12.12	12.77	0.65
AW-1	36	NA	NA	NA	14.70	18.55	3.85	NA	NA	NA
AW-2	31	NA	NA	NA	12.69	14.59	1.9	NA	NA	NA
MTMW-1	40	NA	NA	NA	15.73	18.93	3.2	NA	NA	NA
MTMW-2	NA	NA	NA	NA	13.38	21.48	8.1	NA	NA	NA
MTMW-3	35	NA	NA	NA	17.39	17.84	0.45	NA	NA	NA
MTMW-4	36	NA	NA	NA	12.59	20.64	8.05	NA	NA	NA
DP-31A	18	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-2	30	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-5	29	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-5 Hole	29	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-6 S	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-6 D	29	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-6 Hole	19	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-7	13.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MH-SB-8	26	NA	NA	NA	NA	NA	NA	NA	NA	NA

*- Level measured from grade
MH-SB-#, S,D- McLaren/Hart soil boring number, shallow well or deep well.
MH-SB-#, Hole- McLaren/Hart soil boring number, borehole common with shallow well.
PW- Pumping well
RW- Product recovery well
DP- Direct push monitoring well
MW- Monitoring well
AW- Mantech chemical oxidation pilot test delivery well
MTMW- Mantech chemical oxidation pilot test monitoring well
NA - Not available

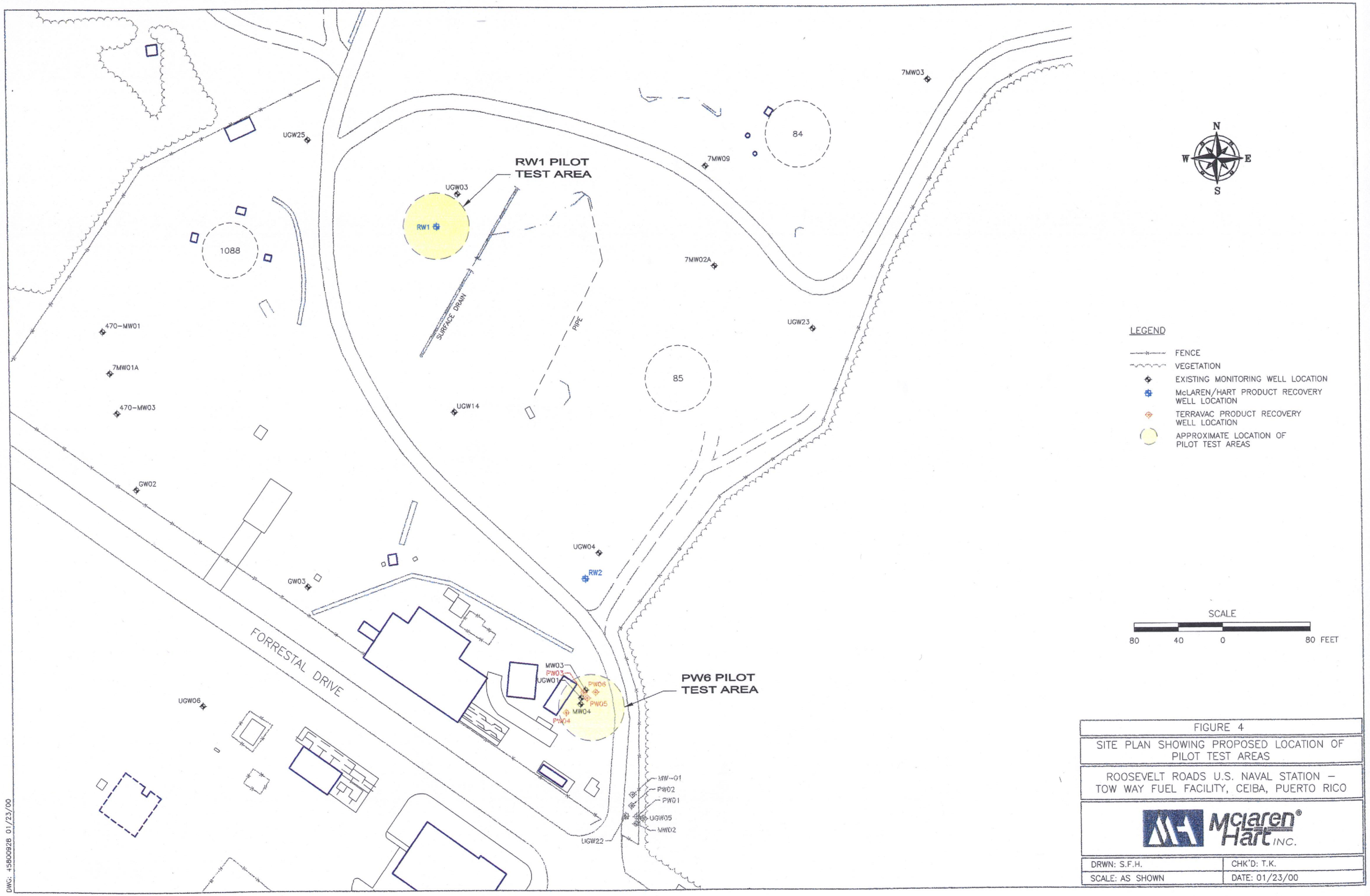


FIGURE 4

SITE PLAN SHOWING PROPOSED LOCATION OF PILOT TEST AREAS

ROOSEVELT ROADS U.S. NAVAL STATION – TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

McLaren Hart INC.

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00

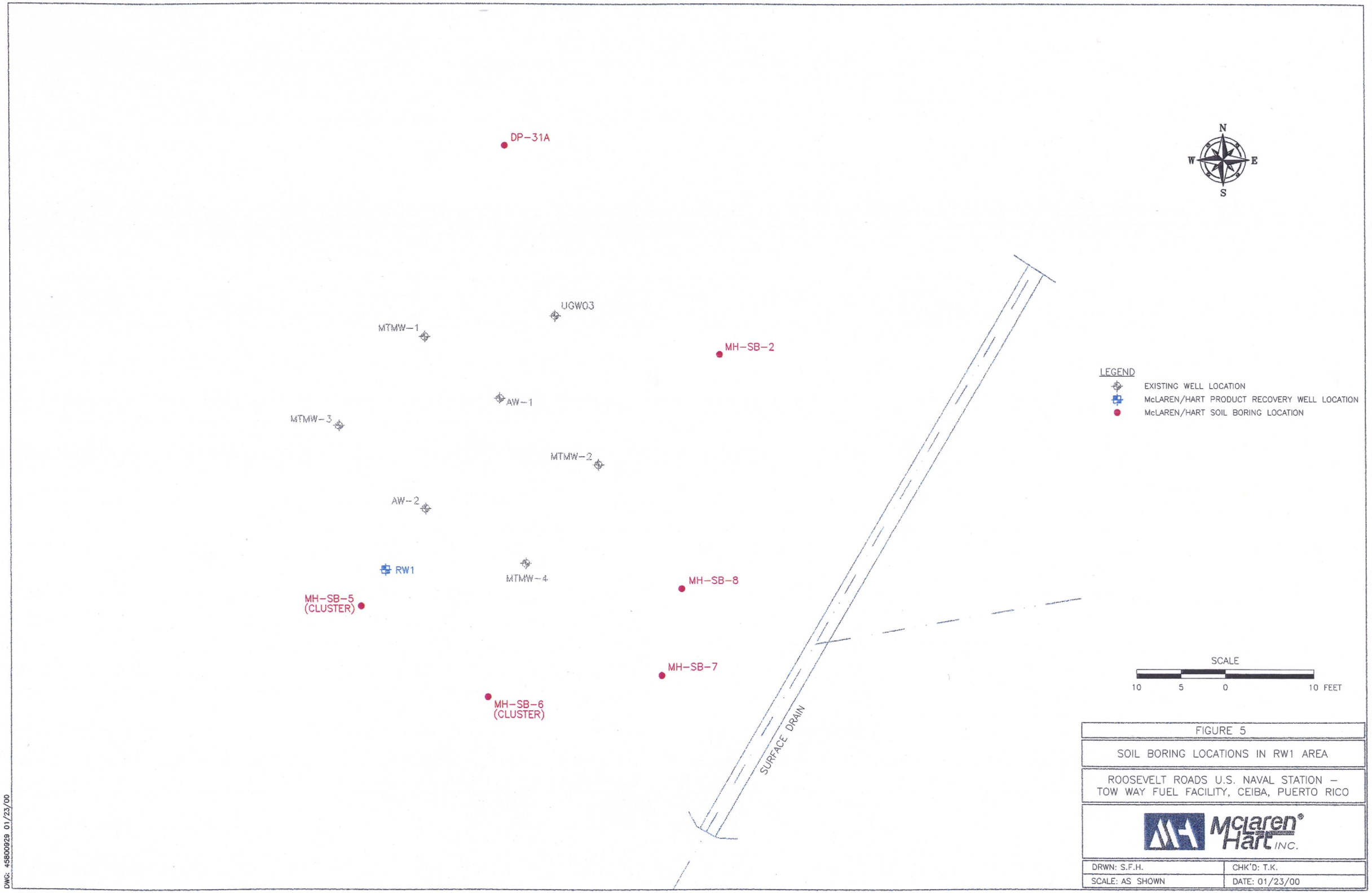


FIGURE 5

SOIL BORING LOCATIONS IN RW1 AREA

ROOSEVELT ROADS U.S. NAVAL STATION –
TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00

DWG: 45800929 01/23/00

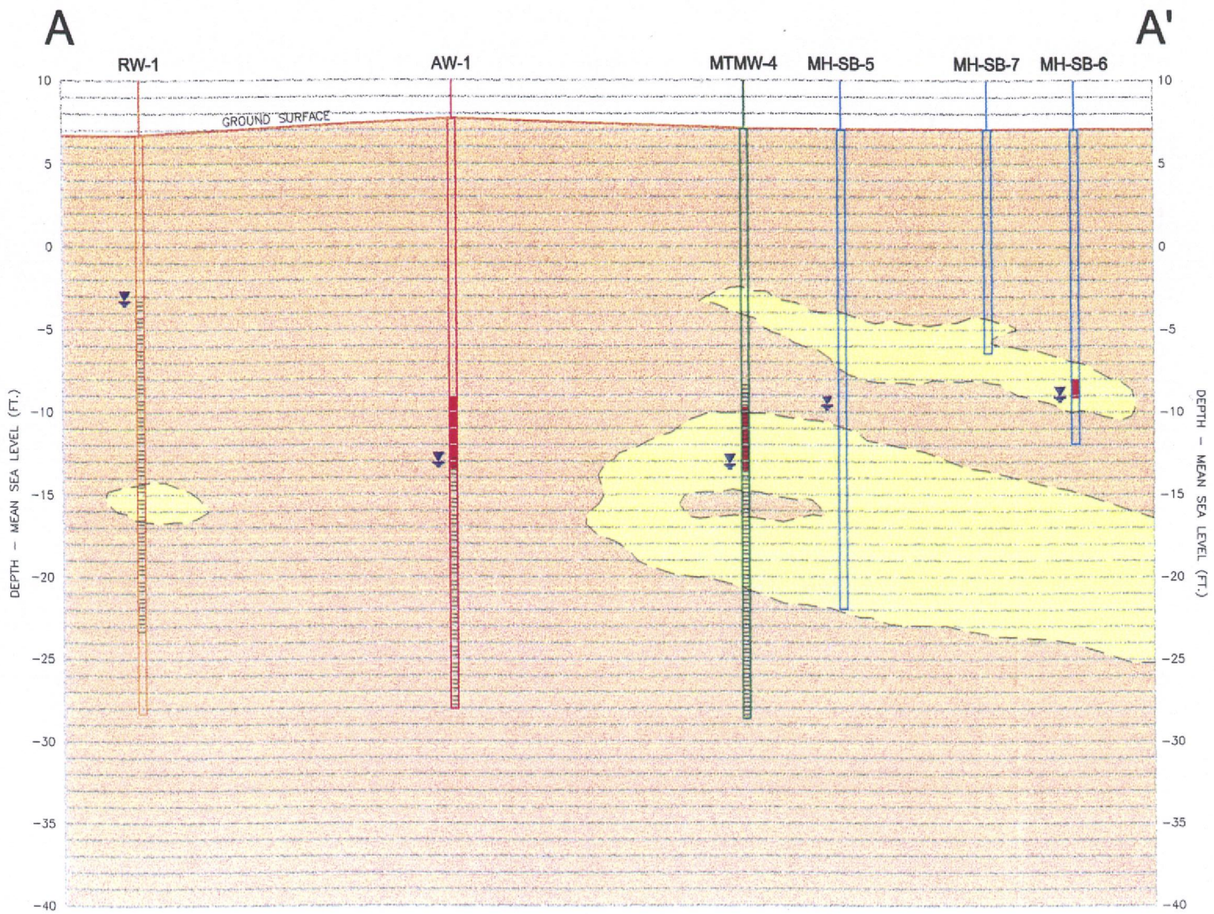
FIGURE 6

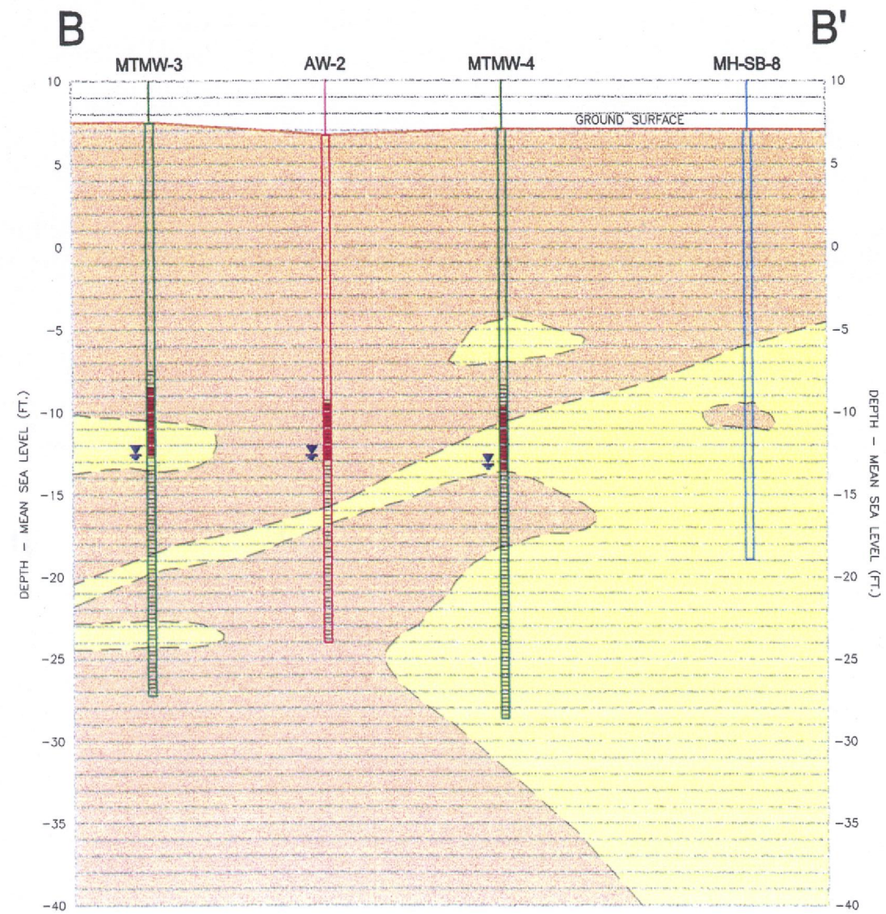
GEOLOGIC CROSS-SECTION LOCATION MAP

ROOSEVELT ROADS U.S. NAVAL STATION –
TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

McLaren Hart INC.

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00





LEGEND

- SCREENED INTERVAL
- PETROLEUM PRODUCT ZONE
- WATER TABLE
- SAND & GRAVEL
- CLAY & SILT

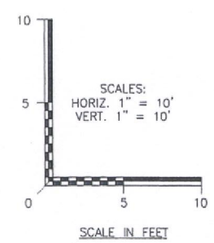


FIGURE 7

GEOLOGIC CROSS–SECTIONS
A–A' AND B–B' FOR RW1 AREA

ROOSEVELT ROADS U.S. NAVAL STATION –
TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

McLaren Hart INC.

