1RP - 2

WORKPLANS

2008 - 2010:

Griswold, Jim, EMNRD

From: Griswold, Jim, EMNRD
Sent: Wednesday, October 22, 2008 8:48 AM
To: 'joshua.morrissette@bjservices.com'
Subject: Former FracMaster Facility (1RP-2) in Hobbs, NM

Joshua,

I have reviewed the *Workplan for Additional Site Investigation Activities* dated 9/22/08 prepared by Brown & Caldwell for the Hobbs site. This workplan is approved with the following conditions:

1. A minimum of one split soil sample from each new bore should be submitted for laboratory assay by Methods 8260, 8270, 8015B, and 300 (chloride), regardless of observed headspace or visual indications of adsorbed contamination. It is preferable that two such samples be submitted from each boring location: one from the vadose zone gathered nearest the observed water table/capillary fringe, and the other corresponding to the highest recorded headspace or visual indication of contamination. At least one soil sample from the 3 new borings should also be assayed for major anions, cations, and metals.

2. Proposed groundwater monitoring well MW-4 will **NOT** be placed outside the former excavation area as depicted in Figure 8 of the workplan. Rather, this well should be located further south between former borings MS and ES within the area of highest probable soil contamination. A vertical migration pathway for contaminants already exists as demonstrated by the confirmed groundwater impact. If the well is properly constructed, no enhanced potential for vertical migration would be created.

3. All wells will be completed with 15 feet of screen, no more than 10 feet of which shall be placed beneath the encountered water table.

4. At least 24 hours should be allowed to elapse between well development and groundwater sampling. After checking for product/DTW with an interface probe, but prior to sampling, a clear or translucent bailer should be gently lowered into each well no more than one foot below the water table and checked for the appearance of a hydrocarbon sheen upon the groundwater. Measurement of each well's total depth (for both existing and new wells) should also be made.

5. If low-flow groundwater sampling is to be implemented, the sampling pump inlet shall be placed no more than 18 inches beneath the static water table and the level be allowed to re-equilibrate for several minutes. Thereafter, the pumping rate should be such that no more than 6 inches of drawdown is sustained. Laboratory samples should not be gathered until a minimum of 3 gallons of groundwater has been removed from each well (not including the volume required to fill the sample tubing) along with stabilization of conductivity and pH.

6. Dissolved oxygen measurements via field titration are preferred. Typically, use of a flow cell in the presence of hydrocarbons will degrade the membrane resulting in erroneous data. Observed DO levels greater than 2.5 mg/l should be considered as indicative of potentially aspirated (and thus invalid) groundwater samples.

Please contact me at least 72 hours prior to the initiation of field activities. Thank you.

Jim Griswold
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ENMRD/Oil Conservation Division
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WORK PLAN
FOR
ADDITIONAL SITE INVESTIGATION ACTIVITIES

Prepared for
BJ Services Company, U.S.A.
Former FracMaster Facility
Hobbs, New Mexico
September 22, 2008

WORK PLAN FOR ADDITION SITE INVESTIGATION ACTIVITIES

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Hobbs, New Mexico
September 22, 2008

Project # 128125

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WORK PLAN FOR ADDITIONAL SITE INVESTIGATION ACTIVITIES

1. INTRODUCTION

Sampling conducted in July 2005 and February 2006 identified impact to soil and groundwater in the area of a former field waste tank located in the central portion of the BJ Services Company, U.S.A. (BJ Services) former FracMaster facility (site) located at 1329 N. West County Road in Hobbs, New Mexico. A site location map is included as Figure 1. The July 2005 and February 2006 investigations were summarized in the following documents that were previously submitted to New Mexico Oil Conservation Division (NMOCD):

- *July 2005 Soil and Groundwater Sampling Report, Hobbs (FracMaster), New Mexico Facility, BJ Services Company, U.S.A.*, dated February 14, 2006; and
- *February 2006 Soil and Groundwater Sampling Report, Hobbs (FracMaster), New Mexico Facility, BJ Services Company, U.S.A.*, dated June 1, 2006.

On August 21, 2008, NMOCD requested submittal of a work plan outlining in detail the installation and sampling of three additional monitor wells at the facility. This work plan has been prepared to meet the objectives specified by NMOCD in their August 21, 2008 correspondence to BJ Services.

1.1 Background

BJ Services assumed control of the former FracMaster site in Hobbs, New Mexico through acquisition of FracMaster. A layout of the facility is shown in Figure 2. A former field waste tank and approximately 1,400 tons of soil were previously removed at the facility. Post-excavation samples collected in March 2005 reportedly indicated impacts to soil by gasoline- and diesel-range total petroleum hydrocarbons (TPH-G and TPH-D). Volatile and semivolatile organic compounds (VOCs and SVOCs) were reportedly detected in the post-excavation floor sample; the post-excavation sidewall samples were not analyzed for VOCs and SVOCs. The approximately 25-foot deep excavated area was subsequently backfilled. The lateral dimensions of the excavated area were determined to measure approximately 25 feet by 30 feet.

1.2 Previous Investigations and Activities

July 2005

Brown and Caldwell installed five soil borings in the vicinity of the previously excavated area to define the vertical and horizontal extent of impacted soils. The locations of these borings are indicated in Figure 2.

TPH, VOC, and SVOC concentrations measured in soil borings situated to the north and south of the former field waste tank excavation were less than NMOCD remediation action levels, but elevated concentrations of these constituents were observed in samples collected from vadose zone soil in borings situated on the eastern and western sides of the previously excavated area (See Table 1). These soil impacts were delineated vertically above the top of the saturated zone.

Groundwater was encountered at approximately 46 feet to 49.5 feet below grade under unconfined conditions in the uppermost aquifer in the vicinity of the previously excavated area. Benzene, naphthalene, and xylenes were detected in the groundwater sample collected from the uppermost aquifer at the "ES" location to the east of the backfilled area at concentrations exceeding New Mexico Water Quality Control Commission (NMWQCC) criteria (see Table 2).

February 2006

Brown and Caldwell installed three monitor wells in the vicinity of the previously excavated area to determine the direction of groundwater flow, to more fully evaluate impact to groundwater at the site, and to define ~~the define~~ the lateral extent of soil impacts. As indicated in Figure 2, monitor well MW-1 was installed approximately 20 feet west the former field waste tank excavation; monitor well MW-2 was installed approximately 50 feet east of the former excavation; and monitor well MW-3 was installed approximately 50 feet north of the former excavation. TPH and BTEX concentrations measured in the soil borings for monitor wells MW-1 and MW-2 were less than the NMOCD remediation action levels (see Table 3), indicating that the lateral extent of impacted soil was defined.

Groundwater elevation data indicated that the groundwater flow direction in the former field waste tank area is to the north, as indicated in Figure 3. Chloride concentrations measured in up-gradient monitor well MW-1 and lateral to down-gradient monitor well MW-2 were greater than the NMWQCC standard of 250 mg/L; the chloride concentration in laterally downgradient monitor well MW-3 was less than the NMWQCC standard. TPH-G, naphthalene, 1,2,4,-trimethylbenzene, and m,p-xylenes were detected in the groundwater sample collected from the uppermost aquifer at the monitor well MW-2 location, but at concentrations less than applicable NMWQCC criteria (see Table 4).

1.3 Geology and Hydrogeology

Based on the boring logs from the July 2005 and February 2006 investigations (See Appendix A), the near-surface stratigraphy at the site consists of interbedded sand (SP and SW), silty sand (SM), clayey sand (SC), sandstone, and siltstone. Figures 4 and 5 are respective east-west and north-south cross-sections through the previously excavated area; existing soil analytical results are also presented in Figures 4 and 5. Figures 6 and 7 depict existing groundwater data on the same east-west and north-south cross-sections presented as Figures 4 and 5.

2. ADDITIONAL SITE ASSESSMENT ACTIVITIES

Three additional monitor wells will be installed at the site in accordance with the procedures specified in Section 3.0 of this work plan. Figure 8 depicts the proposed locations of these monitor wells. Details pertaining to the installation of proposed monitor wells MW-4, MW-5, and MW-6 are provided in the following subsections. Groundwater samples will be collected from new and existing monitor wells in accordance with the procedures described in Section 3.0 of this work plan.

2.1 Monitor Well MW-4

NMOCD requested installation of a monitor well within the lateral extent of the former excavation, between the former MS and ES boring locations. Based on the elevated photoionization detector (PID) readings measured in soil cores recovered from the MS boring (see boring log in Appendix A) and the elevated TPH, VOCs, and SVOCs concentrations measured in soil samples from the MS boring (see Table 3), this well (MW-4) will be installed at a location immediately north (*i.e.,* downgradient) of the previously excavated area (see Figure 8) in order to avoid the potential of creating a vertical migration pathway for chemicals previously documented as being present in soil immediately underlying the former field waste tank. A monitor well installed at the proposed MW-4 location will adequately evaluate potential groundwater impact from the former field waste tank while lessening the potential for vertical migration of chemicals from the vadose zone to underlying groundwater.

Soil cores will be collected at approximate 5-foot centers in the MW-4 boring from the ground surface to the top of the saturated zone. Recovered soil cores will be logged in accordance with the Unified Soil Classification System (USCS) and scanned with a calibrated PID. If one or more recovered soil cores display PID readings above background, then a soil sample will be collected from the interval of maximum PID response and submitted for laboratory analysis for the following parameters:

- TPH-G, TPH-D, and mineral spirits range TPH (TPH-M) by Method 8015M;
- VOCs by Method 8260B;
- SVOCs by Method 8270C; and
- Chloride by Method 300.0.