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00

DWG: 45800931 01/23/00

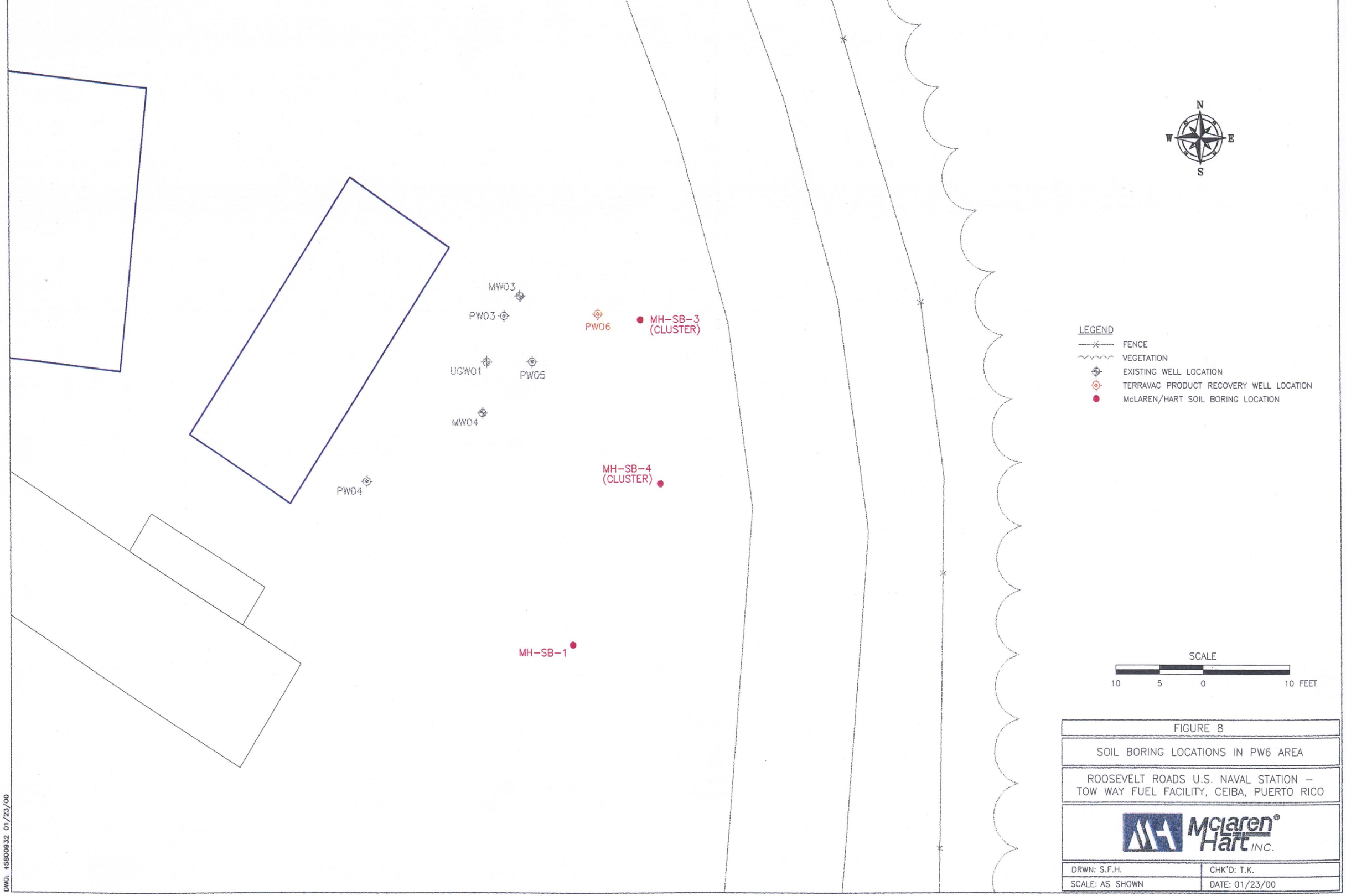


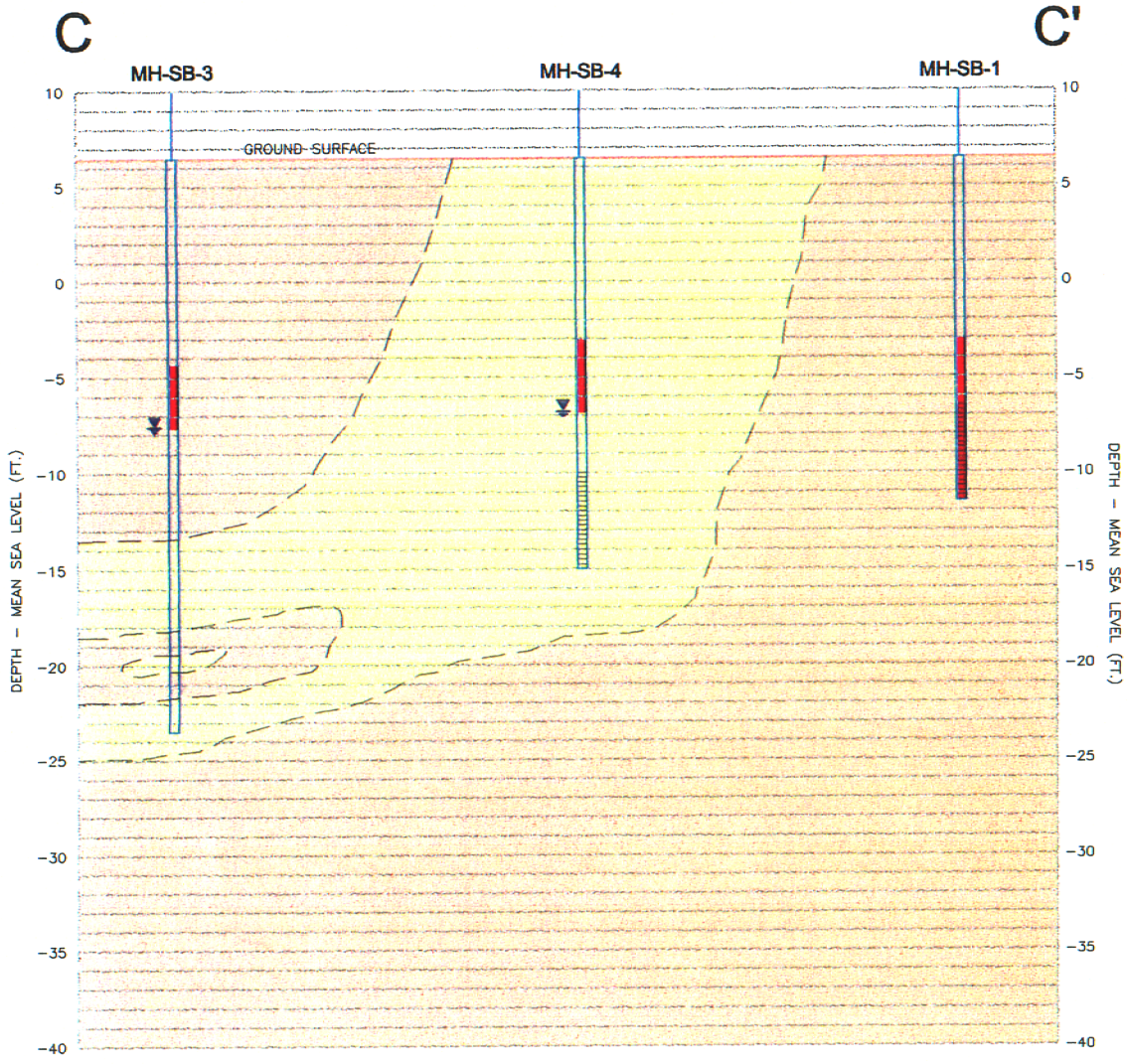
FIGURE 8

SOIL BORING LOCATIONS IN PW6 AREA

ROOSEVELT ROADS U.S. NAVAL STATION –
TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00

DWG: 45B00932 01/23/00



LEGEND

- SCREENED INTERVAL
- PETROLEUM PRODUCT ZONE
- WATER TABLE
- SAND & GRAVEL
- CLAY & SILT

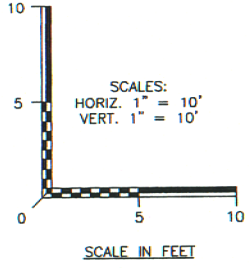


FIGURE 9

GEOLOGIC CROSS-SECTION
C-C' FOR PW6 AREA

ROOSEVELT ROADS U.S. NAVAL STATION –
TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

McLaren Hart INC.

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00

DWG: 45800933 01/23/00

APPENDIX B
PHASE I - PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY USING PNEUMATIC FRACTURING AND PUMPING TECHNIQUES REPORT

PHASE 1
PILOT TEST TO EVALUATE ENHANCEMENT OF PRODUCT RECOVERY USING PNEUMATIC FRACTURING AND PUMPING TECHNIQUES

ROOSEVELT ROADS

1.0 INTRODUCTION AND PURPOSE

In accordance with January 13, 2000 Phase 1 Work Plan, a pilot test has been conducted to evaluate the effectiveness of pneumatic fracturing to enhance the performance of a product recovery system. This report discusses the procedures and outcomes of the pilot test. The test was designed and conducted to establish a product recovery base line for two test plots prior to commencing pneumatic fracturing activities, and to evaluate the effectiveness of two total fluids pumping systems under these conditions. Hydraulic characteristic evaluation was also carried out in the process.

Well development, background monitoring and short-term tests followed by recovery tests were conducted in the RW-01 and PW-06 areas. Locations of all pumping and observation wells are marked on Figure 1. Long-term tests were also started on the basis of the results of short-term tests and these tests are still in progress at the time of this report writing.

2.0 HYDROGEOLOGIC ENVIRONMENT

The site geology and hydrogeology is described as presented in the Quarterly Summary Progress Report Number 8, dated February 26, 1999. The subsurface lithology from 0 feet to 42 feet below ground surface (bgs) is predominantly silt and clay with isolated pockets of sand and gravels. Varying amounts of weathered volcanic rock fragments is also present in the matrix. The clays are primarily grayish-green, yellowish-brown, grayish-brown, and olive-brown as based on color matching with the Munsell soil color chart. Intermixed with the primary colors are shades of red, grayish-brown, olive-gray and bluish-gray. The clays are cohesive, stiff, and range from dry to moist. A review of boring logs from several of the recovery wells indicates that much of the near-surface geology consists of silt and clays, and that at one location (RW-4), the bedrock is fairly close to the surface.

The average horizontal hydraulic gradient is 0.012 ft/ft towards the southwest. The dense nature of the volcanic rock and presence of silt and clays has resulted in very poor yielding water bearing zones in the area. Silt and clay behaves as confining or semi-confining unit for underlying aquifers.

3.0 WELL DEVELOPMENT

Depths, liquid levels, and distances of observation wells from proposed pumping wells were measured prior to the initiation of well development program. Table 1 presents well

information in the RW-01 area and Table 2 presents well information in the PW-06 area. It was observed that depths of wells in RW-01 area are less as compared to their depths at the time of well installation. This may be due to the silts settling at the bottom of wells, as these wells are not being pumped/used regularly. Original depths of PW-06 area wells were not available for comparison with the current depths.

Well development was carried out on all pumping and observation wells in order to restore natural hydraulic properties and to enhance the efficiency of the well so that water flows more freely in the well through screens. Wells in RW-01 and PW-06 area were developed between January 19 and 21, 2000.

Mechanical surging in combination with pumping was considered adequate to develop poor yielding wells in the area. Wells were surged starting from bottom to the top of screens and surged water was pumped out. This process continued until a considerable change in color and cleaner water was observed on the surface. A double diaphragm pneumatic pump was used to pump these wells. Product and water were containerized in 55-gallon drums and later transferred to 4000-gallon storage tank, free product-holding tank.

4.0 BACKGROUND MONITORING

Background monitoring was conducted for 24 hours between January 24 and 25, 2000 to evaluate water level trend in response to the barometric pressure in absence of any pumping influences in the pilot test area. Ten- (10) psi Teflon cable transducers were installed in wells PW-06 and MW-04, and a Hermit 3000 data logger was programmed to record water level and barometric pressure at 20 minute intervals. Figure 2 shows water level trends in PW-06 and MW-04 wells and the barometric pressure changes during the background monitoring phase.

The fluctuation observed in the atmospheric pressure does not appear to affect water levels and corrections for barometric pressure changes are not required for this test. In view of that, there is no need to obtain tidal information data as well.

5.0 SHORT TERM TESTS

5.1 RW-01 Short-term Test

Three short-term tests of 3.5 hours each were conducted on January 26, 2000. RW-01 was pumped using double pneumatic diaphragm pump and depths to product and water were monitored hourly in observation wells AW-2, UGW-3, MTMW-1, 2, 3 & 4 and AW-1. A product-water interface probe was used to measure liquid levels. All pumped water was containerized in 55-gallon drums and later transferred to the 4000-gallon tank. Details of short-term tests are summarized in Table 3. All measurements were taken from the top of the casing (TOC).

Test 1 was conducted at a pump elevation of 19 feet below TOC for 3.5 hours. A total of 58 gallons of water and product was pumped. No measurable product thickness was observed in the 55-gallon drum.

The pump was then lowered to 22 feet below TOC after the completion of Test 1 for initiation of Test 2. Test 2 yielded 77 gallons of water and product in 3.5 hours. 0.83 gallons of product contributed to the total volume of the liquid.

Test 3 was conducted at the final pump elevation of 24.75 feet, which is the bottom of the well. A total of 80 gallons of liquid was pumped in 3.5 hours. 1.03 gallons of product contributed to the total liquid volume.

5.1.1 Recovery Test

Pressure transducers were installed in RW-01 (pumping well) and AW-02 (observation well) prior to the initiation of short-term tests in order to start water level recovery test immediately after the completion of the short-term tests. The data logger was programmed to record water level recovery on a logarithmic cycle.

The recovery test started at the end of short-term test and continued over night. Over 90 % of water level recovery was observed in the morning and therefore the test was stopped. Data from the logger were downloaded on a laptop computer. Water level data were then converted to construct residual drawdown Vs t/t' (time since pump started / time since pump stopped) ratio plot in order to calculate aquifer parameters. Residual drawdown versus t/t' ratio plots for RW-01 and AW-02 were developed and are presented in Figure 3 and Figure 4 respectively.

The time-recovery plot is more accurate than time-drawdown plot because residual drawdown measurements are more accurate. During the recovery period, water level measurements can be made without being affected by pump vibrations and variation in pumping rate and pump elevations in this kind of test.

In analyzing the time-recovery plot, its slope is of primary interest. Aquifer transmissivity, storage coefficient and hydraulic conductivity were calculated from Figure 3 and Figure 4.

Formulas used are as follows:

$T = 264\ Q / {}^{a}s$ $\qquad S = 0.3Tt_0 / r^2$ $\qquad K = T / b$

Where,

T = Transmissivity in gpd/ft
Q = Pumping rate (volume of water / duration) in gallons per minute (gpm)
${}^{a}s$ = Slope on the residual drawdown graph in feet
S = Storage coefficient

K = Hydraulic conductivity in gpd/ft^2
b = Aquifer thickness (length of screen) in feet
t_0 = intercept of extended straight line at 0 drawdown in days
r = distance from the pumping well in feet

Transmissivity calculated from Figure 3 is 9.97 gpd/ft and from Figure 4 it is 10.56 gpd/ft. The hydraulic conductivity is 0.67 gpd/ft^2.

Figure 5 is a distance versus drawdown graph. This graph was developed to evaluate and compare aquifer parameters calculated from the time-recovery graphs. The transmissivity calculated from the distance drawdown graph is 14.36 gpd/ft and storage coefficient is 2.1 x 10^{-3}. Formula used :

$T = 528\ Q / {}^{a}s$

$S = 0.3Tt_0 / r^2$

5.2 MTMW-04 Short-term Tests

Three short-term tests were conducted on January 28, 2000. First two tests were conducted for 3 hours each and the third test lasted for 2.5 hours. MTMW-04 was pumped using double pneumatic diaphragm pump and depths to product and water were monitored hourly in observation wells RW-1, AW-2, UGW-3, MTMW-1, 2, & 3 and AW-1. A product-water interface probe was used to measure liquid levels. All pumped water was containerized in 55-gallon drums and later transferred to the 4000-gallon tanker. Details of short-term tests are summarized in Table 4. All measurements were taken from the top of the casing (TOC).

Test 1 was conducted at a pump elevation of 19 feet below TOC for 3.5 hours. A total of 165 gallons of water and product was pumped. 0.62 gallons of product contributed to the total volume.

The pump was then lowered to 22 feet below TOC after the completion of Test 1 for initiation of Test 2. Test 2 yielded 148 gallons of water and product in 3.5 hours. 1.24 gallons of product contributed to the total volume of the liquid.

Test 3 was conducted at the final pump elevation of 27 feet below TOC. A total of 153 gallons of liquid was pumped in 2.5 hours. 0.62 gallons of product contributed to the total liquid volume.