2.2 Monitor Well MW-5

Monitor well MW-5 will be installed at a downgradient location to the north of the former field waste tank location, in the area between existing monitor wells MW-2 and MW-3 (see Figure 8). If a soil sample is collected from the monitor well MW-4 soil boring, then a soil sample will be collected from the corresponding depth interval of the monitor well MW-5 soil boring, and analyzed for all of the constituents detected in the soil sample collected from the monitor well MW-4 soil boring.

2.3 Monitor Well MW-6

Monitor well MW-6 will be installed at an upgradient location approximately 75 feet south of the south corner of the former field waste tank excavation (see Figure 8). If a soil sample is collected from the monitor well MW-4 soil boring, then a sample will be collected from the corresponding depth interval of the monitor well MW-6 soil boring and analyzed for all of the constituents detected in the soil sample collected from the monitor well MW-4 soil boring.

3. FIELD PROCEDURES

The following sections describe the procedures and methodology that will be employed during the additional site assessment activities described herein.

3.1 Installation of Soil Borings and Collection of Soil Samples

Soil borings will be advanced for installation of monitor wells. Use of hollow-stem auger drilling techniques is anticipated.

Recovered soil and soil cores will be USCS-logged and screened for VOCs using a calibrated PID. Intervals from which soil cores are not recovered will be logged on the basis of recovered soil cuttings. Recovered soil cores will be split, with one half of the representative sample interval being placed in a sealed plastic bag and the other half of the representative sample interval placed in a laboratory-cleaned glass container. The portion of the core placed in the plastic bag will be screened for VOCs. PID measurements and USCS logging will be recorded on boring logs similar to those presented in Appendix A.

If soil samples are collected, they will be placed in appropriate clean, laboratory-supplied sample containers, labeled to indicate boring identification and depth interval, then placed in an insulated cooler containing ice for management until shipped to the analytical laboratory in accordance with the procedures specified in Section 4.0.

3.2 Monitor Well Installations

A monitor well will be installed in each of the designated soil borings. Monitor wells will be constructed of 2-inch diameter Schedule 40 PVC. Each monitor well will be equipped with a sealing bottom cap, an approximate 1-foot sediment sump, 15 feet of machine-slotted 0.010-inch slot well screen, sufficient riser pipe to extend the well approximately 2 feet above the ground surface, a water tight cap, a protective casing equipped with a lock, and up to three protective posts.

If unconfined aquifer conditions exist at a given well location, then the screen will be set such that it straddles the apparent top of the water table, with approximately 2 feet to 3 feet of screen above the top of the saturated zone and approximately 12 feet to 13 feet of screen placed below the top of the water table. If confined aquifer conditions exist at a given well location, then the screen will be set such that the top of the screen is placed approximately 1 foot above the top of the water-bearing unit. Note that the uppermost aquifer at the site appears to be unconfined on the basis of water level and lithologic data from monitor wells MW-1, MW-2, and MW-3 (see Figures 6 and 7).

The annular area surrounding each well will be backfilled with 20/40-grade filter sand to be installed from the total depth of the boring to approximately 1 foot above the top of the well screen. Following well development activities (see Section 3.3), the remaining annular area will be backfilled as follows:

- Additional filter sand will be added, as necessary, to bring the top of the filter pack back up to approximately 1.5 feet above the top of the well screen;
- Approximately 1.5 feet of hydrated bentonite shall be installed atop the sand filter;
- The remainder of the annular area will be backfilled with cement/bentonite grout installed using a tremie pipe.

The depth of the filter pack and bentonite seal will be verified using a weighted tape measure or other appropriate measuring device.

The monitoring wells will be completed as stick up completions. A 4-foot by 4-foot by 3-inch thick concrete pad sloping away from the well shall be set around each well. All wells shall be equipped with locking caps and keyed-alike locks.

3.3 Monitor Well Development

The subcontracted driller, with oversight by Brown and Caldwell personnel, will develop the newly installed monitor wells using a surge block and submersible pump or other appropriate methodology for a period of time not to exceed 2 hours per well or until water recovered from the well is free of suspended sediment. Development will be performed after the filter sand is initially installed and before the bentonite seal is installed. The depth to the top of the sand pack shall be measured periodically during well development. If the filter pack settles during development, then additional filter sand will be installed such that the depth to the top of the filter pack is restored to approximately 1.5 feet above the top of the screen.

Development fluids will be stored in clean, 55-gallon drums to be supplied by the subcontracted driller.

3.4 Groundwater Level Measurements

The static depth-to-groundwater will be measured in each new monitor well and in each previously existing monitor well prior to commencement of groundwater sampling operations and after each new well has had sufficient time to recover following completion of well development operations. A decontaminated oil/water interface probe will be used to collect depth-to-water measurements in each well. The groundwater levels will be measured to the nearest 0.01 foot and recorded in the field log book. Groundwater levels will be measured in all site monitor wells on the same day.

The presence and thickness of phase-separated hydrocarbons (PSH) and/or sheen, if observed or measured in any monitor wells, will be noted. Monitor wells containing PSH are not to be sampled.

The Brown and Caldwell Project Manager or other designated personnel will be notified as soon as possible in the event that a measurable quantity of PSH is detected in a monitor well.

The groundwater elevation data can be used to calculate the volume of water in the well, using the following formula for a 2-inch diameter well:

Water Volume in Well = 0.165 x thickness of water column in the well.

3.5 Well Purging

A suitable work area should be established around the perimeter of the well prior to commencement of well purging. This work area can be prepared by placing new polyethylene (PE) sheeting on the ground around the well, taking care not to step on it. Alternatives include the placement of a clean PE-lined trash can, a clean PE covered table, or similar adjacent to the well. To the extent possible, the monitor wells should be purged and sampled in order of least impact to most impacted, based on observations made during installation of the wells.

The water level in the well will be verified immediately prior to well purging using a decontaminated water-level indicator or oil/water interface probe. The water level indicator or oil/water interface probe will remain in the well during the purging process in order to monitor the water level throughout the purging process.

The monitor wells will be purged with a submersible pump and previously unused down-hole tubing until groundwater stabilization occurred. Low flow/low stress purging will be performed to maintain the water level at or near the static water level in accordance with the procedures for low flow sampling described by Puls and Barcelona (1996) (see Appendix B).

The placement of the intake of the device that will be used for well purging is critical in order to ensure a complete exchange of the entire water column. For low-flow purging and sampling, the pump intake should initially be placed at the approximate midpoint of the screened interval of the well. Typically, flow rates on the order of 0.1 liter per minute (L/min) to 0.5 L/min are used, but flow rate may be dependent on site-specific hydrogeology. If the pump rate exceeds the well recovery rate, the pump will have to be lowered as needed based upon the amount of drawdown.

The flow rate of the pump should be adjusted, if possible, so that the water level in the well is maintained at no less than 80% of the static water level in the well. If possible, the depth to water should be measured and recorded along with field geochemical readings during purging operations. At a minimum, the depth to groundwater will be measured upon conclusion of purging and sampling operations.

Field parameter measurements for pH, specific conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), and temperature will be collected at approximate 1-liter intervals using a YSI (or equivalent) flow cell. Field parameter readings will be listed on Groundwater Sampling Field Data Sheets (see Appendix C). All data entries should be made using black indelible ink and should be written legibly. Entry errors should be crossed out with a single line, dated, and initialed by the person making the correction.

The wells will be purged until they go dry or until groundwater stabilization occurs and a minimum of 3 liters of groundwater (for low flow/low stress purging operations) or 3 well volumes for non-low flow/low stress purging operations) have been produced. Of these conditions, the least desirable is for purging procedures to result in the well going dry, so care should be taken to avoid this condition if possible. Groundwater will be considered stabilized when all of the following criteria are met, as measured during successive incremental measurements:

- **Variability of less than 3 percent for specific conductivity;**
- **Variability of less than 10 percent for dissolved oxygen;**
- **Variability of less than 10 mv for ORP; and**
- **Variability of less than 0.1 pH units is achieved.**

Additional groundwater parameters (*i.e.*, dissolved oxygen and ferrous iron) will be measured using HACH Test Kit ampules upon conclusion of purging activities to assess the potential for natural attenuation. These readings will be taken immediately prior to commencement of groundwater sample collection.

Calibration of the DO meter will be performed before and after collection of DO data at the site, and during the sampling process if suspect DO data are generated. Calibration data will be recorded in the field notebook.

Water removed from the well during the purging process will be placed in 55-gallon drums, then subsequently transferred to the on-site central drum storage area (see Section 5.0).

3.6 Groundwater Sampling Procedures

Upon completion of purging operations, groundwater samples will immediately be collected from the monitor well discharge tubing after it is disconnected from the flow cell. Each sample will be transferred into laboratory-supplied, clean glass or plastic containers containing the appropriate preservatives, labeled (see Section 3.8), and placed on ice in an insulated cooler for shipment in accordance with the procedures described in Section 4.0.

Sample containers should be labeled immediately upon filling in order to avoid possible confusion as to which sample came from which well.

The groundwater samples will be analyzed for the following parameters to evaluate groundwater impact:

- TPH-G, TPH-D, and TPH-M by Method 8015M;
- VOCs by Method 8260B;
- SVOCs by Method 8270C; and

- Chloride by Method 300.

The groundwater samples will be analyzed for the following additional parameters to evaluate the potential for natural attenuation of hydrocarbons in site groundwater:

- Nitrate by Method 300;
- Sulfate by Method 300;
- Methane by Method RSK 147/175; and
- Alkalinity by Method 310.1.

3.7 Quality Assurance / Quality Control (QA/QC) Samples

QA/QC samples will be collected throughout the duration of field activities for the project. The following types of QA/QC samples will be collected during the investigation:

- Trip Blanks;
- Field Blanks;
- Rinsate Blanks; and
- Duplicate Samples.

Discussions of the preparation, frequency of collection, and laboratory analysis of each of these types of QA/QC samples is presented in the following subsections.

3.7.1 Trip Blanks

Trip blanks are used to detect possible contamination of sample containers by VOCs during the time from when the sample containers leave the analytical laboratory until they are returned from the field to the laboratory. Trip blanks are created in the laboratory by pouring analyte-free water into sets of 40-ml vials. Trip blanks accompany other sample containers from the laboratory into the field, and remain unopened until returned to the laboratory for analysis.

One trip blank per cooler will be submitted with samples for VOCs analysis on each day that one or more soil or groundwater samples designated for VOCs analysis are shipped to the laboratory. Trip blanks will be analyzed for VOCs only.

Trip blanks should be labeled as specified in Section 3.8.4 and listed on the chain-of-custody form along with other investigation-related and QA/QC samples.

3.7.2 Field Blanks

Field blanks are used to detect possible atmospheric contamination present at sample collection locations that could affect sample integrity. Field blanks are created in the field by pouring distilled water into sets of 40-ml vials at a sample collection location.

Field blanks will typically be collected at a rate of one field blank per day on any day during which a soil or groundwater sample designated for VOCs analysis is collected. Field blanks may be collected more frequently during the course of a day during which a soil or groundwater sample designated for VOCs analysis is collected in the event that multiple instances of suspected atmospheric contamination at sample collection locations is suspected.

Field blanks will be analyzed for VOCs only.

3.7.3 Rinsate Blanks

Rinsate blanks are used to detect possible introduction of contaminants to environmental samples from the equipment used to collect the samples. Rinsate blanks are created in the field by pouring distilled water onto decontaminated sample collection equipment (see Section 5.1) in the field and collecting the runoff from the sample collection equipment in appropriate laboratory containers.

Rinsate blanks will be analyzed for the same analytical parameters as the associated investigation-related groundwater samples, excluding natural attenuation evaluation parameters.

3.7.4 Duplicate Samples

Duplicate samples are field samples collected independently at a sampling location during a single act of sampling under consistent field conditions. Duplicate samples are used to test the accuracy of the analytical laboratory in obtaining like concentration data for identical samples.

A duplicate sample is assigned a sample identification number that is different from the sample identification number assigned to the corresponding original investigation-related sample. A fictitious sample collection time may be assigned to a duplicate sample to avoid tipping off the laboratory to the fact that the sample is indeed a duplicate sample. The true sample collection time of all duplicate samples and the original investigation-related samples to which the duplicate samples correspond will be noted by field sampling personnel in the field notebook for the project.

Duplicate groundwater samples are collected at the wellhead by alternately filling appropriate sample containers pertaining to an original investigation-related sample and those pertaining to the duplicate sample. Duplicate groundwater samples will be collected at a rate of one duplicate sample for every 10 (or less) investigation-related groundwater samples collected from monitor wells. Duplicate samples will be analyzed for the same analytes as the associated investigation-related groundwater samples, excluding natural attenuation evaluation parameters.

3.8 Sample Nomenclature

The following subsections present the nomenclature system that will be applied to soil, groundwater, and QA/QC samples to be collected during the investigation.

3.8.1 Soil Samples

Soil samples collected during the investigation will be given a two-component code to track information concerning each particular sample. The code's two components will identify the location at which the sample is collected and the depth interval from which the sample is collected.

The first component of the code will identify the location at which the sample is collected, per Figure 8. The second component will denote the depth interval, in feet below grade, from which the soil sample is collected. For example, a soil sample collected from the 24- to 25-foot depth interval at the MW-4 location would be identified as: "MW4-24-25".

3.8.2 Groundwater Samples

Groundwater samples collected during the investigation will identified by the name of the well from which the sample is collected. For example, a groundwater sample collected from monitor well MW-1 would be identified as "MW-1".

3.8.3 Duplicate Samples

Duplicate groundwater samples will be assigned a similar code as corresponding investigation-related groundwater samples. The identity of and nomenclature assigned to each duplicate sample and its corresponding investigation-related sample shall be recorded in the project field notebook by the person collecting the samples at the time of their collection.

For duplicate groundwater samples, the first component of the code will identify a fictitious monitor well, starting with "MW-100" for the first duplicate groundwater sample collected, and increasing by successive integer values thereafter.

3.8.4 Other QA/QC Samples

A three-component code will be used to identify trip blanks, field blanks, and rinsate blanks. The first component will identify the specific QA/QC sample type, as follows:

- TB - Trip Blank;
- FB - Field Blank; and
- RB - Rinsate Blank.

The second component will consist of six digits representing the month, day, and year (i.e., *mm-dd-yr*) on which the sample is collected.

The third component of the code will be used if more than one specific type of QA/QC sample is collected during the course of a single calendar day. The third component will start with "1" for the first QA/QC sample type collected each day, and will increase by successive integer values as necessary.

For example, the first field blank collected on October 1, 2008 would be designated as FB-100108-1.

3.9 Surveying Activities

The vertical and horizontal locations of soil and groundwater sample locations will be determined by Brown and Caldwell using field measuring and surveying techniques. The top-of-casing elevation of each of the monitor wells will be determined to the nearest 0.01 foot, relative to an arbitrary site datum. The horizontal locations of the wells will be measured relative to one or more fixed points of reference and confirmed using Global Positioning System (GPS) readings.

4. SAMPLE MANAGEMENT

Filled and labeled containers for aqueous samples should be placed in bubble wrap as supplied by the analytical laboratory and then placed within zip-lock plastic bags and sealed. If the container size is such that the sample container will not seal, place the sample container in the bag with the neck of the sample container extending through the top of the bag.

Place the sample containers in an ice chest containing ice for temporary storage until ready to prepare the samples for shipment. Samples should be prepared for shipment according to the following procedures:

- Place a previously unused large volume plastic trash bag in the ice chest or cooler.
- Place the sample containers in the plastic bag. The sample containers should be placed upright in the cooler in such a manner that they will not touch during shipment.
- Place inert packing material (e.g., vermiculite, kitty litter, etc.) to partially cover the sample containers (approximately halfway). Place ice or chemical ice (i.e., "blue ice") on top of the sample containers and seal the plastic bag. Ice will be double bagged inside zip-lock plastic bags.
- Fill the remainder of the cooler with cushioning material.
- Place the completed chain-of-custody form in a waterproof plastic bag and tape it to the interior lid of the shipping container.
- Tape the drain plug of the ice chest or cooler shut (if present).
- Secure the lid by taping with clear packing/strapping tape at a minimum of two locations.
- Attach the completed shipping label to the top of the cooler. Secure it with clear packing/strapping tape.
- Affix signed and dated custody seals on the front right and back left sides of the shipping container. Cover the seals with clear packing/strapping tape.

Samples will be forwarded by overnight delivery service to Southern Petroleum Laboratory (SPL) in Houston, Texas using strict chain-of-custody procedures for analysis. The address for SPL is as follows:

Georgia Jones
Southern Petroleum Laboratory
8880 Interchange Drive
Houston, Texas 77054
Phone 713-660-0901

Samples are to be shipped using pre-paid FedEx shipping labels supplied by SPL. If samples are to be delivered to the laboratory on Saturday or Sunday, arrangements for receipt of the samples by laboratory personnel on Saturday or Sunday must be made with SPL on the Friday, prior to shipment of the samples.

5. DECONTAMINATION AND WASTE MANAGEMENT

5.1 Decontamination

For large-scale equipment (*e.g.*, augers, bits, drill rods), the driller will perform decontamination activities upon arrival at the site, between soil borings and monitor well installations, and upon the conclusion of drilling activities using facilities, equipment, water and power to be supplied by the driller. Augurs and other down-hole equipment will be cleaned with a high-pressure water to remove particulate matter between usage at different locations. Sample tubes and other materials that contact soil samples will be decontaminated between each usage using the following procedure:

- Wash with a solution of potable water and Alconox® or equivalent to remove particulate matter and surficial film;
- Rinse with distilled water; and
- Allow to air dry, if possible.

The driller will construct a temporary decontamination pad at the site to contain decontamination fluids. Decontamination fluids and solids will be stored in clean, 55-gallon drums supplied by the driller.

Small-scale sampling and measurement equipment (*e.g.*, soil sample trimming equipment, water level indicators) will be decontaminated using a tap water and phosphate-free detergent wash, followed by a tap water rinse, followed by a deionized/distilled water rinse. Decontamination fluids will be contained and stored in the drums described above.

Dedicated downhole tubing will be used in purging and groundwater sampling activities conducted at each monitor well. The field measurement equipment used in groundwater sampling will be decontaminated prior to and after each use. The flow cell will be rinsed after usage at each well by flushing with potable water.