5.2.1 Recovery Test

Pressure transducers were installed in MTMW-04 (pumping well) and AW-02 (observation well) wells prior to the initiation of short-term tests in order to start water level recovery test immediately after the completion of the short-term tests. The data logger was programmed to record water level recovery on a logarithmic cycle.

Same methods and procedures were used for data analysis as described in RW-01 test section of this report. Figure 6 and Figure 7 are residual drawdown versus t/t' plots for MTMW-04 and AW-02 wells respectively. Figure 8 is the distance drawdown plot.

Transmissivity values calculated from Figure 6 and 7 are 165 gpd/ft and 217 gpd/ft respectively. The hydraulic conductivity is calculated to be 8.5 gpd/ft^2.

Transmissivity and storage coefficient values from Figure 8 is 269 gpd/ft and 7 x 10^{-2} respectively.

5.3 PW-06 Short-term Tests

Two short-term tests for 3 hours each were conducted on January 27, 2000. PW-06 was pumped using 4-inch top loading pneumatic pump and depths to product and water were monitored hourly in observation wells PW-5, PW-3, UGW-1, MW-3 and MW-4. A product-water interface probe was used to measure liquid levels. All pumped water was containerized in 55-gallon drums and later transferred to the 4000-gallon tanker. Details of short-term tests are summarized in Table 5. All measurements were taken from the top of the casing (TOC).

Two short-term tests were conducted at this location.

Test 1 was conducted at a pump elevation of 16 feet below TOC (top of the pump) for 3 hours. A total of 13.8 gallons of water and product was pumped. 0.20 gallons of product contributed to the total volume.

The pump was then lowered to 19 feet below TOC (top of the pump) after the completion of Test 1 for initiation of Test 2. Test 2 yielded 8.08 gallons of water and product in 3 hours. 0.20 gallons of product contributed to the total volume of the liquid.

5.3.1 Recovery Test

Pressure transducers were installed in PW-06 (pumping well) and PW-05 (observation well) wells prior to the initiation of short-term tests in order to start water level recovery test immediately after the completion of the short-term tests. The data logger was programmed to record water level recovery on a logarithmic cycle.

Same methods and procedures were used for data analysis as described in RW-01 test section of this report. Figure 9 and Figure 10 are residual drawdown versus t/t' plots for PW-06 and PW-05 wells respectively. Figure 11 is the distance drawdown plot (refer to Table 6 for the drawdown data).

Transmissivity values calculated from Figure 9 and 10 are 0.95 gpd/ft and 52.8 gpd/ft respectively. The hydraulic conductivity could not be calculated because screen intervals for PW-06 are not available.

Transmissivity and storage coefficient values from Figure 11 is 91 gpd/ft and 1 x 10^{-2} respectively.

5.5 PW-06 Short-term VER Tests

Three short-term vacuum enhanced recovery (VER) tests for 3 hours each were conducted. Test 1 was conducted on February 01 and Test 2 and 3 were conducted on February 02, 2000. A 2-inch top loading pneumatic pump was installed in PW-06 at a depth of 19 feet (top of the pump) below TOC and depths to product and water were monitored hourly in observation wells PW-5, PW-3, UGW-1, MW-3 and MW-4 while pumping. The pump elevation of 19 feet in PW-06 was selected because this elevation yielded better ratio of product and water during the pneumatic pump test conducted earlier.

Vacuum at three different levels of mercury was applied at the well head in combination with the pumping. A product-water interface probe was used to measure liquid levels. All pumped water was containerized in 55-gallon drums and later transferred to 4000 gallons tanker. Details of short-term tests are summarized in Table 6. All measurements were taken from the top of the casing (TOC).

Test 1 was conducted at a 15” of mercury for 3 hours. A total of 20 gallons of water and product was pumped. 0.20 gallons of product contributed to the total volume.

Test 2 was conducted at a 20” of mercury for 3 hours. A total of 38.7 gallons of water and product was pumped. 2.3 gallons of product contributed to the total volume.

Test 3 was conducted at a 25” of mercury for 3 hours. A total of 33.15 gallons of water and product was pumped. 2.4 gallons of product contributed to the total volume.

The recovery test was not performed after the completion of these tests, as the data collected during the recovery phase after the pneumatic pump test only was adequate to evaluate the aquifer parameters for this area.

6.0 LONG TERM TESTS

On the basis of the results of short-term tests, long term tests were initiated. Two long-term tests on RW-01 and PW-06 respectively are in progress at the time of this reporting and the rationale is discussed below. These tests are expected to last for about 30 days from the their starting dates.

6.1 RW-01 Area Test

Well RW-01 was selected for the long-term test to evaluate product recovery system of this area. Tables 3 and 4 summarize product to water ratio pumped out and drawdowns observed in observation wells during the short-term tests. Tests 2 and 3 on RW-01 yielded better ratio of product and water as compared to MTMW-4 tests. Even the

observed drawdowns in the observation wells were more during RW-01 test as compared to the MTMW-4 test. This means that pumping RW-01 for a longer period will bring more product and less water, regionally as compared with MTMW-4.

In view of the above, a 4" top loading pneumatic pump was installed at 24.75 feet (bottom of the well) below TOC in RW-01 and long term test started on January 29, 2000. The difference in the pump elevation is due to the length (3.4 feet) of the pneumatic pump. Therefore the actual pumping elevation is 21.35 feet below TOC (22.55 bgs).

The same observation wells, as previously used during the short-term tests, are being monitored by using water-product interface probe. The order of monitoring is once daily for the first week and then reduced to 2 to 3 times per week for the remaining period of the test.

Pumped product and water is being containerized in a 6000 gallons tanker. Water is routed to this tanker via a 55-gallon drum by gravity feed. A product-water separator is also on the site for later use.

6.2 PW-06 Area Test

The long-term test on PW-06 started on February 02, 2000. A top loading 2" well pneumatic pump was installed at 19 feet (top of pump elevation) below TOC, approximately 20 feet bgs, in PW-06 for this purpose. This pump elevation was selected on the basis of short-term test results.

A vacuum of 20 inches of mercury will be applied at the well head after 7 days of long term pumping. 20 inches of mercury has been selected because of a better product to water ratio obtained at this level during the short-term VER tests conducted earlier. Another advantage of applying 20 inches of mercury over 25 inches is less consumption of power over a longer period of time and still drawing approximately same product water ratio. More water was observed at the end of the second VER test (refer to Table 6) because of the fact that the pumping well had recovered overnight between the completion of Test 1 and start of Test 2.

Same observation wells, as previously used during the short-term tests, are being monitored by using water-product interface probe. The order of monitoring is once daily for the first week and then reduced to 2 to 3 times per week for the remaining period of the test.

Pumped product and water is being containerized in the 6000 gallons tanker. Water is fed to this tanker through a 55-gallon drum by gravity feed. A product-water separator is also on the site for later use.

7.0 VARIATIONS FROM THE PROPOSED WORK PLAN

There were few variations during the implementations of the pilot test operations from the initially proposed work plan. The variations were due to the actual field conditions encountered. Major variations and the consequences are discussed below.

- Background monitoring wells: Well MW-04 was used instead of PW-04 because PW-04 was found damaged at the time of the background monitoring. MW-04 was selected, as it is located closer to the ocean as compared to other monitoring wells around PW-06.
- Discharged product/water were containerized in 55-gallon drums near the pumping wells and later transferred to the 4000 gallon tank. This allowed for more efficient operation.
- Double pneumatic diaphragm pumps were used in RW-01 and MTMW-04 short-term tests due to unavailability and later malfunctioning of the pneumatic pumps. The end results are still the same.
- Short-term test hours were reduced from 4 hours to either 3.5 hours or 3 hours in effort to complete tests within one-day field day light conditions. Ratio of total volume pumped against time still served the purpose.
- The recovery test on PW-06 was performed after the pneumatic pump test because it was not feasible to install a transducer in this well while vacuum was being applied.

8.0 FINDINGS AND RECOMMENDATIONS

- Baseline aquifer coefficients were established prior to fracturing.
- Optimal pump settings were determined. It was found that deeper pump installation depths produced better water to product ratio.
- Advantage of using Vacuum Enhanced Recovery (VER) along with dynamic pumping was established. This combination produced better water to product ratio.
- The following table summarizes aquifer parameters evaluated from the short-term tests.

	Recovery Data			Distance Drawdown Data		
Well Number	Transmissivity (gpd/ft)	Storage Coefficient	Hydraulic Conductivity (gpd/ft^2)	Transmissivity (gpd/ft)	Storage Coefficient	Hydraulic Conductivity (gpd/ft^2)
RW-01	9.97–10.56	NA	0.67	14.36	2.1×10^{-3}	NA
MTMW-04	165-217	NA	8.5	269	7×10^{-2}	NA
PW-06	0.95-52.8	NA	NA	91	1×10^{-2}	NA

- Low values of T and K represent poor yielding aquifer.
- Storage coefficient values suggest that the aquifer is of confined to semi-confined nature in this area.

- *It should be noted that aquifer parameters were analyzed within the limitations of the scope of short-term tests. The short-term tests were designed for establishing a base line for pneumatic fracturing rather then to evaluate hydraulic characteristics. Wells were not pumped at constant pumping rates at a certain pump elevation. In view of that, calculated parameters may not define the aquifer "accurately". However, these parameters are accurate enough to understand the aquifer system in the area.*
- A 72-hour aquifer test followed by 90 – 95 % recovery test is recommended for proper evaluation of hydraulic characteristics in the area.
- Rehabilitation and/or periodical well development and water level monitoring is recommended.
- Groundwater contour maps can be prepared to understand groundwater flow/divide etc.
- Geophysical survey may be useful in delineating areas with product.
- A geological map will be useful.

General

- Order equipment well in advance and test them before the due tests
- Same procedures of tests may be followed after the pneumatic fracturing
- Field crew should get more familiar with pneumatic pumps, other equipment
- Keep back up plans and equipment when required
- Keep good supply of sun cream, bug spray and cold water etc.
- Lighting options if late night working is unavoidable

Table 1. RW-1 Area Well Information
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Date	Well ID	Original Well Depth	Measured Well Depth	Original Screen Intervals	Well Diameter	Depth to Product	Depth to Water	Product Thickness	Distances from RW-1	Top of Casing Elevations	Water Level Elevation
		(ft)	(ft)	(ft)	(in)	(ft)	(ft)	(ft)	(ft)	(ft amsl)	(ft amsl)
1/19/00	RW-1	30.00	24.75	10-30	6	16.10	16.20	0.10	NA	121.25	105.05
	MTMW-1	39.50	35.80	19.5-39.5	2	13.30	13.40	0.10	31.70	123.16	109.76
	MTMW-2	38.00	37.50	18-38	2	14.45	17.45	3.00	27.60	122.29	104.84
	MTMW-3	35.00	35.00	15-35	2	12.35	12.45	0.10	15.90	122.14	109.69
	MTMW-4	36.00	34.50	15-35	2	13.36	17.45	4.09	16.90	121.82	104.37
	AW-1	35.50	34.90	20-35.5	2	13.00	13.10	0.10	23.10	122.20	109.10
	AW-2	31.00	29.75	16-31	2	13.40	14.00	0.60	9.70	121.35	107.35
	UGW-3	35.40	35.40	25.4-35.4	2	15.80	15.82	0.02	34.40	125.21	109.39

NA: Not Applicable
amsl: Above mean sea level

Table 2. PW-6 Area Well Information
Tow Way Fuel Facility, Roosevelt Roads, Puerto Rico

Date	Well ID	Measured Well Depth (ft)	Well Diameter (in)	Depth to Product (ft)	Depth to Water (ft)	Product Thickness (ft)	Distances from PW-06 (ft)	Top of Casing Elevations (ft amsl)	Water Level Elevation (ft amsl)
1/21/00	PW-06	23.12	4	8.66	8.67	0.01	NA	117.69	109.02
	UGW-1	26.87	2	10.09	10.17	0.08	14.10	116.57	106.40
	PW-05	29.10	4	10.90	10.95	0.05	9.10	117.42	106.47
	PW-03	28.05	4	10.88	10.89	0.01	9.70	117.33	106.44
	MW-03	22.20	2	7.23	7.33	0.10	11.20	117.22	109.89
	MW-04	26.83	2	6.67	6.68	0.01	17.20	116.56	109.88

NA: Not Applicable
amsl: Above mean sea level
Original well depths and screen intervals not available

Table 3. RW-1 Short Term Tests Details, 01/26/2000
Tow Way Fuel Farm, Roosevelt Roads, Puerto Rico

				Test 1, 3.5 Hrs., Pump at 19', 0.28 gpm			Test 2, 3.5 Hrs., Pump at 22', 0.37 gpm			Test 3, 3.5 Hrs., Pump at 24.75', 0..38 gpm			
Well Number	**Well Use**	**Depth to Product before start of Tests (ft)**	**Depth to Water before start of Tests (ft)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Drawdown at the end of the third test (ft)**
RW-1	PW	12.60	12.86	18.95	18.95	NM / 58	22.02	22.04	0.83 / 76.17	24.50	24.51	1.03 / 78.97	11.65
AW-2	OW	13.56	14.95	17.40	18.55		19.20	20.17		19.75	20.90		5.95
UGW-3	OW	15.72	15.73	15.74	15.74		15.71	15.72		15.72	15.73		0
MTMW-1	OW	13.72	13.73	13.71	13.72		13.70	13.73		13.72	13.75		0.02
MTMW-2	OW	15.06	15.07	15.23	15.51		15.32	15.62		15.40	15.65		0.58
MTMW-3	OW	12.59	12.60	12.61	12.61		12.62	13.35		12.62	13.35		0.75
AW-1	OW	13.04	13.35	13.14	13.15		13.21	14.49		13.27	14.60		1.25
MTMW-4	OW	14.63	14.63	14.80	14.90		14.92	15.09		15.40	15.65		0.47

AW- Mantech chemical oxidation pilot test delivery well
MTMW- Mantech chemical oxidation pilot test monitoring well
PW- Pumping Well
OW- Observation Well
NM- Not measurable

Table 4. MTMW-4 Short Term Tests Details, 01/28/2000
Tow Way Fuel Farm, Roosevelt Roads, Puerto Rico

				Test 1, 3.5 Hrs., Pump at 19', 0.78 gpm			Test 2, 3.5 Hrs., Pump at 22', 0.70 gpm			Test 3, 2.5 Hrs., Pump at 27', 0.27 gpm			
Well Number	**Well Use**	**Depth to Product before start of Tests (ft)**	**Depth to Water before start of Tests (ft)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Drawdown at the end of the third test (ft)**
MTMW-4	PW	14.80	14.95	-	-	0.62 / 164.38	-	-	1.24 / 146.38	-	-	0.62 / 152.38	-
RW-1	OW	13.32	13.33	13.15	13.20		13.15	13.30		13.25	13.45		0.12
AW-2	OW	14.50	15.39	14.25	15.55		14.35	15.65		14.50	15.70		0.31
UGW-3	OW	15.77	15.78	15.87	15.88		15.82	15.83		15.82	15.83		0.05
MTMW-1	OW	13.78	13.79	13.85	13.86		13.81	13.82		13.81	13.82		0.03
MTMW-2	OW	15.21	15.48	16.25	16.55		16.73	17.00		16.81	17.07		1.59
MTMW-3	OW	12.62	13.37	12.75	13.45		12.72	13.40		12.71	13.41		0.04
AW-1	OW	13.17	14.60	13.37	14.75		13.38	14.80		13.40	14.80		0.2

AW- Mantech chemical oxidation pilot test delivery well
MTMW- Mantech chemical oxidation pilot test monitoring well
PW- Pumping Well
OW- Observation Well
'-' Could not measure

Table 5. PW-6 Short Term Tests Details, 01/27/2000
Tow Way Fuel Farm, Roosevelt Roads, Puerto Rico

				Test 1, 3 Hrs., Pump at 16', 0.08 gpm			Test 2, 3 Hrs., Pump at 19', 0.04 gpm		
Well Number	**Well Use**	**Depth to Product before start of Tests (ft)**	**Depth to Water before start of Tests (ft)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**
PW-6	PW	7.92	7.99	-	-	0.20 / 13.6	-	-	0.20 / 7.88
PW-5	OW	12.63	12.63	12.55	12.56		12.55	12.55	
PW-3	OW	12.29	12.29	12.31	12.32		12.30	12.30	
UGW-1	OW	10.63	10.66	10.60	10.62		10.55	10.66	
MW-3	OW	8.41	8.41	8.41	8.41		8.39	8.40	
MW-4	OW	7.61	7.62	7.57	7.58		7.56	7.57	

PW- Pumping Well
OW- Observation Well
'-' Could not measure
No fixed trend in drawdowns

Table 6. PW-6 Short Term VER Tests Details, 02/01-02/00
Tow Way Fuel Farm, Roosevelt Roads, Puerto Rico

				Test 1, 3 Hrs., Pump at 19', 15" of Mercury, 0.11 gpm			Test 2, 3 Hrs., Pump at 19', 20" of Mercury, 0.22 gpm			Test 2, 3 Hrs., Pump at 19', 25" of Mercury, 0.18 gpm			
Well Number	**Well Use**	**Depth to Product before start of Tests (ft)**	**Depth to Water before start of Tests (ft)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Depth to Product at the end of Test (ft)**	**Depth to Water at the end of Test (ft)**	**Product / Water (gallons)**	**Drawdown at the end of the third test (ft)**
PW-6	PW	-	-	-	-	0.20 / 19.8	-	-	2.3 / 36.40	-	-	2.4 / 30.75	-
PW-5	OW	12.19	12.21	12.19	12.21		12.21	12.24		12.29	12.23		0.02
PW-3	OW	12.61	12.63	12.60	12.63		12.82	12.85		13.31	13.36		0.73
UGW-1	OW	10.55	10.61	10.54	10.60		16.60	16.63		10.60	10.70		0.09
MW-3	OW	7.99	8.00	7.99	7.99		8.01	8.02		8.00	8.01		0.01
MW-4	OW	8.20	8.31	8.11	8.17		8.25	8.34		8.25	8.37		0.06

PW- Pumping Well
OW- Observation Well
'-' Could not measure

FIGURE 1

GEOLOGIC CROSS-SECTION LOCATION MAP

ROOSEVELT ROADS U.S. NAVAL STATION – TOW WAY FUEL FACILITY, CEIBA, PUERTO RICO

McLaren Hart INC.