5.2 Waste Management

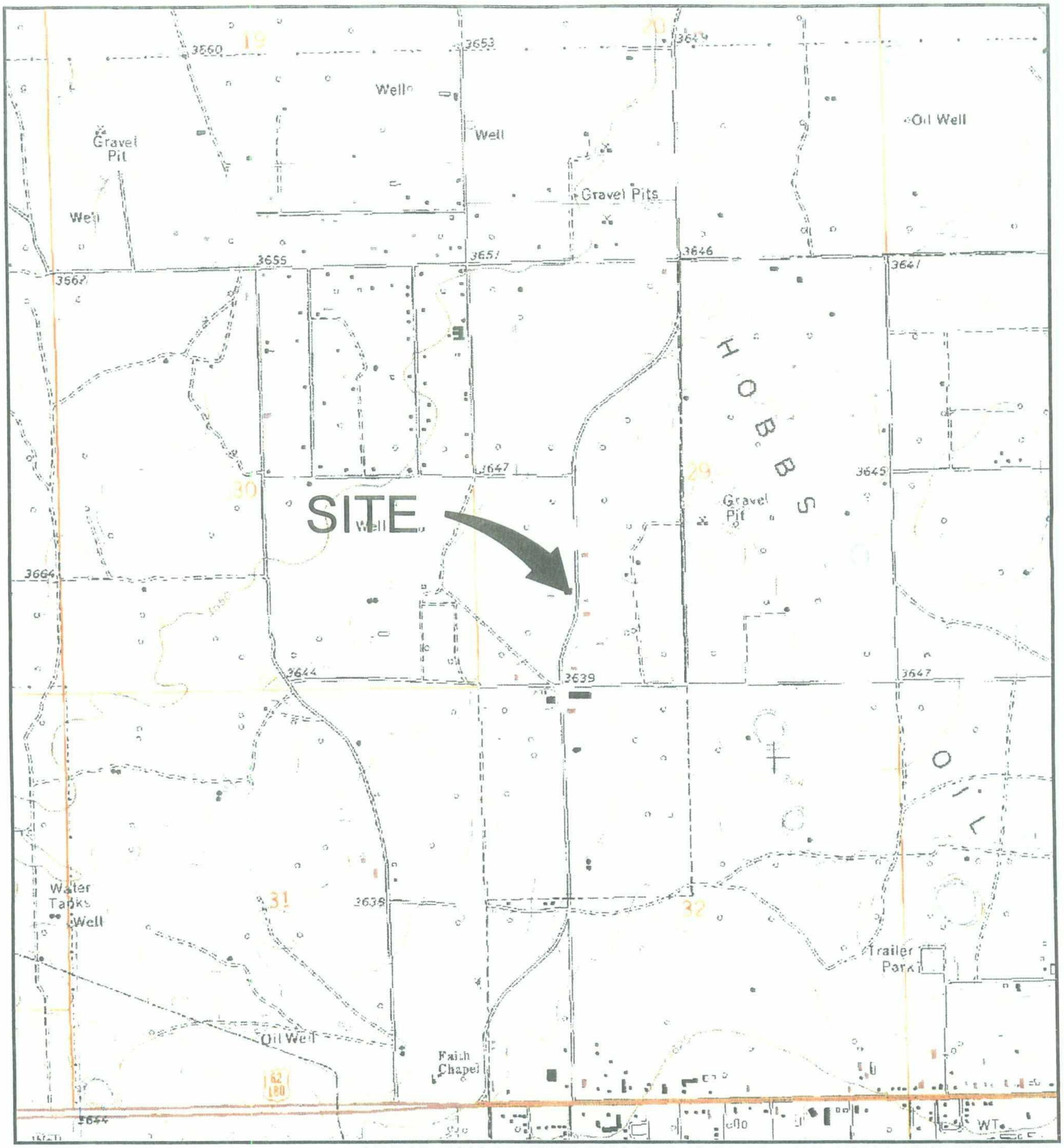
Drill cuttings, purge water and decontamination water will be placed in 55-gallon drums at the drill sites, labeled as to contents and date of filling. The drums will be transferred to a central storage area for temporary storage pending waste profiling and subsequent disposal by BJ Services.

Composite samples of soil cuttings will be collected at a rate of one sample per monitor well installation location and analyzed for the following waste characterization parameters:

- TPH;
- BTEX;
- RCRA Metals; and
- Reactivitiy, Corrosivity, and Ignitability (RCI).

Disposal options for decontamination water and development and purge water will be evaluated after review of the analytical results of the soil and groundwater samples. One composite sample will, however, be collected and analyzed for RCI.

FIGURES



SOURCE: USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE - HOBBS, NEW MEXICO; 1979

SCALE: 1" = 2000'

BROWN AND CALDWELL

Figure 1

SITE LOCATION MAP
BJ SERVICES FRACMASTER
BJ SERVICES COMPANY, U.S.A.

1329 N. WEST COUNTY ROAD
HOBBS, NEW MEXICO

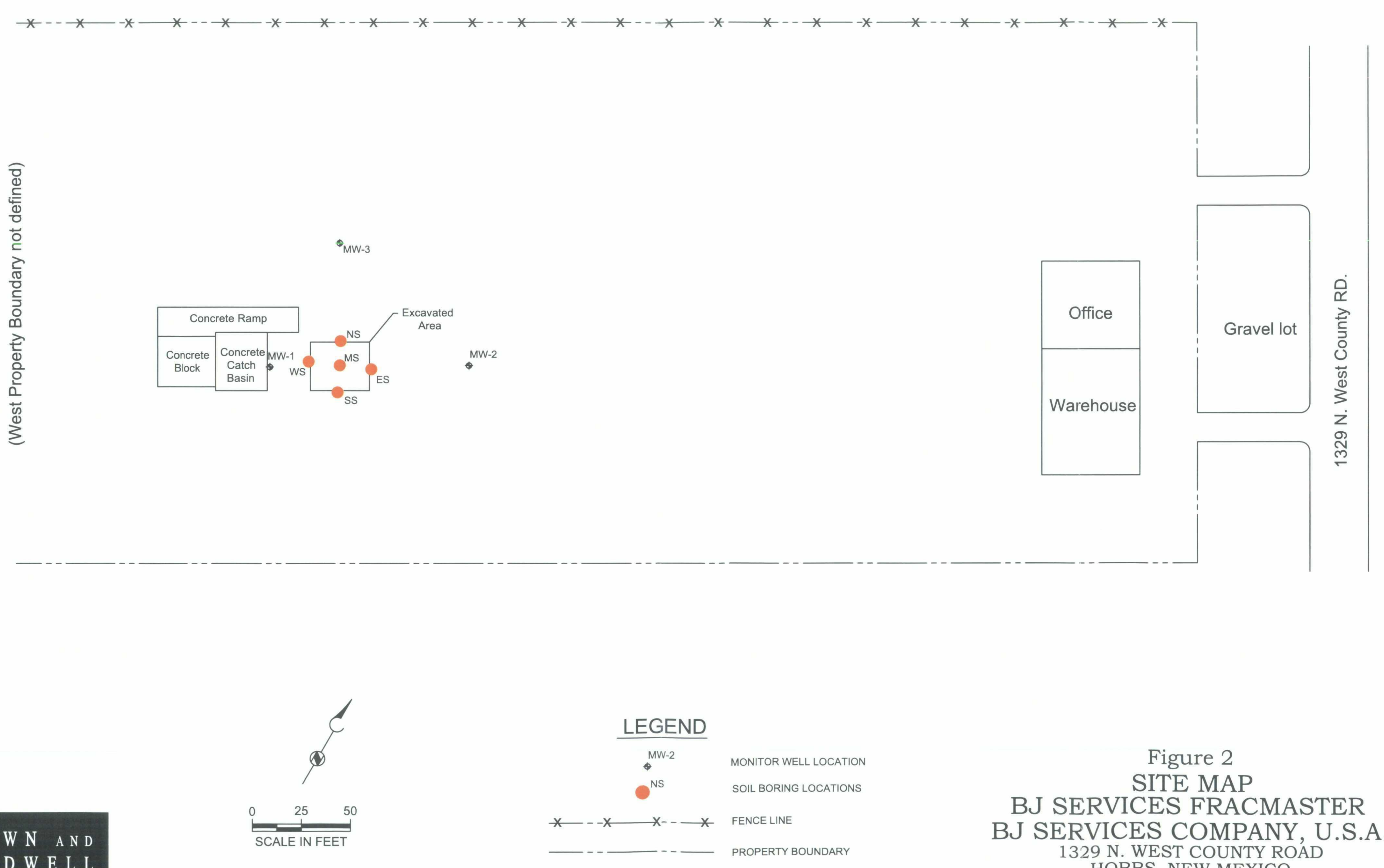


Figure 2
SITE MAP
BJ SERVICES FRACMASTER
BJ SERVICES COMPANY, U.S.A.
1329 N. WEST COUNTY ROAD
HOBBS, NEW MEXICO

BROWN AND
CALDWELL

Sep 09, 2008 - 10:55am
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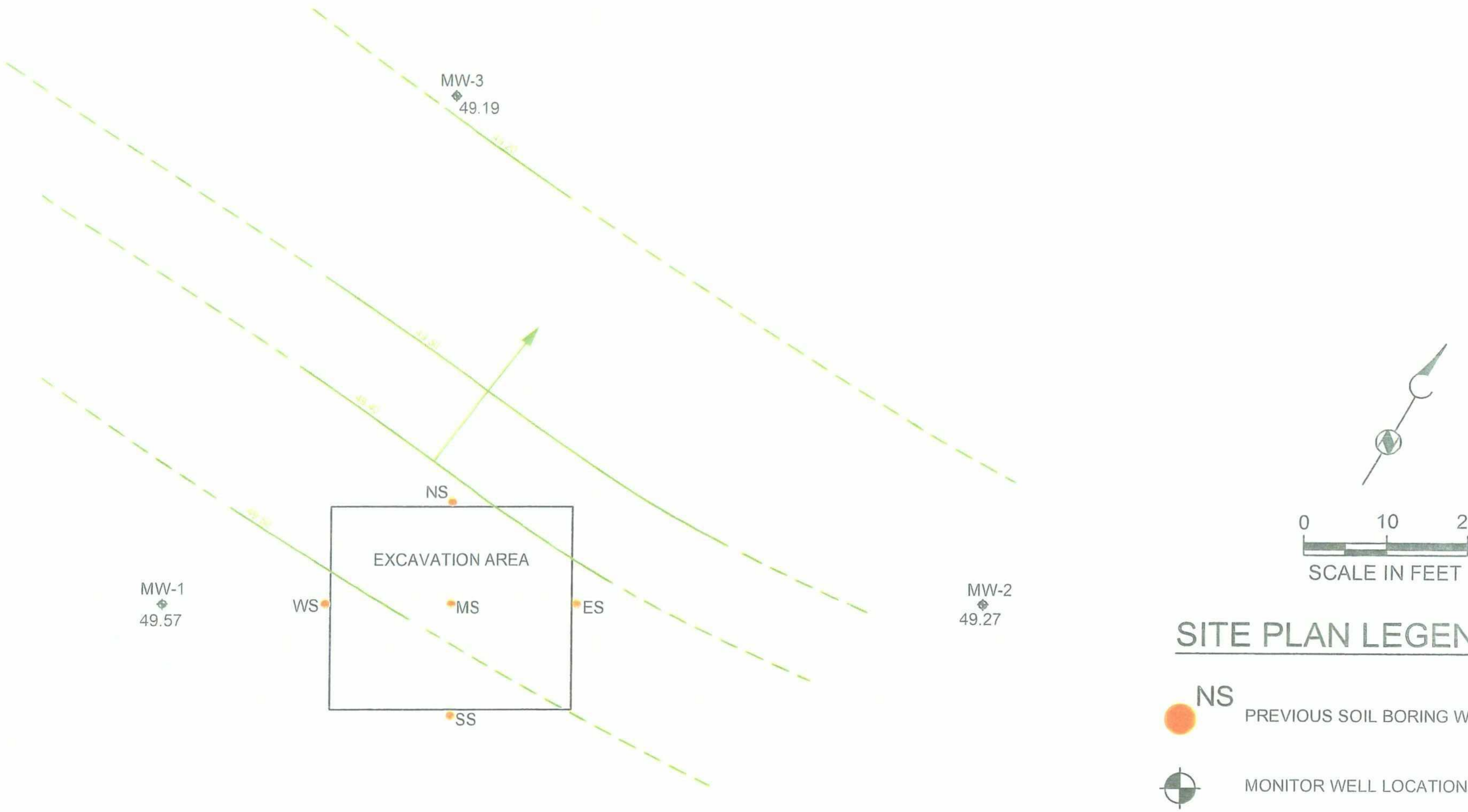


SITE PLAN LEGEND

● NS	PREVIOUS SOIL BORING W/LOCATION
⊕	MONITOR WELL LOCATION
49.19	GROUNDWATER ELEVATION (FEET) GROUNDWATER ELEVATION CONTOUR
→	GROUNDWATER FLOW DIRECTION

DATE	PROJECT NUMBER
3-21-05	128125

BROWN AND CALDWELL
HOUSTON

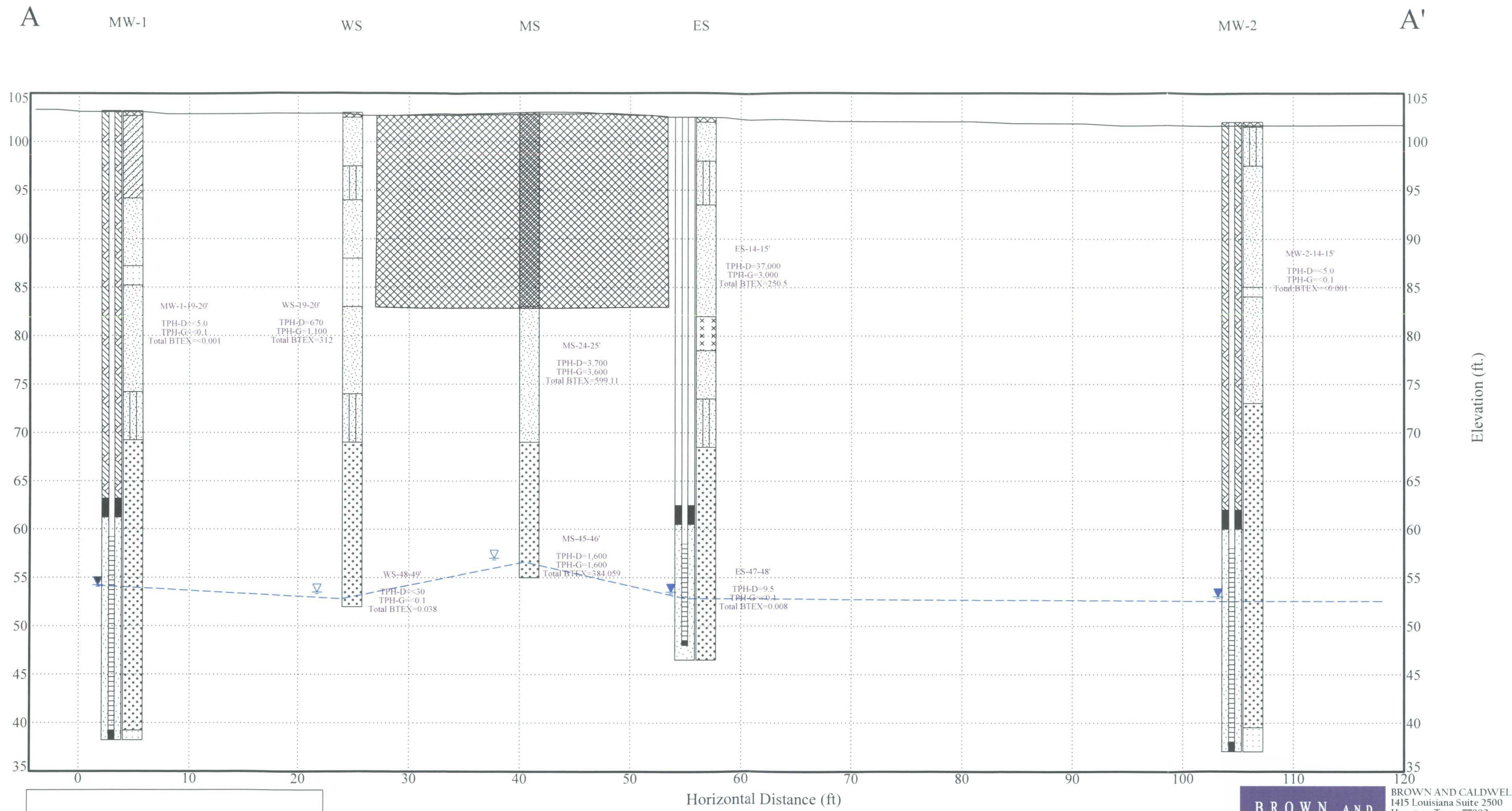
GROUNDWATER ELEVATION MAP
FEBRUARY 23, 2006
BJ SERVICES FRACMASTER-FACILITY

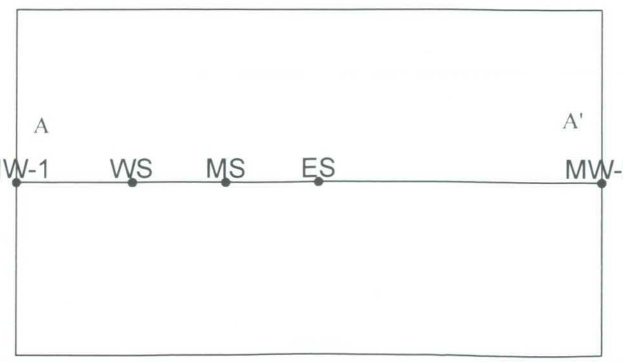
PROJECT LOCATION

BJ SERVICES COMPANY, U.S.A.
1329 N. WEST COUNTY ROAD
HOBBS, NEW MEXICO

0 10 20
SCALE IN FEET

FIGURE
3





N

LEGEND

▼ - Static water level

▽ Water level encountered during drilling

Concentrations reported in milligrams per kilogram (mg/Kg)

NMOCD Soil Remediation Action Levels

TPH	100 mg/Kg
Total BTEX	50 mg/Kg

▩	Fill (made ground)
▨	USCS Poorly-graded Sand
▥	USCS Silty Sand
☒	Siltstone
▦	USCS Well-graded Sand
▧	USCS Clayey Sand
▤	Sandstone