DRWN: S.F.H.	CHK'D: T.K.
SCALE: AS SHOWN	DATE: 01/23/00

DWG: 45B00949 01/23/00

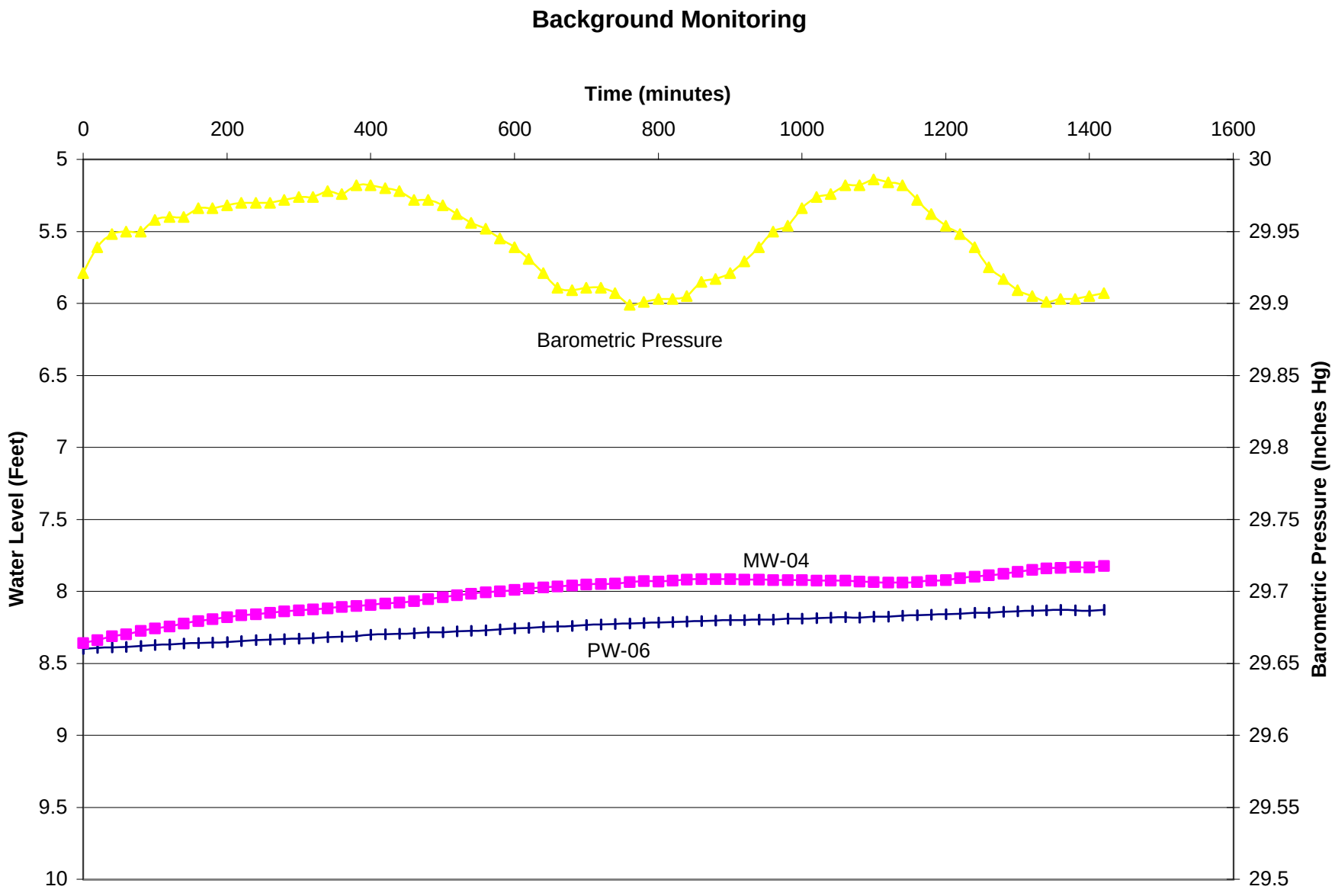


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Figure 2.

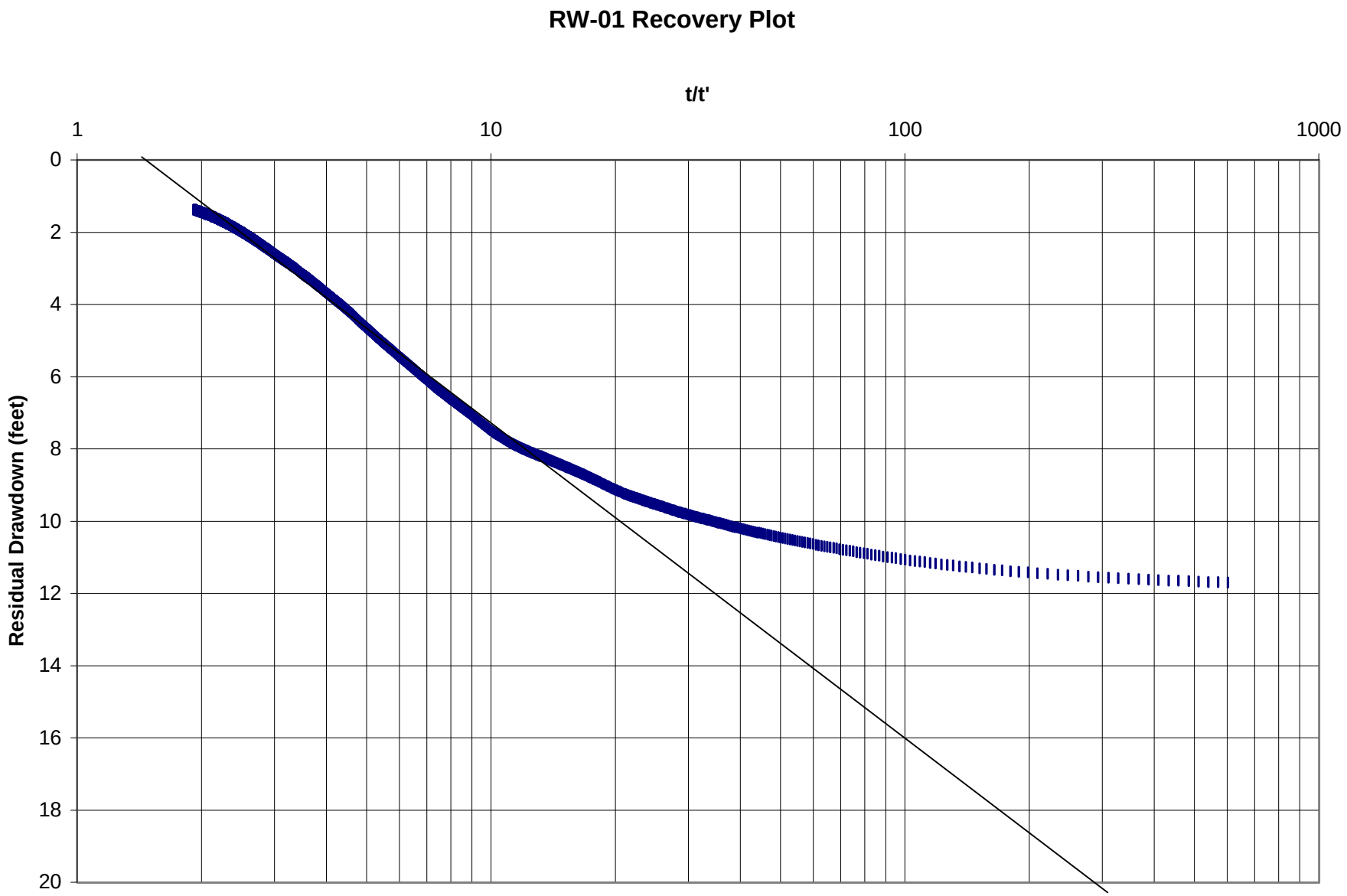

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Figure 3.

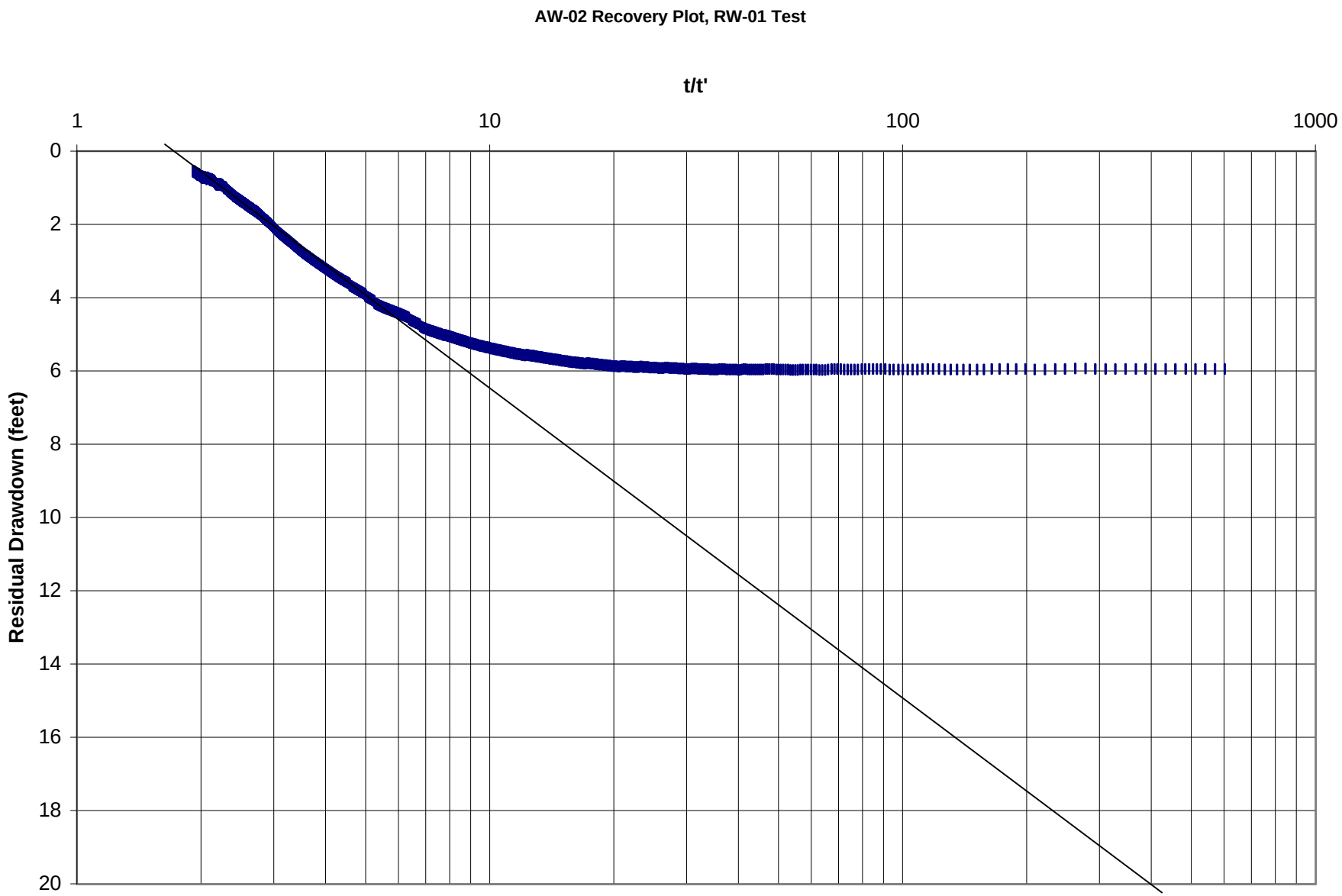

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Figure 4.

Distance Drawdown Plot, RW-01 Test

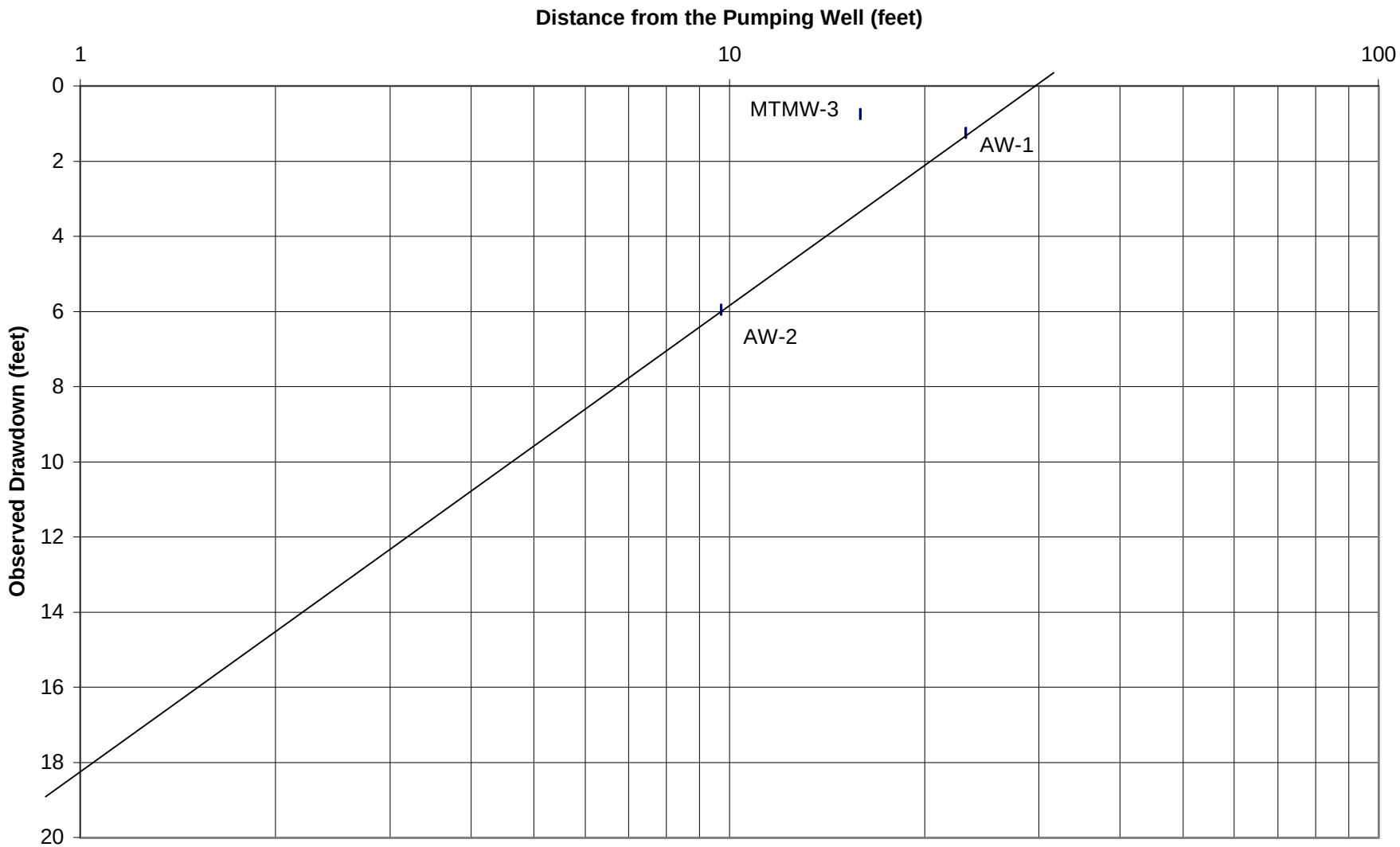

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Figure 5.

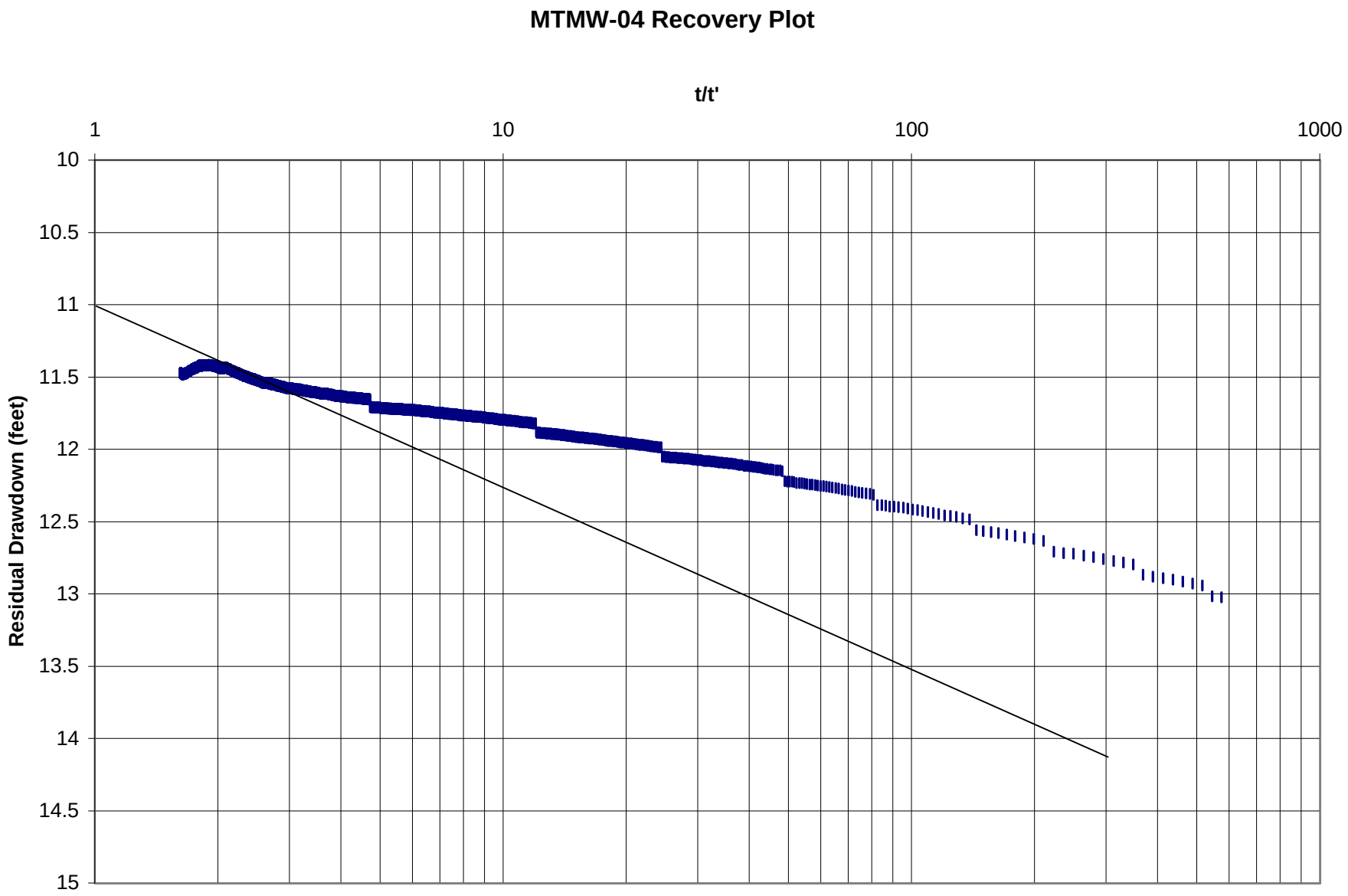

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Figure 6.

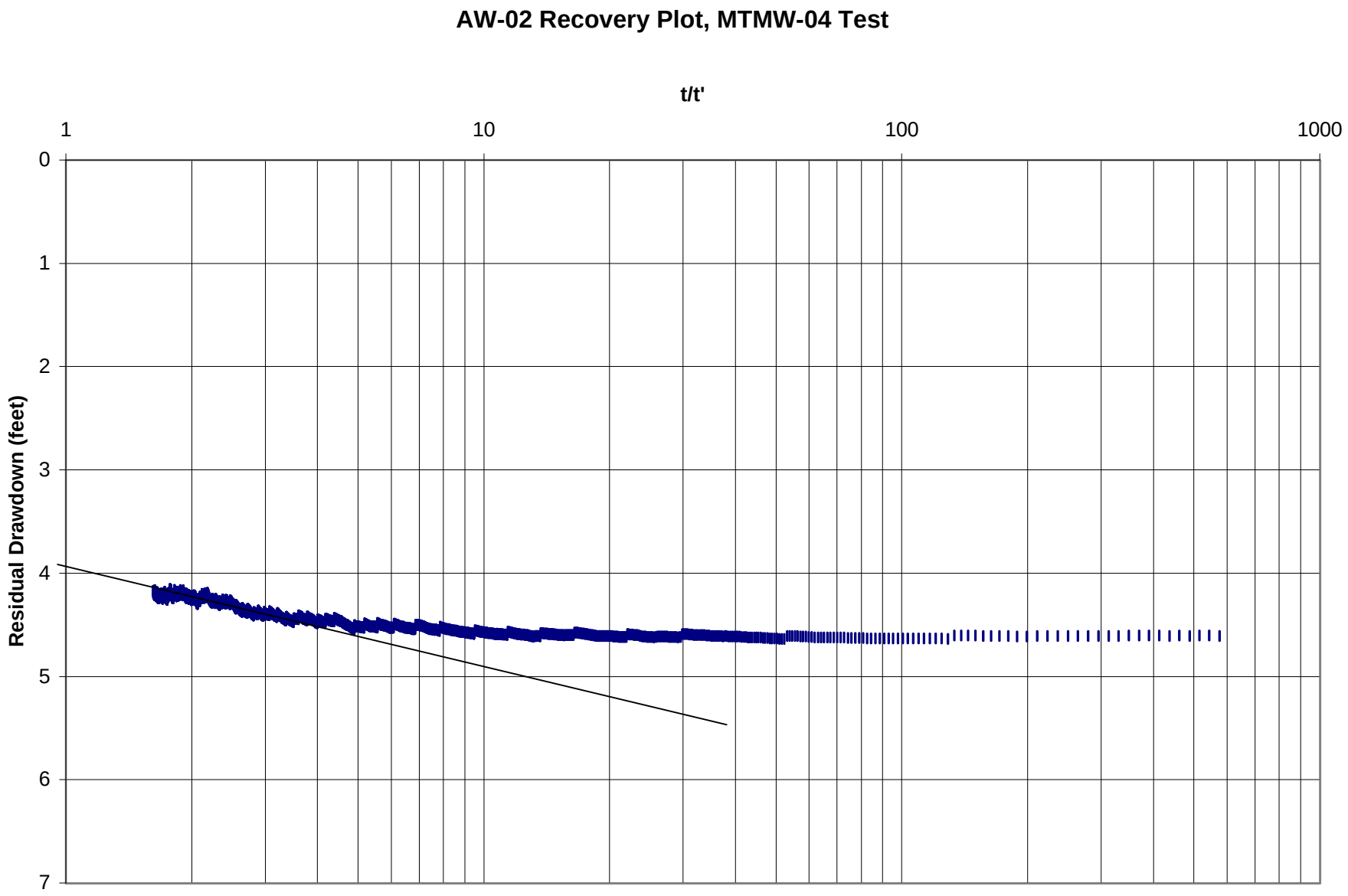

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Figure 7.

Distance Drawdown Plot, MTMW-04

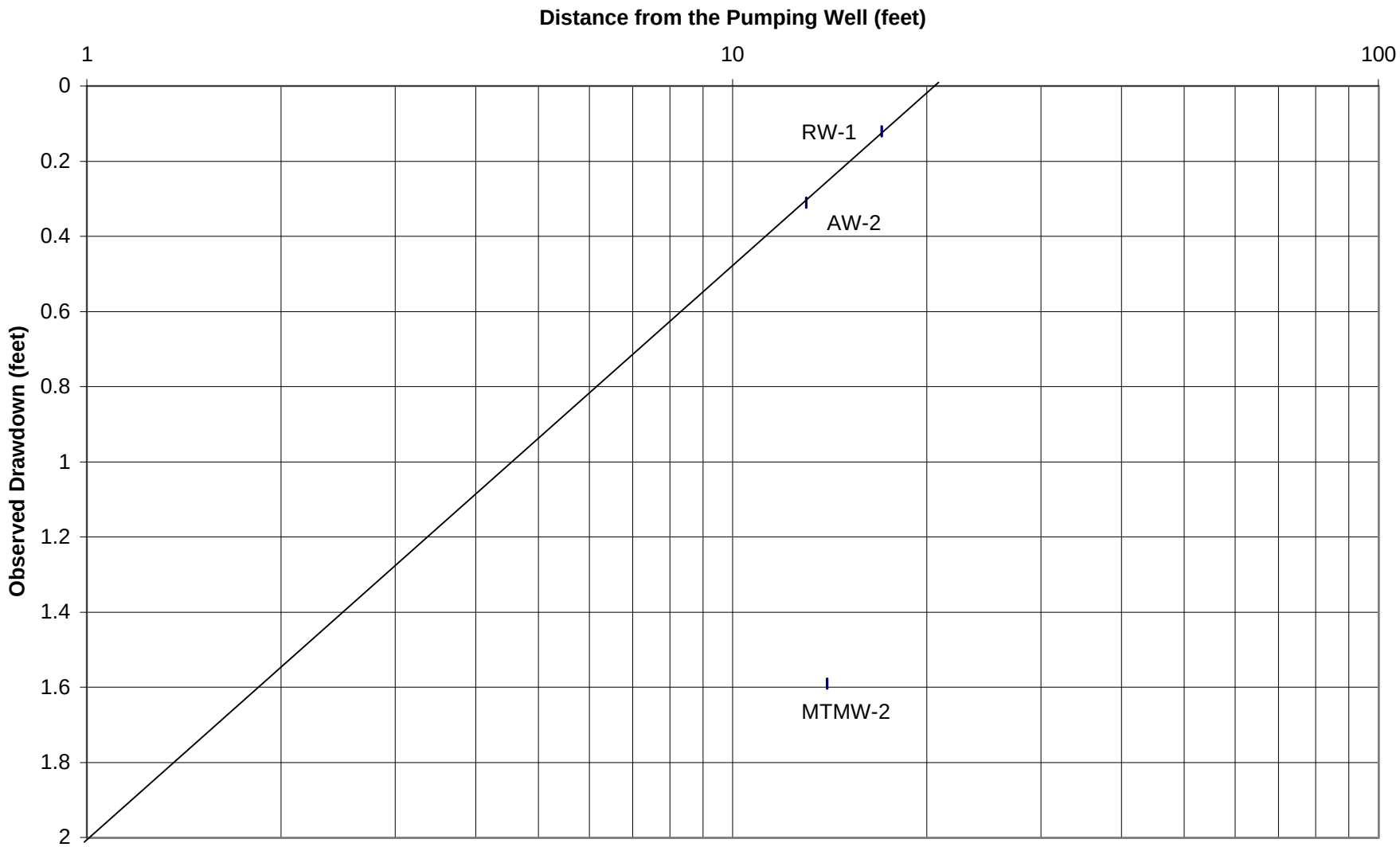

Figure 8.

PW-06 Recovery Plot

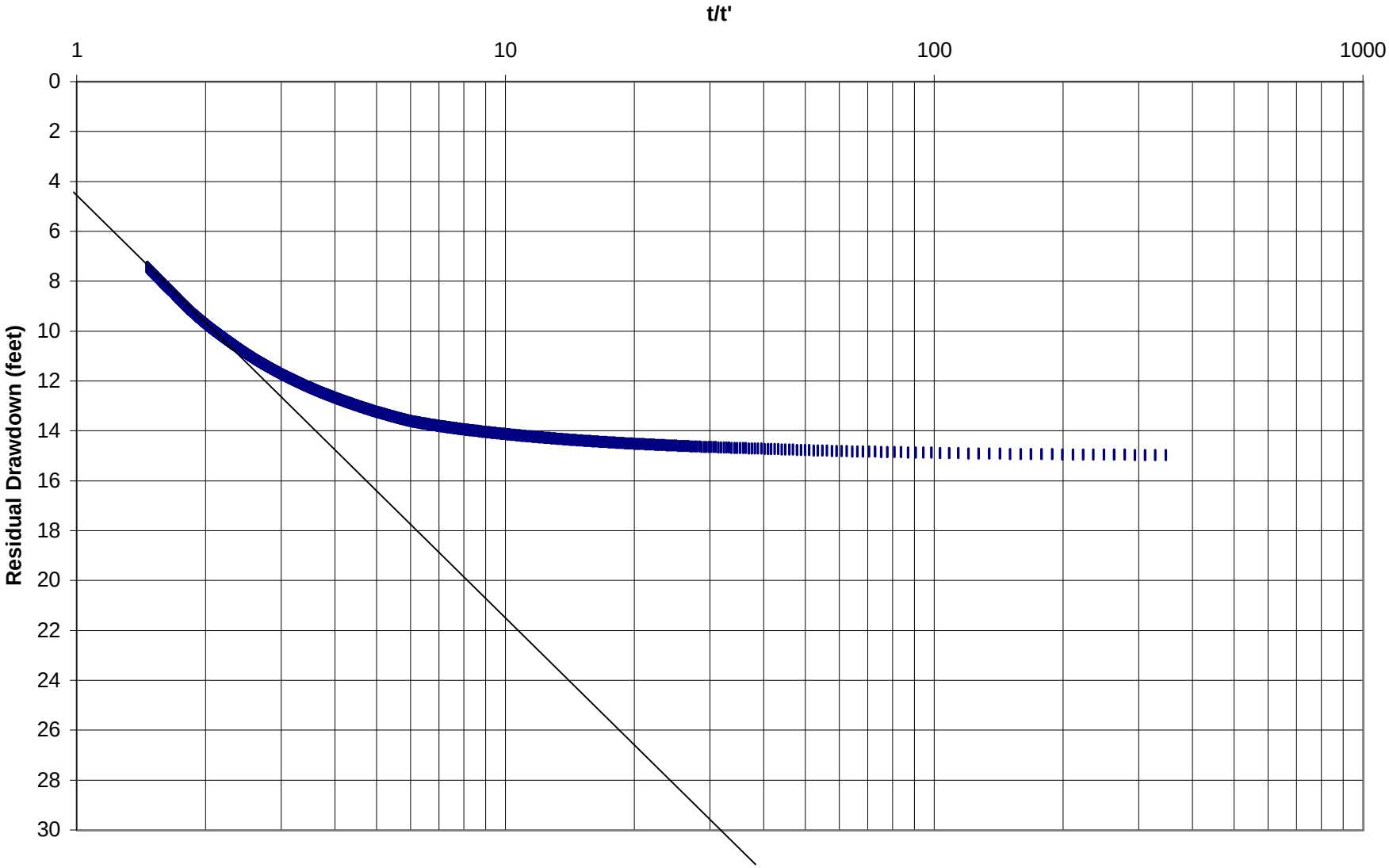

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Figure 9.