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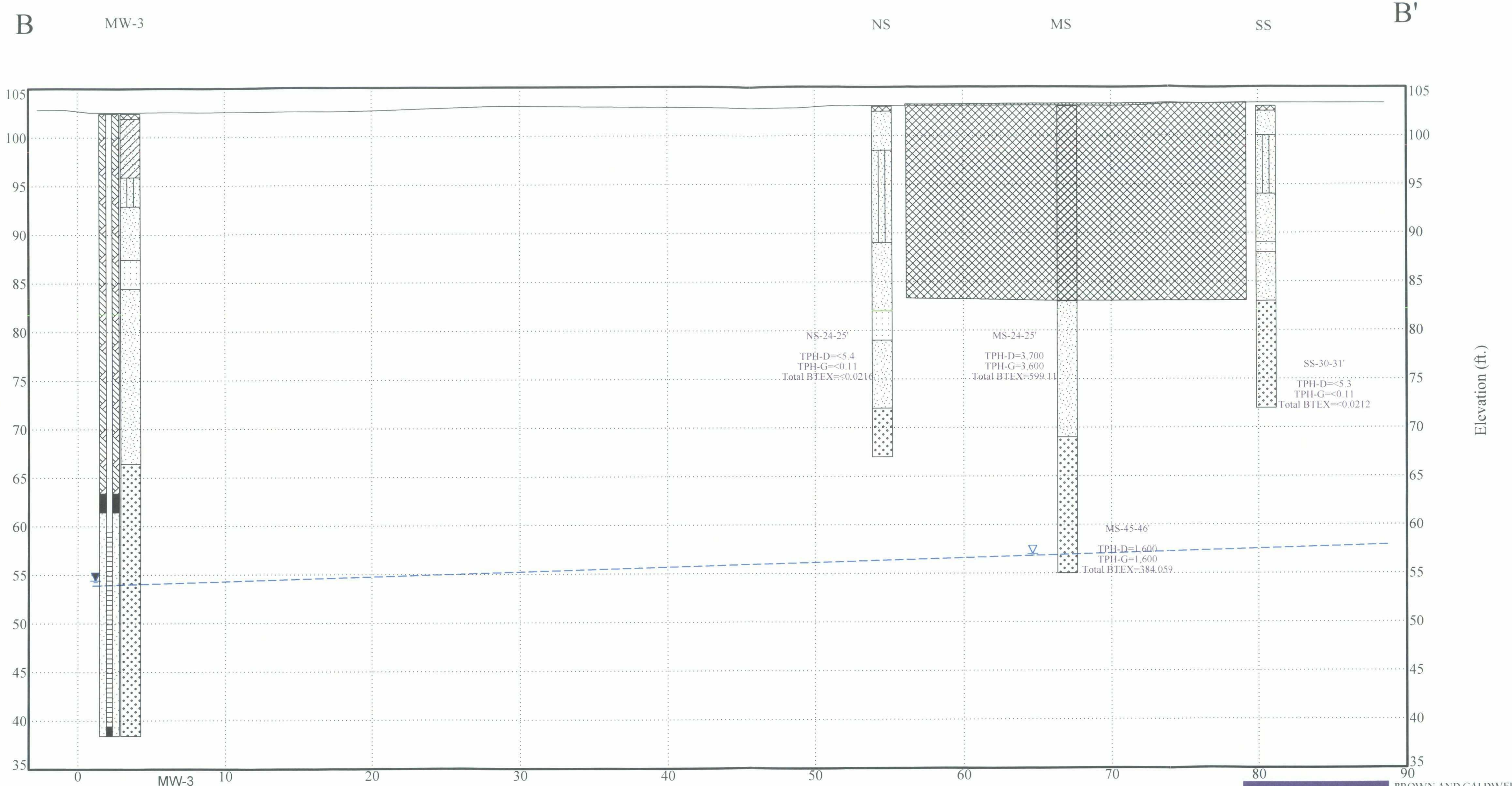
A-A'
East - West Soil Lab Data Cross Section

BJ Services Company, U.S.A. - Fracmaster Facility
Hobbs, NM

PROJECT NO.:	DATE:	FIGURE:
128125	November 2nd, 2006	4



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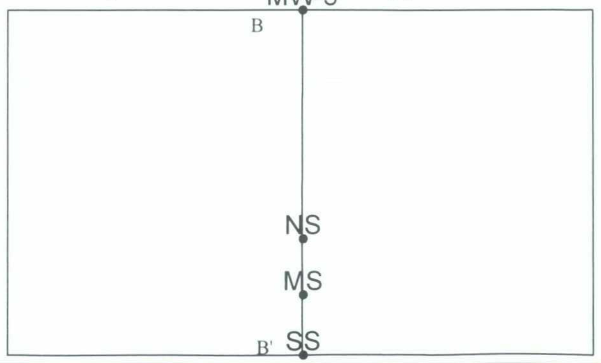

N

LEGEND

▼ - Static water level

▽ - Water level encountered during drilling

Concentrations reported in milligrams per kilogram (mg/Kg)

NMOCD Soil Remediation Action Levels

TPH	100 mg/Kg
Total BTEX	50 mg/Kg

▩	Fill (made ground)
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⋯	Sandstone

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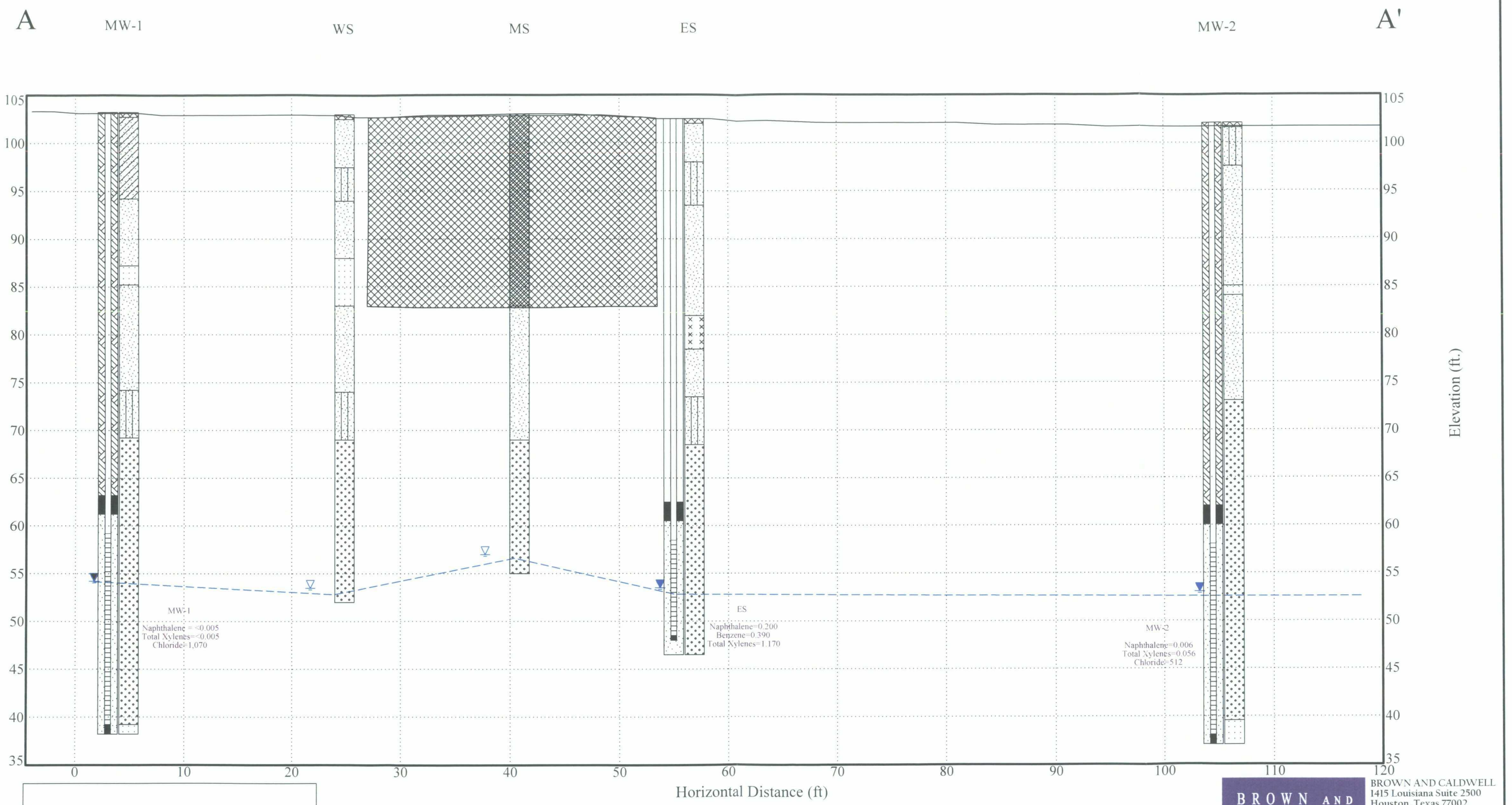
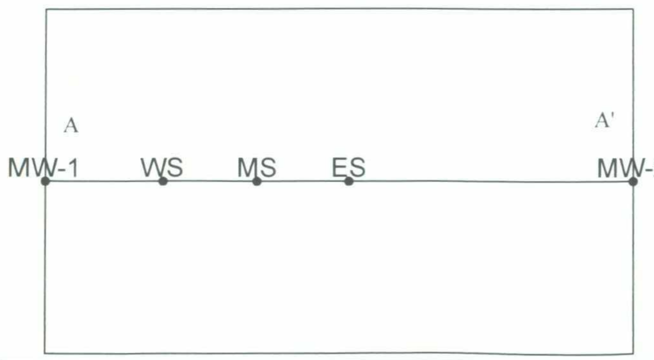
BJ Services Company, U.S.A. - Fracmaster Facility
Hobbs, NM

PROJECT NO.:	DATE:	FIGURE:
128125	November 9th, 2006	5





N

LEGEND

▼ - Static water level
▽ Water level encountered during drilling
Concentrations reported in milligrams per liter (mg/L)

NMOCD Groundwater Remediation Action Levels

Naphthalene	0.03 mg/L
Benzene	0.01 mg/L
Total Xylenes	0.62 mg/L
Chloride	250 mg/L

▩ Fill (made ground)