PW-05 Recovery Plot, PW-06 Test

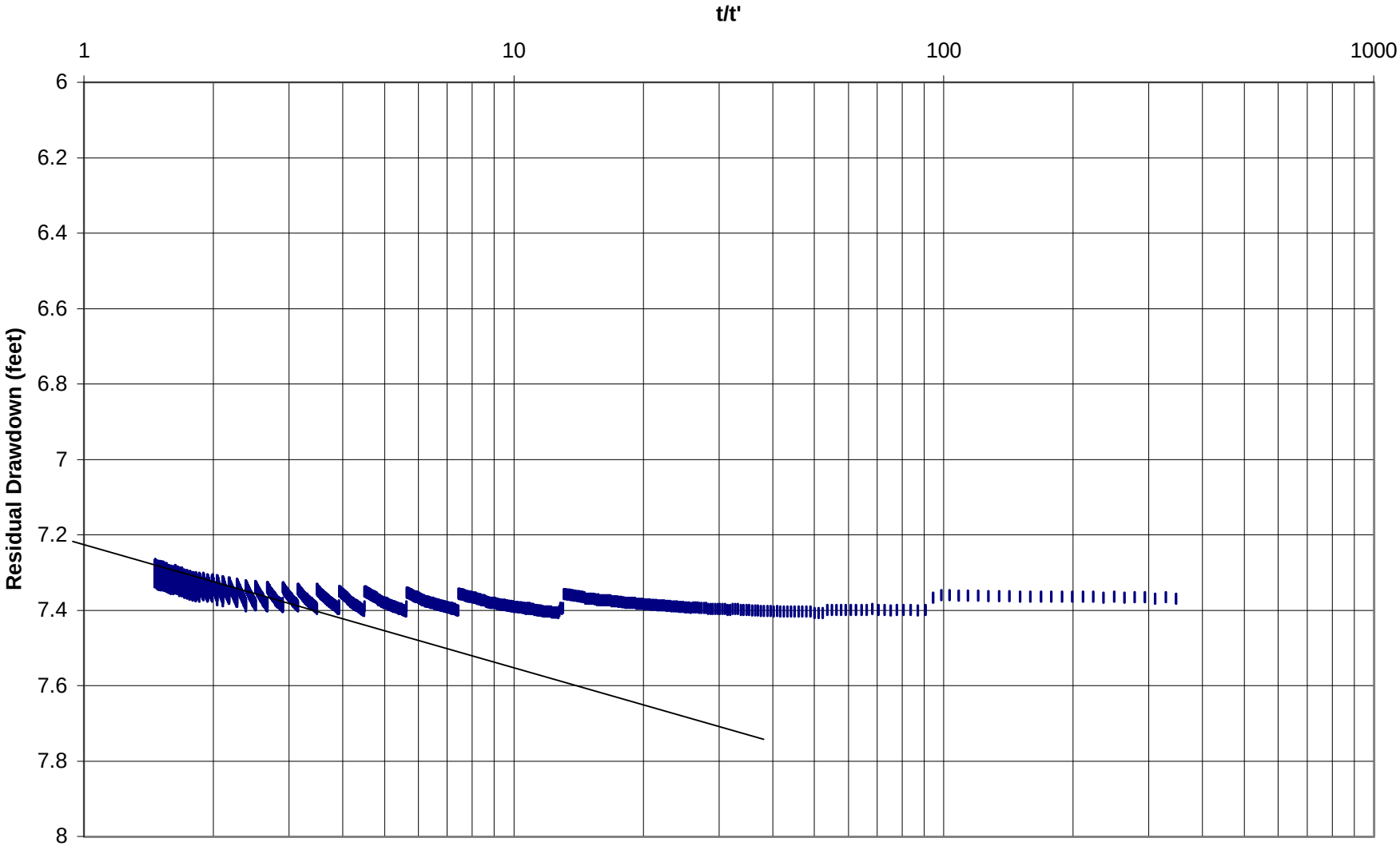

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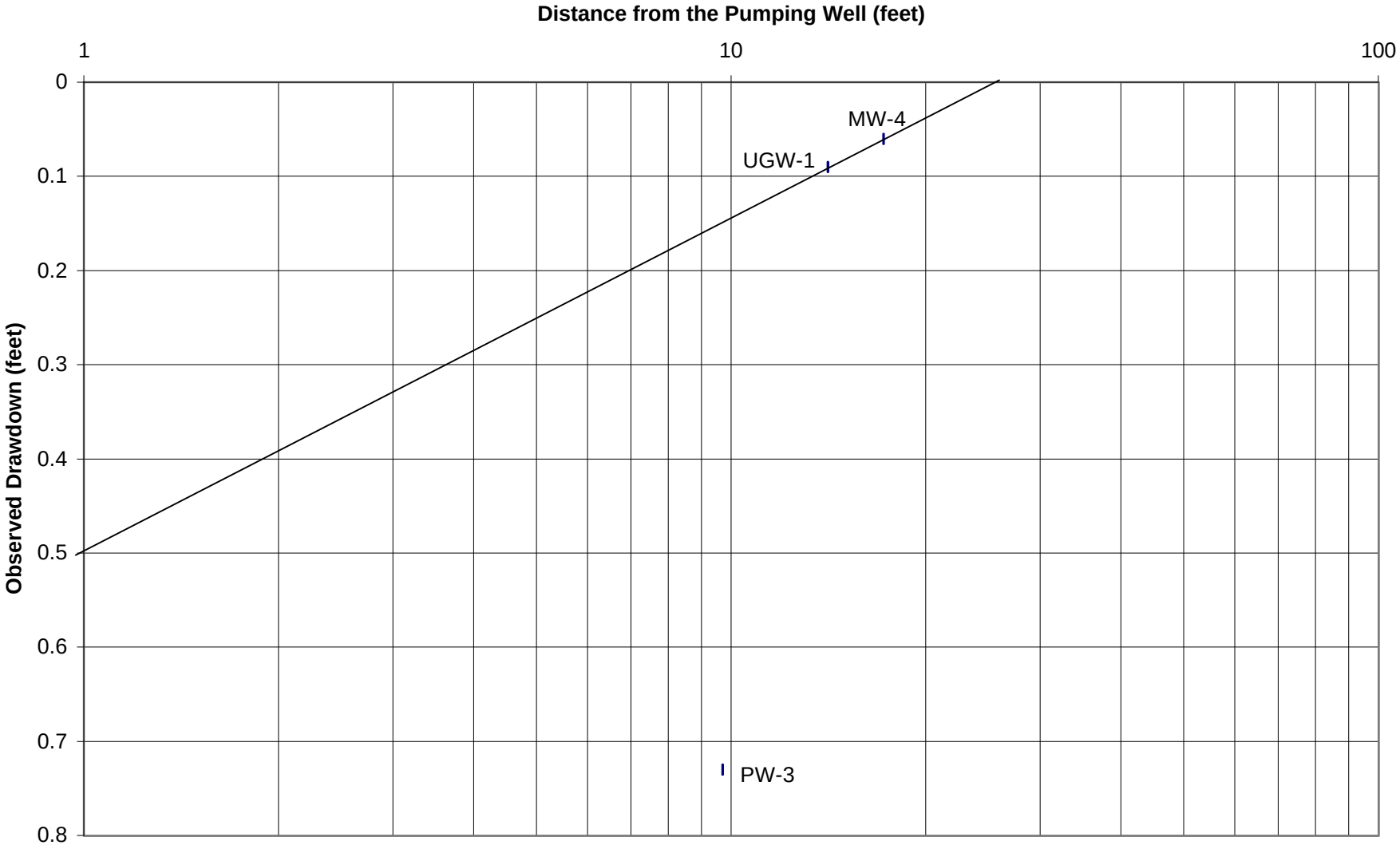
Figure 10.

Distance Drawdown Plot, PW-06 Test



APPENDIX C
BORING LOGS

APPENDIX C

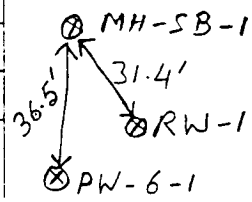
SOIL BORING LOGS:

1 - McLaren/Hart
2 – Mantech Environmental
3 – RW-1

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-1**
Client:	U.S. Naval Station
Boring Location:	MH-SB-1
Northing:	18.23204716
Easting:	-65.61994268
Start - Finish Date:	9/17/99 - 9/17/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Will Whitesell/Pittsburgh
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	18.0
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

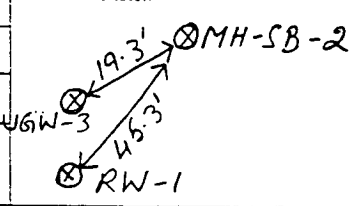


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
		1.63/2	SILT, clayey, stiff, light brown, tan; with fill. Dry.			S-1
2		1.25/2	SILT, clayey, stiff, reddish brown and light gray; with some silty sand. Dry.		0	S-2
4		0.83/2	SILT and GRAVEL, very stiff, gray red; with some pebbles and cobbles.		1	S-3
6		0.75/2	SILT, very soft, light brownish tan; with some orange stained fresh and weathered gabbro. Dry.			S-4
			SILT, medium stiff brown; with light gray and orange severly weathered and fresh gabbro.			
8		1.17/2				S-5
10		1/1	SILT, clayey, very stiff, light brown; with some reddish orange silt, moist petroleum, heavy odor. Moist.			S-6
12		0.38/0	SILT, very soft, light brown; with some gray highly weathered gabbro, heavy odor. Dry.			S-7
14		0.67/0	SILT, very soft, light brown; with some gray highly weathered gabbro, heavy odor.			S-8
16		0/0	No recovery.			S-9
		0/1				S-10
18			End of boring at 18' bgs.			

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-2**
Client:	U.S. Naval Station
Boring Location:	MH-SB-2
Northing:	18.2338933
Easting:	-65.62022733
Start - Finish Date:	9/18/99 - 9/19/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Trevor King/Warren
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	30.3
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

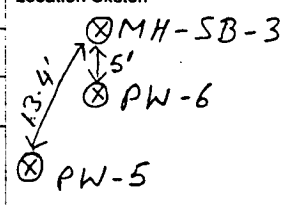


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
		1.08/2	SILT, sandy, very soft, brown with fill. Dry.			S-1
2		1.29/2	CLAY, sandy, very stiff, light brown and reddish with fresh gabbro cobbles and pebbles. Moist.			S-2
4		0.83/2	CLAY, sandy, very stiff, light brown and reddish with some fresh gabriel or fill pebbles, cobbles. Moist.			S-3
6		0.21/2	CLAY, stiff reddish brown, with some granular sand and moderatly weathered pebble gabbro. Moist.			S-4
8		1.33/2	CLAY, stiff reddish brown with trace light gray coloring. Moist.			S-5
10		1.79/2	CLAY, stiff reddish brown with trace light gray coloring. Moist.			S-6
12		1.75/2	CLAY, stiff reddish brown with trace light gray coloring. Moist.			S-7
14		1.96/2	SILT, sandy, very stiff, light brown; with light gray and light tan fine to coarse weathered gabbro, heavy odor. Slightly moist. SILT, sandy, very stiff, brown; with some highly weathered gabbro, granular pebbles with reddish orange coloring. Slightly moist.			S-8
16		0.92/2	CLAY, sandy, stiff, gray; with highly weathered gabbro and staining. Large pebbles, gabbro or fill between 15 to 15.5', heavy odor. Moist. SILT, clayey, hard, greenish gray; with dark gray highly weathered gabbro and staining. Dry.			S-9
18		0.13/1	ROCK, slightly weathered gabbro; with some clayey silt, odor. Dry.			S-10
20		1.92/2	ROCK, very stiff, dark gray, slightly weathered gabbro; with some sandy silt, possible staining, odor. Dry. ROCK, and debries, fresh gabbro.			S-11
22		2/2	CLAY, sandy, hard olive gray and dark gray; with trace highly weathered rock or gabbro, odor. Moist.			S-12
24		0.46/1	SILT, soft, light brown to tan; with highly weathered gabbro. Refusal: 23.5-24', slight odor.			S-13
		0.42/1	CLAY, silty, very stiff, olive gray and reddish orange; with fine grained highly weathered gabbro. Refusal: 24.5-25', slight odor. Dry.			S-14
		0.86/2	SILT, sandy, stiff, dark gray; with some white fine to medium stiff debries. Moist.			S-15
26		0.83/1	SILT, sandy, soft, olive gray reddish brown, top 1" saturated. Moist.			S-16
		0.58/1	SILT, sandy, soft, olive gray reddish brown, with semi moderate to highly weathered gabbro. Wet.			S-17
28		1.33/2	SILT, sandy, stiff, reddish orange; with some weathered gabbro, dark gray, dark staining. Fresh to slightly weathered gabbro towards to bottom, Wet and saturated sample. Wet.			S-18
30		0.25/0	End of boring at 30.25' bgs.			S-19
32						

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-3**
Client:	U.S. Naval Station
Boring Location:	MH-SB-3
Northing:	18.23215581
Easting:	-65.61992843
Start - Finish Date:	9/20/99 - 9/21/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Will Whitesell/Pittsburgh
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	30.0
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

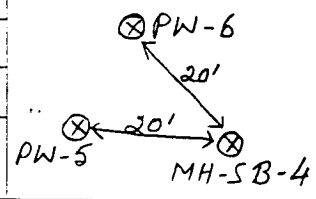


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
		0.7/2	CLAY, sandy, very stiff, dark gray; with rock fill. Slightly moist.			S-1
2		1.4/2	CLAY, sandy, very soft, yellowish red; with some grayish pebbles and coarse sand, highly weathered, heavy odor. Moist.			S-2
4		1.25/2	SILT, sandy, soft, light brown; with trace clay, heavy odor. Moist.			S-3
			CLAY, sandy, very stiff, greenish and olive gray; with some moderate to highly weathered gabbro, slight odor. Dry.			
6		1/2	CLAY, sandy, very stiff, greenish and olive gray; with highly weathered large pebble gabbro. Slightly moist.			S-4
8		1.4/2	CLAY, sandy, very stiff, greenish and olive gray, dark gray to blackish staining; with highly weathered large pebble gabbro, heavy odor.			S-5
10		1.3/2	SILT, sandy, stiff, dark gray; with reddish and black trace clay, staining, some highly weathered gabbro. Moist.		8-12	S-6
12		1.3/2	SILT, sandy, stiff, dark gray; with reddish and black trace clay, dark staining, some fresh to moderatly weathered gabbro with trace sandy silt. Dry.		10-19	S-7
14		1.25/2	SILT, sandy, stiff, dark gray; with reddish and black trace clay, dark staining, some fresh to moderatly weathered gabbro with trace sandy silt. Dry.		25-43	S-8
16		1.7/2	CLAY, silty, very stiff, dark gray; with mostly highly weathered gabbro \ rock, trace reddish color, dark staining. Moist.		37-50	S-9
18		0.5/1	SILT, clayey, stiff, dark brown to dark olive gray; with trace of some moderatly weathered gabbro.		30-40	S-10
		0.8/1	GRAVEL, very dense, gray-rust-brown; some medium to coarse sand, little silty clay. Slightly moist.		30-40	S-11
20		1.5/2	GRAVEL, sandy, very dense, rust brown, gray mottling and some silty clay.		50-100	S-12
22		1.7/2	0-6": GRAVEL, sandy, very dense, rust brown, gray mottling and some silty clay. 6-8": SAND, medium to coarse, red-gray-white. 8-20": GRAVEL, sandy dark gray , red, little silty clay. Slightly moist.		250	S-13
24		1.7/2	0-3": SAND, medium to coarse, medium dense, light gray (rock, some gravel). 3-6": SILT, clayey, very stiff, light gray-rust-brown, trace gravel. Slightly moist.		35	S-14
26		1.8/2	0-7": SILT, clayey, very stiff, light gray brown. 7-22": Silt, clayey, hard rust brown, light gray.		20	S-15
28		1.3/2	0-6": Sand, gravely, very dense, light gray-rust brown; some clayey silt. 6-16": SAND, silty, very dense, rust brown/light gray; trace gravel, trace clay. Slightly moist.		20-70 15-40	S-16
30			End of boring at 30' bgs.			
32						

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-4**
Client:	U.S. Naval Station
Boring Location:	MH-SB-4
Northing:	18.23209721
Easting:	-65.61990645
Start - Finish Date:	9/21/99 - 9/22/99
Drilling Contractor:	STC
Driller:	Luciano Rodriguez Velez
Logged By:	T. King/Warren & W. Whitesell/Pittsburg
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	21.5
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

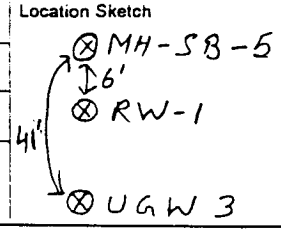


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
		1.7/2	GRAVEL, sandy, medium to very dense light gray and rust-brown highly weathered, some clayey silt. Dry.			S-1
2		1.4/2	GRAVEL, sandy, very dense light gray highly weathered (saprolitic), little clayey silt. Dry.			S-2
4		1.5/2	SAND, gravelly, very dense light gray (saprolitic), trace fine sand. Dry.		21	S-3
6		1.25/2	SAND, gravelly, very dense light gray, brown; trace fine sand. Dry.		20-50	S-4
8		1.6/2			8-10	S-5
10		1.4/2	SAND, gravelly, very dense light gray, brown; trace fine sand, trace clayey silt. Dry.			S-6
12		1.4/2				S-7
			SAND, gravelly, very dense reddish-gray (saprolitic); trace clayey silt. Dry.			
14		1.3/2	SAND, gravelly, very dense light gray (saprolitic); trace clayey silt, refusal at 15.5'. Dry.		5.5-10	S-8
			Auger advanced to 16'. No recovery.			
16		1.3/2	SAND, gravelly, very dense reddish-gray (saprolitic); trace clayey silt. Moist.			S-9
			SAND, dark brown fine to medium grained, moist to wet with product from 16.5-17'. Dry with odor from 17-18'. 2 feet of diesel in auger (16-18').			
18		0.7/1	SAND, gravelly, very dense rust-brown and gray highly weathered (saprolitic). Refusal at 18.8'. Moist.			S-10
			Auger to 19.5', difficult drilling. No recovery. Auger to 20'.			
20		0.8/1	SAND, gravelly, very dense rust-brown and gray highly weathered (saprolitic). Refusal at 20.9', wet.			S-11
		0.5/1	1' SAND. Difficulty drilling; refusal at 21.5'. Auger cuttings like slop with diesel.			S-12
22			End of boring at 21.5' bgs.			