☒ Siltstone

░ Sandstone

░ USCS Poorly-graded Sand

⁘ USCS Well-graded Sand

▥ USCS Silty Sand

▨ USCS Clayey Sand

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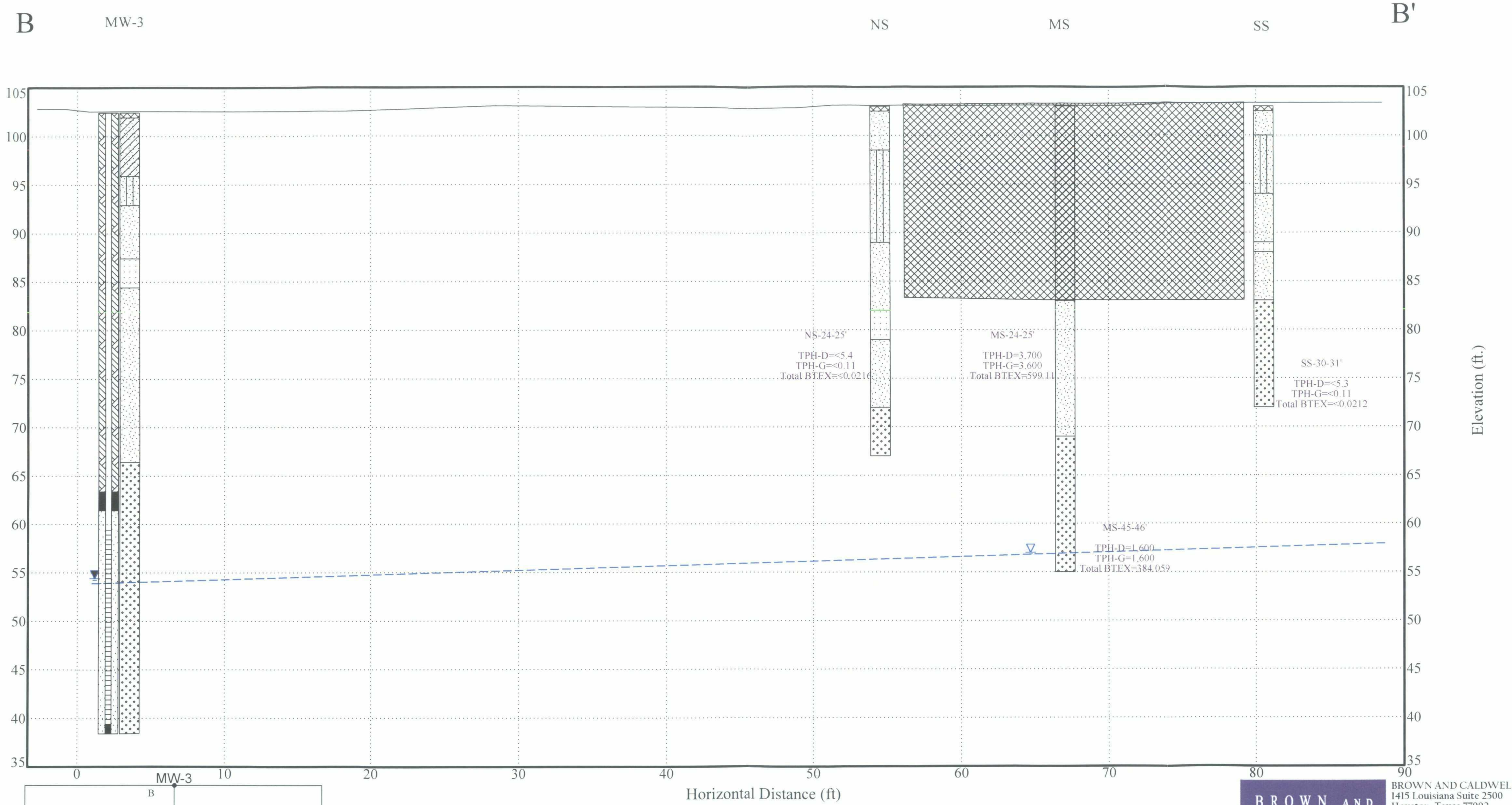
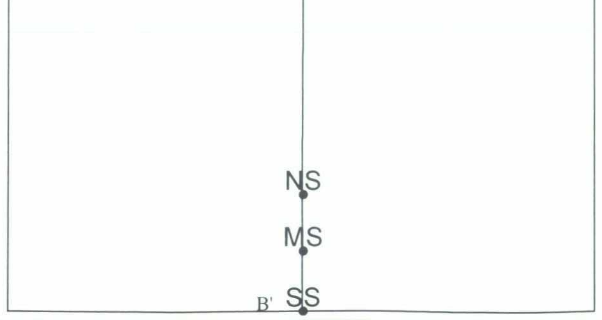
BJ Services Company, U.S.A. - Fracmaster Facility
Hobbs, NM

PROJECT NO.:	DATE:	FIGURE:
128125	November 2nd, 2006	6

HOUSTON CROSS SECTION NO GRAPHS STRAT DESCRIPTION 128125_CH FOR CROSS SECTIONS.GPJ 11/2/06





N

LEGEND

▼ - Static water level

▽ - Water level encountered during drilling

Concentrations reported in milligrams per kilogram (mg/Kg)

NMOCD Soil Remediation Action Levels

TPH	100 mg/Kg
Total BTEX	50 mg/Kg

▩	Fill (made ground)	▒	USCS Poorly-graded Sand	▦	USCS Well-graded Sand
▨	USCS Clayey Sand	▥	USCS Silty Sand	░	Sandstone

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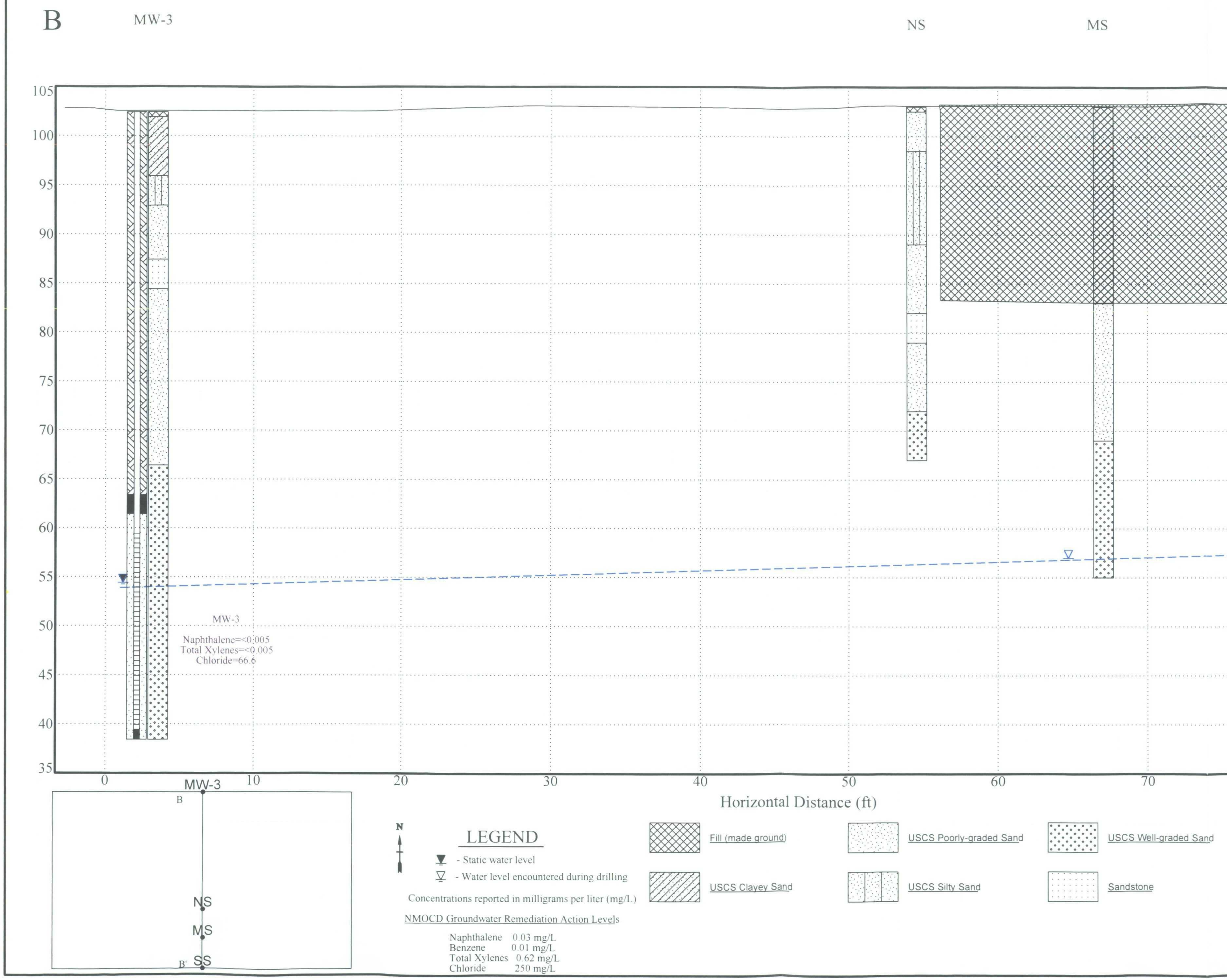
B-B'
North - South Soil Lab Data Cross Section

BJ Services Company, U.S.A. - Fracmaster Facility
Hobbs, NM

PROJECT NO.:	DATE:	FIGURE:
128125	November 9th, 2006	5



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B-B'
North - South Groundwater Lab Data Cross Section

BJ Services Company, U.S.A. - Fracmaster Facility
Hobbs, NM

PROJECT NO.:	DATE:	FIGURE:
128125	November 9th, 2006	7

SITE PLAN LEGEND

● NS	PREVIOUS SOIL BORING W/LOCATION
◒	EXISTING MONITOR WELL LOCATION
⊕	PROPOSED MONITOR WELL LOCATION
49.19	2/23/06 GROUNDWATER ELEVATION (FEET)
—	GROUNDWATER ELEVATION CONTOUR
→	GROUNDWATER FLOW DIRECTION