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-5**
Client:	U.S. Naval Station
Boring Location:	MH-SB-5
Northing:	18.23330955
Easting:	-65.62034561
Start - Finish Date:	9/22/99 - 9/22/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Trevor King/Warren
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	29.0
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch



Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
		0.8/2	0-5": SILT, clayey, medium stiff, dark brown; trace fine sand and gravel, grass roots. 5-8": SAND, medium to coarse grained, soft to medium hard, brown and gray. 8-10": same as 0-5".. Moist.			S-1
2		1.08/2	CLAY, silty, stiff rust-brown, mottling gray; trace gravel and fine sand. Moist.		0	S-2
4		1.08/2	CLAY, silty, stiff rust-brown mottling gray; trace fine sand. Moist.			S-3
6		1.17/2	CLAY, silty. 0-9": very stiff to hard, rust-brown mottling gray, trace fine sand. 9-14": hard, rust-brown, mottling of gray and black color; some fine to coarse sand.		0	S-4
8		0/2	No recovery. Augered soil same as between 6-8"..		0	S-5
10		1.75/2	0-5": CLAY, silty, very stiff, rust-brown mottling gray. 5-2" : GRAVEL, sandy, medium dense to dense; trace clayey silt.. Slightly moist.		0	S-6
12		0.92/2	GRAVEL, fine and sand, dense, light and dark gray, rust brown; trace coarse gravel, trace clayey silt. Slightly moist.		0	S-7
14		1.58/2	SILT, clayey, hard, rust-brown and gray; some fine to coarse sand. 15-18": fine to coarse sand - dry.		20-50	S-8
16		1.17/2	SAND, fine to coarse grained, very stiff to hard, dark gray and rust brown; some clayey silt, trace gravel. Slightly moist.		10-30	S-9
18		1.33/2	SAND,fine to coarse, very dense, rust-brown and gray; trace gravel, trace clayey silt. Slightly moist.		100-200	S-10
20		1.42/2	0-8", 14-17": SAND,fine to coarse, very dense, rust-brown and gray; trace gravel, trace clayey silt. 8-14": same but less clay and sand. Dry.		90-110	S-11
22		0/1	SAND,fine to coarse, very dense, rust-brown and gray; trace gravel, trace clayey silt. Refusal at 22', auger to 23'. Moist.		100-120	S-12
		0/1				S-13
24		0/1				S-14
		0/1				S-15
		0/1				S-16
26		0/1				S-17
		0/1				S-18
		1.83/2	0-14": SAND, very dense, rust-brown and dark gray mottlings; some gravel and fine sand, little to some clayey silt. 14-22": SAND, clayey, hard, light gray, white, rust-brown mottled, trace coarse sand (saprolitic appearance). Slightly moist.			S-19
28		0.67/1	CLAY, mottled, hard, light gray, white, rust-brown; some fine to coarse sand, trace gravel. Refusal at 28'7".		3-10	S-20
30			~~End of boring at 29' bgs.~~ Auger to 29'.			S-21

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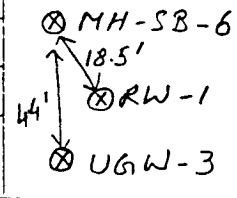
McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-6**
Client:	U.S. Naval Station
Boring Location:	MH-SB-6
Northing:	18.23328684
Easting:	-65.62029761
Start - Finish Date:	9/22/99 - 9/22/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Trevor King/Warren
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	29.0
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

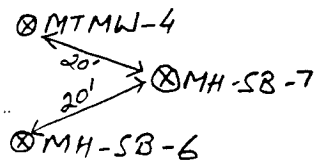


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
			Auger advanced to 10' below ground surface (b.g.s.). Moist.			
10		1.7/2	CLAY, silty. 0-9": hard rust- brown/gray, trace sand. 9-20": dense, light and dark gray; with some rust-brown fine gravel and sand. Moist.		120 210	S-1 S-2
12		1.6/2	CLAY, sandy, hard olive gray/rust-brown and white mottling(saprolitic appearance), trace gravel. Moist.		150	S-3
14		1.6/2	CLAY, sandy, very stiff to hard olive gray/rust-brown and white mottling(saprolitic appearance), trace gravel. 9-14": fine to coarse sand, trace gravel. Dry.		200 60	S-4
16		1.75/2	CLAY, sandy, hard olive gray/rust-brown and white mottling(saprolitic appearance), trace gravel. Moist.		120 30	S-5
18		1.7/2	CLAY, sandy, hard olive gray/rust-brown and white mottling(saprolitic appearance), friable and crumbling; trace gravel. Slightly moist.		120 70	S-6
20		1.4/2	CLAY, sandy, hard olive gray/rust-brown and white mottling(saprolitic appearance), friable and crumbling; trace gravel. 10-12": dry sand and gravel. Moist.		160	S-7
22		1.7/2	SAND, 0-9": very dense, rust-brown and gray, gravelly fine to coarse grained; little clay. 9-20": very dense, rust-brown with some gray white mottling clayey sand, trace gravel. Wet.		100	S-8
24		1.4/2	SAND, very light gray brown, fine to medium grained, trace coarse sand. 5-7": gray sand and gravel. 7-17": sandy clay, very stiff to hard olive gray/rust brown and white mottling (saprolitic appearance), trace gravel. Wet and saturated towards the bottom. Wet.			S-9
26		1.5/2	SAND, 0-6": clayey, very dense rust-brown and white mottling (saprolitic appearance). 6-18": fine to medium grained, very dense, rust-brown with white/gray crystals, trace gravel, trace clay.			S-10
28			Auger to 29'.			S-11
30			End of boring at 29' bgs.			

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-7**
Client:	U.S. Naval Station
Boring Location:	MH-SB-7
Northing:	18.23329614
Easting:	-65.62023884
Start - Finish Date:	9/24/99 - 9/24/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Trevor King/Warren
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	13.4
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

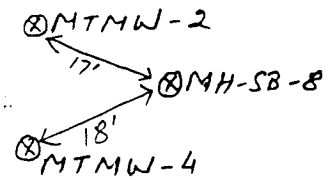


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
2, 4			CLAY, silty, soft to medium stiff, olive gray and brown; trace fine to medium sand. Moist.			S-1
6, 8			CLAY, silty, soft to medium stiff, olive gray and light brown; trace fine to medium sand. Moist.			S-2
10		1.08/2	0-5": CLAY, silty, soft rust-brown gray; trace fine to medium sand. 5-19": SAND and gravel, light gray; little silty clay. Moist.			S-3
12		1.58/2	0-7": CLAY, silty, very stiff rust-brown gray; trace fine to medium sand. 7-16": SAND and gravel, very dense light gray; trace silty clay. 16-19": SAND and gravel, very dense rust-brown; trace silty clay. Slightly moist.			S-4
14			End of boring at 13.42' bgs.			

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**MH-SB-8**
Client:	U.S. Naval Station
Boring Location:	MH-SB-8
Northing:	18.23333816
Easting:	-65.62023577
Start - Finish Date:	9/24/99 - 9/24/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	Trevor King/Warren
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	BK-51
Total Depth (ft):	26.0
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch

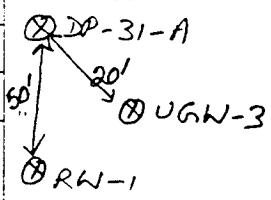


Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
2, 4		NA	CLAY, silty, soft to medium stiff, yellowish orange; trace fine to medium sand. Moist.			S-1
6, 8		NA	CLAY, silty, soft to medium stiff, yellowish orange; trace fine to medium sand. Moist.			S-2
10		1.83/2	0-5": CLAY, silty, stiff rust-brown; trace sand. 5-13": CLAY, sandy, hard rust-brown, gray and white crystals (saprolitic appearance); trace gravel. 13-22": GRAVEL and sand, dense rust-brown gray and white crystals (saprolitic appearance); little silty cl. Slightly moist.			S-3
12		1.5/2	SAND, clayey, dense to very dense rust-brown (saprolitic appearance), gray and white crystals; little gravel. Moist.			S-4
14		1.33/2	SAND, fine to medium grained, medium dense to dense, yellowish orange, light gray; trace gravel, little clay (saprolitic and crumbling). Moist.			S-5
16		1.5/2	0-9": CLAY, silty, hard rust-brown light gray and white crystals; trace sand. 9-18": SAND, fine to coarse, very dense, light gray; trace gravel, trace clayey silt (smell of diesel in cuttings). Wet.			S-6
18		1.33/2	SAND, fine to coarse, very dense, light and olive gray and white crystals, trace gravel (smell of diesel, core not well defined). Slightly moist.			S-7
20		1.67/2	SAND, fine to medium grained, very dense, light gray and brown; trace coarse sand, trace clayey silt. Moist.			S-8
22		1.75/2	SAND, fine to medium grained, very dense, light gray and brown; trace coarse sand, trace clayey silt (6-10": crumbled), several horizontal breaks.			S-9
24		1.42/2	0-9": SAND,very dense rust-brown. 9-17": SAND, and gravel, very dense light brown; trace clay. Dry.			S-10
26			End of boring at 26' bgs.			
28						

McLaren Hart INC.

Site:	Tow Way Fuel Farm, Roosevelt Roads
Location:	Roosevelt Roads , Puerto Rico
Boring ID:	**DP-31A**
Client:	U.S. Naval Station
Boring Location:	DP-31A
Northing:	
Easting:	
Start - Finish Date:	9/15/99 - 9/15/99
Drilling Contractor:	STC
Driller:	Robert Marrero Mojica
Logged By:	T. King/Warren & W. Whitesell/Pittsburg
Boring Permit:	N/A
Drilling Method:	Hollow-stem auger
Drilling Equipment:	SIMCO 2400 SK-1
Total Depth (ft):	18.0
Ground Elevation (ft):	NA
Vertical Datum:	
Horiz Coor Sys:	Lat/Long 1983
Sampling Method:	2" Split spoon
Borehole Diameter (in):	6
Memo:	

Location Sketch



Depth (ft)	Geoprobe Sample	Recovery (ft)	Soil Description	Lithology	PID/FID (ppm)	Sample ID
		0.33/2	FILL, very soft, clay and conglomerate fill. Very moist.			S-1
2		1.17/2	CLAY, very stiff, brown; with some fine gravel fill.			S-2
4		0.79/2	CLAY, very stiff, brown; with some fine gravel fill.			S-3
6		1.08/2	FILL, blueish-gray, coarse sand; trace clay. Moist.			S-4
			GABBRO, fresh dark gray jointed. 8.0': refusal. Jointing due to pneumatic system (not geological).			
8		1.58/2	GABBRO, highly weathered reddish brown and gray olive. Dry.			S-5
10		1.5/2	GABBRO, weathered blue gray; some coarse sand and red staining. Moist.			S-6
12		1.75/2	GABBRO, (coarse sand) highly weathered brown and gray; red staining, trace clay. Moist.			S-7
14		2/2	GABBRO, (fine gravel) highly weathered light gray, strong organic odor. Dry.			S-8
16		1.91/2	CLAY, silty, stiff, tan white orange; some fine sand, less weathered towards the bottom, slight odor. Moist.			S-9
18			End of boring at 18' bgs.			

MANTECH ENVIRONMENTAL
14290 Sullyfield Circle, Suite 100
Chantilly, Virginia 20151

LOG OF BORING AW-1

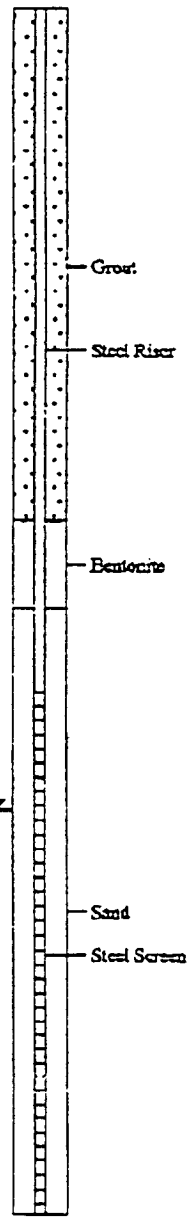
(Page 1 of 1)

Naval Station Roosevelt Roads
Tow Way Fuel Farm
Ceiba, PR
Project # 8207.000

Drilling Method	: Hollow Stem Auger	Static Water Level	: 24 feet bgs
Driller	: Sell Tech	Stick Up	: 0
ManTech Rep.	: Carol Callaghan	Well Inner Diameter	: 2 inch
Sample Type	: Split Spoon, Grab	Well Construction	: PVC Screen/Riser
Hole Diameter	: 8 inches	Well Depth	: 36 Feet

Well1: AW-1
Elev.: 7.7 Feet Above Mean Sea Level

Depth in Feet	DESCRIPTION	USCS	GRAPHIC	Depth in Feet	Samples	Blow Count
0	Brown silty clay	CH		0		
16	Dense gray clay with gravel and cobbles. Petroleum odor. Dry	CH		16		
18	Dense brown clay with angular cobbles and boulders, slight petroleum odor. Dry	CH		18		
24	Dense red-brown clay slight petroleum odor. Dry	CH		24		
26	Rock-angular cobbles and boulders, WET WITH PETROLEUM PRODUCT	PD		26		
28	Brown clay with gravel, Wet	CH		28		
30	Brown silty gravel, Wet	GW		30		
36				36		



MANTECH ENVIRONMENTAL
14290 Sullyfield Circle, Suite 100
Chantilly, Virginia 20151

LOG OF BORING AW-2

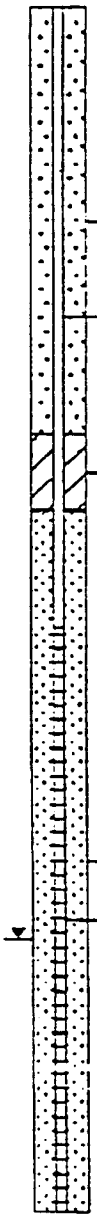
(Page 1 of 1)

Naval Station Roosevelt Roads
Tow Way Fuel Farm
Ceiba, PR
Project # 8207.000

Drilling Method	: Hollow Stem Auger	Static Water Level	: 24 Feet bgs
Driller	: Soil Tech	Stick Up	: 0
ManTech Rep.	: Carol Callagan	Well Inner Diameter	: 2 inches
Sample Type	: Split Spoon, Grab	Well Construction	: Steel Screen/Riser
Hole Diameter	: 8 Inches	Well Depth	: 31

Well1: AW-2
Elev.: 6.7 Feet Above Mean Sea Level

Depth in feet	DESCRIPTION	USCS
0–8	Cuttings brown silty clay, then light brown - red clay	CH
8–9	Red brown silty clay, Dry	CH
9–10	Brown and grey mottled clay, Dry	CH
10–12	Dense brown clay, Dry	CH
12–16	Dense brown clay with cobbles, Dry	CH
16–20	Grey silty clay with cobbles, petroleum odor, Dry	CH
20–21	Dense grey clay with cobbles WET WITH PETROLEUM PRODUCT	CH
21–22	Dense grey clay with cobbles, Dry	CH
22–23	Angular cobbles of gabbro petroleum stained, Wet	GW
23–24	Red Clay, Dry	CH
24–31	Silty clay with cobbles, petroleum stained, Wet	CH



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14290 Sullyfield Circle, Suite 100
Chantilly, Virginia 20151

LOG OF BORING MTMW-1

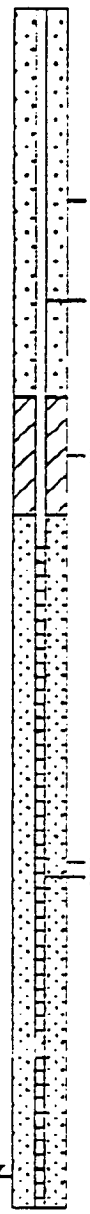
(Page 1 of 1)

Naval Station Roosevelt Roads
Tow Way Fuel Farm
Ceiba, PR
Project # 8207.000

Drilling Method	: Hollow Stem Auger	Static Water Level	: 39 Feet bgs
Driller	: Soil Tech	Stick Up	: 0
ManTech Rep.	: Carol Callaghan	Well Inner Diameter	: 2 inches
Sample Type	: Split Spoon, Grab	Well Construction	: PVC Screen/Riser
Hole Diameter	: 8 Inches	Well Depth	: 40

Well1: MTMW-1
Elev.: 8.6 Feet Above Mean Sea Level

Depth in Feet	DESCRIPTION	USCS	GRAPHIC	Depth in Feet	Samples	Blow Count
0	Brown silty clay, Dry.			0		
2				2		
4				4		
6				6		
8				8		
10				10		
12				12		
14		CH		14		
16				16		
18				18		
20				20		
22				22		
24				24		
26				26		
28				28		
30	WET WITH PETROLEUM PRODUCT.	PD		30		
	Brown silty clay, Wet at 39 feet bgs.					
32				32		
34		CH		34		
36				36		
38				38		
40				40		



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Chantilly, Virginia 20151

LOG OF BORING MTMW-2

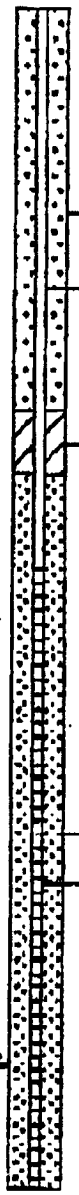
(Page 1 of 1)

Naval Station Roosevelt Roads
Tow Way Fuel Farm
Ceiba, PR
Project # 8207.000

Drilling Method	: Hollow Stem Auger	Static Water Level	: 24 Feet bgs
Driller	: Soil Tech	Stick Up	: 0
MinTech Rep.	: Carol Gallagher	Well Inner Diameter	: 2 inches
Sample Type	: Split Spoon, Grab	Well Construction	: PVC Screen/Riser
Hole Diameter	: 8 Inches	Well Depth	: 38

Depth in Feet	DESCRIPTION	USCS	GRAPHIC	Depth in Feet	Samples	Blow Count
0	Grey clay and gravel with petroleum odor. Water at 24 feet bgs.	CH		0		
2				2		
4				4		
6				6		
8				8		
10				10		
12				12		
14				14		
16				16		
18				18		
20				20		
22				22		
24				24		
26				26		
28				28		
30				30		
32				32		
34				34		
36				36		
38				38		

Well: MTMW-2
Elev.: 8.0 Feet Above Mean Sea Level



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LOG OF BORING MTMW-3

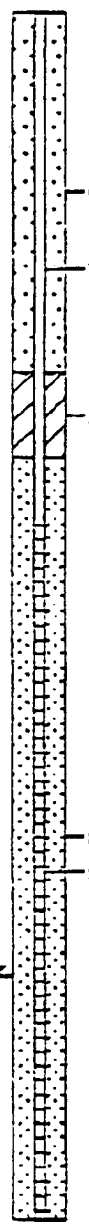
(Page 1 of 1)

Naval Station Roosevelt Roads
Tow Way Fuel Farm
Ceiba, PR
Project # 8207.000

Drilling Method	: Hollow Stem Auger	Static Water Level	: 28 feet bgs
Driller	: Soil Tech	Stick Up	: 0
MacTech Rep.	: Carol Callaghan	Well Inner Diameter	: 2 inch
Sample Type	: Split Spoon, Grab	Well Construction	: PVC Screen/Riser
Hole Diameter	: 8 inches	Well Depth	: 35 Feet

Depth in Feet	DESCRIPTION	USCS	GRAPHIC	Depth in Feet	Samples	Blow Count
0	Silty clay	CH		0		
1				1		
2				2		
3				3		
4				4		
5				5		
6				6		
7				7		
8				8		
9				9		
10	Dense red brown to olive silty clay with cobbles, Dry	CH		10		
11				11		
12				12		
13				13		
14				14		
15	Dense red and grey mottled clay, Dry	CH		15		
16	Gravel and cobbles, Dry	GW		16		
17				17		
18	Dense greyish gabbro saprolite, strong petroleum odor, dry	GW		18		
19				19		
20	Dense petroleum stained brown silty clay with cobbles, dry	CH		20		
21				21		
22	Dense petroleum stained grey silty clay with cobbles, Dry	CH		22		
23				23		
24	Dense petroleum stained grey silty clay with cobbles, WET WITH PETROLEUM PRODUCT	PD		24		
25		CH		25		
26	Silty sand with cobbles, Dry	CH		26		
27	Red brown silty clay with cobbles			27		
28	Silty sand with cobbles, Wet at 30 Feet	CH		28		
29				29		
30	Silty clay	CH		30		
31				31		
32				32		
33				33		
34				34		
35				35		

Well1: MTMW-3
Elev.: 7.5 Feet Above Mean Sea Level



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LOG OF BORING MTMW-4

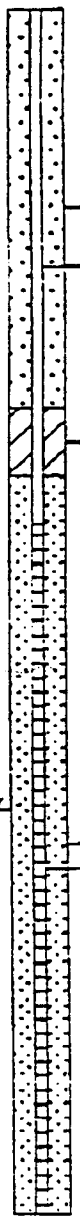
(Page 1 of 1)

Naval Station Roosevelt Roads
Tow Way Fuel Farm
Ceiba, PR
Project # 8207.000

Drilling Method	: Hollow Stem Auger	Static Water Level	: 22
Driller	: Soil Tech	Stick Up	: 0
ManTech Rep.	: Carol Callaghan	Well Inner Diameter	: 2 inch
Sample Type	: Split Spoon, Grab	Well Construction	: PVC Screen/Riser
Hole Diameter	: 8 in.	Well Depth	: 36 Feet

Depth in Feet	DESCRIPTION	USCS	GRAPHIC	Depth in Feet	Samples	Blow Count
0–8	Brown silty clay	CH		0–8		
8–9	Dense brown and grey mottled clay, dry	CH		8–9		
9–10	Gravel, dry	GW		9–10		
10–12	Red clay, dry	CH		10–12		
12–13	Grey clay, strong petroleum odor, dry	CH		12–13		
13–14	Grey clay some angular gravel, strong petroleum odor, dry	CH		13–14		
14–16	Green silty clay with angular gabbro gravel, petroleum odor, dry	CH		14–16		
16–18	Angular gabbro gravel, dry	GW		16–18		
18–20	Angular gabbro gravel, WET WITH PETROLEUM PRODUCT	PD		18–20		
20–22	Silty clay with gravel, strong petroleum odor, dry	CH		20–22		
22–26	Gabbro gravel, wet	GW		22–26		
26–36	Olive silty clay, wet	CH		26–36		

Well1: MTMW-4
Elev.: 7.1 Feet Above Mean Sea Level

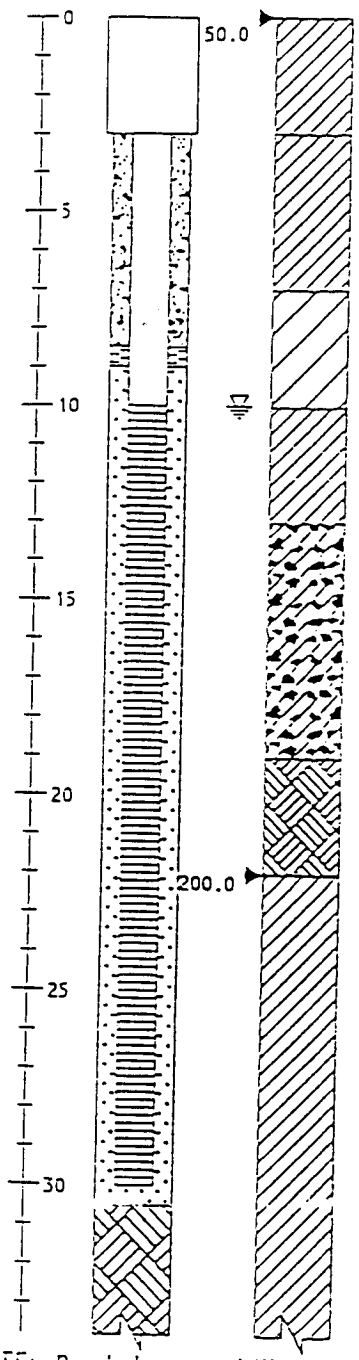


BORING / WELL LOG

BORING NO.: RW-1

PROJECT: Free Product Recovery
PROJECT NO.: 945809
CLIENT/OWNER: U.S. Navy
BORING LOCATION: Upper Tow-Way Fuel Facility
DRILLING CO.: Soil Tech
DRILLER: Jorge Diaz
DRILLING METHOD: 8 1/4" HSA
DRILL RIG: Mobile B-90

DATE DRILLED: 10/17/96
TOC ELEVATION:
GS ELEVATION:
DTW AT COMPLETION: 10'9"
DTW AFTER 24 HOURS:
LOGGED BY: D. Drozd



ELEVATION/ DEPTH (feet)	WELL DETAIL	PID READINGS, SOIL SYMBOLS, SAMPLERS, AND TEST DATA	USCS	DESCRIPTION	SAMPLE No.	SAMPLE Rec.	STANDARD PENETRATION TEST DEPTH	STANDARD PENETRATION TEST N	STANDARD PENETRATION TEST CURVE (10 30 50)
0		50.0	cl	SILT and CLAY, little gravel, brown, moist, fill					
			3.0 cl	CLAY, some silt, some gravel, gray-green, strong odor, moist, compacted					
			7.0 ch	CLAY, light brown, strong odor, moist, compacted					
			10.0 cl	CLAY, some silt, little gravel, angular to subangular, light brown, slight odor, compacted					
			13.0 gc	GRAVEL, little clay, light brown, medium odor, moist, uncompacted					
			19.0 rock	ROCK, subangular, gray-green, hard, little clay, medium brown, wet, medium odor					
		200.0	22.0 cl	CLAY, little sand, medium to coarse grained, trace gravel, wet, strong odor, compacted					

NOTE: *Borehole was redrilled to a depth of 35 feet because well originally collapsed and to allow room for installation of the well if the borehole collapsed.*

CHECKED BY:

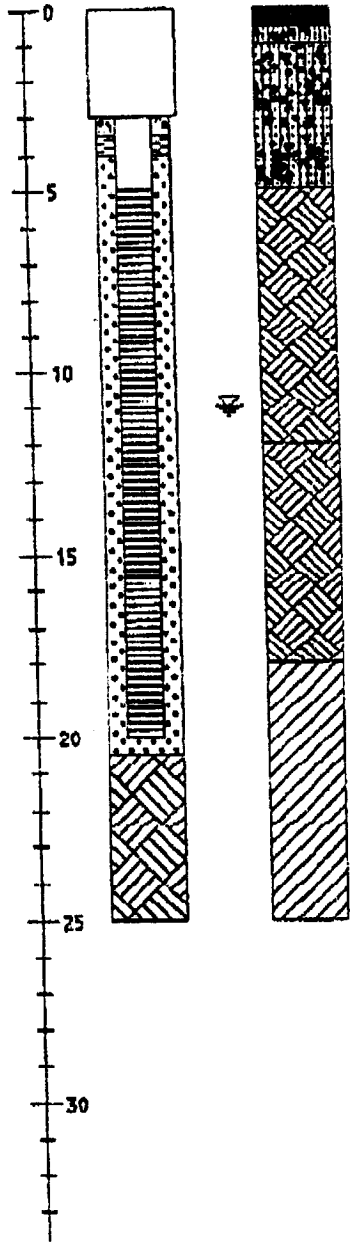
This information pertains only to this boring and should not be interpreted as being indicitive of the site.

BORING / WELL LOG

BORING NO.: RW-7

PROJECT: Free Product Recovery
PROJECT NO.: 945809
CLIENT/OWNER: U.S. Navy
BORING LOCATION: Forrestal Road
DRILLING CO.: Soil Tech
DRILLER: Jorge Diaz
DRILLING METHOD: 8 1/4" HSA
DRILL RIG: Mobile B-90

DATE DRILLED: 10/18/96
TOC ELEVATION:
GS ELEVATION:
DTW AT COMPLETION: 11'3"
DTW AFTER 24 HOURS:
LOGGED BY: D. Drozd



ELEVATION/ DEPTH (feet)	WELL DETAIL	PID READINGS, SOIL SYMBOLS, SAMPLERS, AND TEST DATA	USCS	DESCRIPTION	SAMPLE No.	SAMPLE Rec.	STANDARD PENETRATION TEST DEPTH	STANDARD PENETRATION TEST N	CURVE (10 30 50)
			0.5	ASPHALT					
			vg 1.0	BEDDING					
			GP-GM	GRAVEL, some silt, trace sand, brown, dry, uncompacted, fill					
			5.0 rock	ROCK, grey-green, hard, subangular to angular, little silt, brown, dry, medium odor, uncompacted					
			12.0 rock	ROCK, grey-green, hard, slight to medium odor, dry, uncompacted					
			19.0 cl	CLAY, trace gravel, trace sand, light to medium brown, medium odor, wet, compacted					
			25.0	Bottom of Boring					

NOTE: *Borehole was drilled to a depth of approximately 25 feet to allow room for installation of well if borehole collapsed.*

CHECKED BY:

This information pertains only to this boring and should not be interpreted as being indicitive of the site.

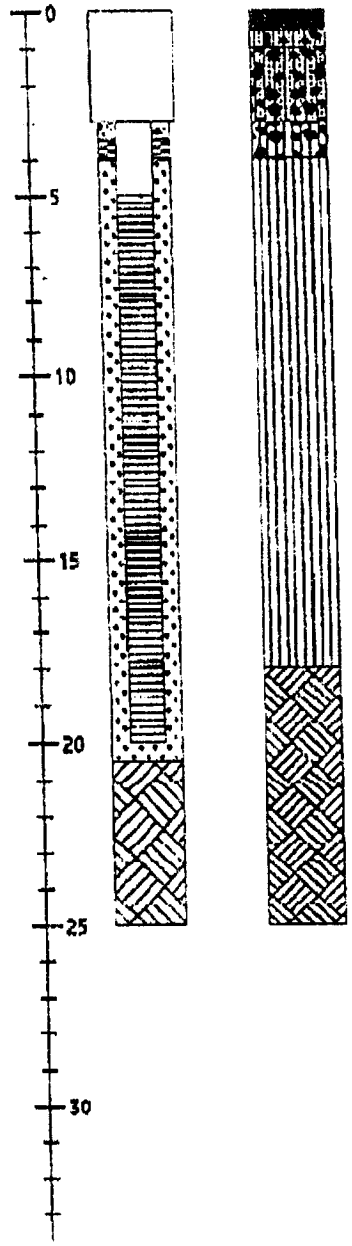
ICHOR Services, Inc.

BORING / WELL LOG

BORING NO.: RW-8

PROJECT: Free Product Recovery
PROJECT NO.: 945809
CLIENT/OWNER: U.S. Navy
BORING LOCATION: Forrestal Road
DRILLING CO.: Soil Tech
DRILLER: Jorge Diaz
DRILLING METHOD: 8 1/4" HSA
DRILL RIG: Mobile B-90

DATE DRILLED: 10/21/96
TOC ELEVATION:
GS ELEVATION:
DTW AT COMPLETION:
DTW AFTER 24 HOURS:
LOGGED BY: D. Drozd



ELEVATION/ DEPTH (feet)	WELL DETAIL	PID READINGS, SOIL SYMBOLS, SAMPLERS, AND TEST DATA	USCS	DESCRIPTION	SAMPLE No.	SAMPLE Rec.	STANDARD PENETRATION TEST DEPTH	STANDARD PENETRATION TEST N	CURVE 10 30 50
			0.5	ASPHALT					
			vg 1.0	BEDDING					
			SM-GM 3.0	GRAVEL and SAND, some silt, trace clay, medium brown, dry, uncompacted, fill					
			gm 4.0	GRAVEL and SILT, some sand, medium brown, dry, uncompacted, fill					
			ml	SILT, some gravel, some sand, dry, light to medium brown, uncompacted					
			18.0 rock	ROCK, dark grey, light brown, hard, angular, wet					
			25.0	Bottom of Boring					

NOTE: *Borehole was drilled to a depth of approximately 25 feet to allow room for installation of well if borehole collapsed.*

CHECKED BY

This information pertains only to this boring and should not be interpreted as being indicitive of the site.

ICHOR Services, Inc.