DATE
3–21–05

PROJECT NUMBER
128125

BROWN AND
CALDWELL
HOUSTON

EXISTING AND PROPOSED MONITOR WELL LOCATIONS BJ SERVICES FRACMASTER-FACILITY

PROJECT LOCATION

BJ SERVICES COMPANY, U.S.A.
1329 N. WEST COUNTY ROAD
HOBBS, NEW MEXICO

0 15 30
SCALE IN FEET

FIGURE
8

TABLES

Summary of Detected Constituents in Soil Samples – July 2005

Summary of Detected Constituents in Groundwater – July 2005

Analytical Results for Soil Samples – February 2006

Summary of Detected Constituents in Groundwater – February 2006

Table 1
Summary of Detected Constituents(1) in Soil Samples - July 2005
BJ Services - Hobbs (Fracmaster Facility), New Mexico

Location	NS (North Side)	ES (East Side)		SS (South Side)	WS (West Side)		MS (Middle of Excavated Area)	
Depth (ft. below grade)	*24-25*	*14-15*	*47-48*	*30-31*	*19-20*	*48-49*	*24-25*	*45-46*
TPH-D(2)	<5.4	**37,000**	9.5	<5.3	**670**	<30	**3,700**	**1,600**
TPH-G(2)	<0.11	**3,000**	<0.1	<0.11	**1,100**	<0.1	**3,600**	**1,600**
SVOCs								
2-Methylnaphthalene	<0.360	160.000	<0.330	<0.350	0.770	<0.330	120.000	40.000
2-Methylphenol	<0.360	<20.000	<0.330	<0.350	<0.350	<0.330	<1.900	<4.300
3 & 4-Methylphenol	<0.360	<20.000	<0.330	<0.350	<0.350	<0.330	<1.900	<4.300
Naphthalene	<0.360	57.000	<0.330	<0.350	<0.350	<0.330	140.000	43.000
Phenanthrene	<0.360	30.000	<0.330	<0.350	0.440	<0.330	2.500	<4.300
VOCs								
Benzene(2)	<0.0054	1.500	<0.005	<0.0053	<0.0053	<0.005	0.110	0.059
n-Butylbenzene	<0.0054	30.000	<0.005	<0.0053	<0.0053	<0.005	<0.0056	<0.005
sec-Butylbenzene	<0.0054	20.000	0.009	<0.0053	<0.0053	<0.005	38.000	11.000 J
Carbon disulfide	<0.0054	<0.250	<0.005	<0.0053	<0.0053	<0.005	6.200 J	<0.005
4-Chlorotoluene	<0.0054	4.900	<0.005	<0.0053	<0.350	<0.005	<0.0056	<0.005
Ethylbenzene(2)	<0.0054	32.000	<0.005	<0.0053	8.000	<0.005	39.000	45.000
Isopropylbenzene	<0.0054	21.000	0.017	<0.0053	1.300 J	<0.005	17.000 J	7.400 J
4-Isopropyltoluene	<0.0054	19.000	<0.005	<0.0053	<0.0053	<0.005	18.000 J	5.600 J
4-Methyl-2-pentanone	<0.011	<0.500	<0.010	<0.011	<0.011	<0.010	<0.011	<0.010
Naphthalene	<0.0054	44.000	0.082	<0.0053	0.170	0.008	21.000	130.000
n-Propylbenzene	<0.0054	36.000	0.045	<0.0053	2.300 J	<0.005	74.000	20.000
Toluene(2)	<0.0054	52.000	<0.005	<0.0053	1.000 J	<0.005	230.000	34.000
1,2,4-Trimethylbenzene	<0.0054	160.000	0.110	<0.0053	12.000	0.025	590.000	160.000
1,3,5-Trimethylbenzene	<0.0054	78.000	0.042	<0.0053	3.700 J	0.008	99.000	29.000
m,p-Xylenes	<0.0054	120.000	0.008	<0.0053	230.000	0.026	230.000	240.000
o-Xylene	<0.0054	45.000	<0.005	<0.0053	73.000	0.012	100.000	65.000
Total Xylenes(2)	<0.0054	165.000	0.008	<0.0053	303.000	0.038	330.000	305.000
Total BTEX	<0.0216	**250.500**	0.008	<0.0212	**312**	0.038	**599.11**	**384.059**

(1) - All analytical results in mg/kg

(2) - NMOCD Soil Remediation Action Levels for Unsaturated Contaminated Soils, based on Hazard Ranking >19(3),(4)

Benzene	10 mg/kg
Total BTEX	50 mg/kg
TPH	100 mg/kg

(3) - Hazard Ranking determined at >19, based on groundwater occurrence at <50 feet

(4) - from NMOCD Publication "Guidelines for Remediation of Leaks, Spills and Releases" (August 18, 1993) (www.emnrd.state.nm.us\OCD)

Bold font indicates exceedance of Remediation Action Level

Table 2
Summary of Detected Constituents(1) in Groundwater - July 2005
BJ Services - Hobbs (Fracmaster Facility), New Mexico

Location	ES (East Side)	NMWQCC Groundwater Standard(2)
TPH-D	2.3	-
TPH-G	11	-
SVOCs		
2-Methylnaphthalene(3)	0.013	0.03
2-Methylphenol	0.130	-
3 & 4-Methylphenol	0.018	-
Naphthalene(3)	**0.046**	0.03
Phenanthrene	<0.005	-
VOCs		
Benzene	**0.390**	0.01
n-Butylbenzene	<0.005	-
sec-Butylbenzene	0.015	-
Carbon disulfide	<0.005	-
4-Chlorotoluene	<0.005	-
Ethylbenzene	0.370	0.75
Isopropylbenzene	0.180	-
4-Isopropyltoluene	<0.005	-
4-Methyl-2-pentanone	0.023	-
Naphthalene(3)	**0.200**	0.03
n-Propylbenzene	0.260	-
Toluene	0.046	0.75
1,2,4-Trimethylbenzene	0.670	-
1,3,5-Trimethylbenzene	0.210	-
m,p-Xylenes	0.770	-
o-Xylene	0.400	-
Total Xylenes	**1.170**	0.62
Metals		
Arsenic (dissolved)	0.0239	0.1
Arsenic (total)	0.0271	
Barium (dissolved)	0.842	1.0
Barium (total)	0.906	
Cadmium (dissolved)	<0.003	0.01
Cadmium (total)	<0.003	
Chromium (dissolved)	0.016	0.05
Chromium (total)	**0.0805**	
Lead (dissolved)	<0.005	0.05
Lead (total)	<0.005	
Mercury (dissolved)	<0.0002	0.002
Mercury (total)	<0.0002	
Selenium (dissolved)	<0.005	0.005
Selenium (total)	<0.005	
Silver (dissolved)	<0.005	0.005
Silver (total)	<0.005	

(1) - All analytical results and standards in mg/L

(2) - from NMOCD Publication "Guidelines for Remediation of Leaks, Spills and Releases" (August 18, 1993) (www.emnrd.state.nm.us\OCD)

(3) - Standard applies to PAHs: naphthalene plus monomethylnaphthalenes

Bold font indicates exceedance of Groundwater Standard

Table 3
Analytical Results(1) for Soil Samples - February 2006
BJ Services - Hobbs (Fracmaster Facility), New Mexico

Sample ID	Depth (feet)	Sample Date	BTEX(2)					TPH-D(2)	TPH-G(2)
			Benzene(2)	Toluene(2)	Ethylbenzene(2)	Total Xylenes(2)	Total BTEX(2)	Diesel Range Organics (C10-C28)	Gasoline Range Organics
MW-1	19-20	2/21/2006	<0.001	<0.001	<0.001	<0.001	<0.001	<5.0	<0.1
MW-2	14-15	2/22/2006	<0.001	<0.001	<0.001	<0.001	<0.001	<5.0	<0.1

(1) - All analytical results in mg/kg

(2) - NMOCD Soil Remediation Action Levels for Unsaturated Contaminated Soils, based on Hazard Ranking >19(3),(4)

Benzene	10 mg/kg
Total BTEX	50 mg/kg
TPH	100 mg/kg

(3) - Hazard Ranking determined at >19, based on groundwater occurrence at <50 feet

(4) - from NMOCD Publication "Guidelines for Remediation of Leaks, Spills and Releases" (August 18, 1993) (www.emnrd.state.nm.us\OCD)

Table 4
Summary of Detected Constituents(1) in Groundwater - February 2006
BJ Services - Hobbs (Fracmaster Facility), New Mexico

Monitor Well ID	MW-1	MW-2	MW-3	NMWQCC Groundwater Standard(2)
Sample Date	2/23/2006	2/23/2006	2/23/2006	
VOCs				
Naphthalene(3)	<0.005	0.006	<0.005	0.03
1,2,4-Trimethylbenzene	<0.005	0.019	<0.005	-
m,p-Xylenes	<0.005	0.056	<0.005	-
Total Xylenes	<0.005	0.056	<0.005	0.62
Chloride	**1070**	**512**	66.6	250
TPH-D	<1.0	<1.0	<1.0	-
TPH-G	<0.1	0.19	<0.1	-
SVOCs(4)	ND	ND	ND	-

(1) - All analytical results and standards in mg/L

(2) - from NMOCD Publication "Guidelines for Remediation of Leaks, Spills and Releases" (August 18, 1993) (www.emnrd.state.nm.us\OCD)

(3) - Standard applies to PAHs: naphthalene plus monomethylnaphthalenes

(4) - ND - not detected

Bold font indicates exceedance of Groundwater Standard

APPENDIX A

Boring Logs and Well Construction Diagrams for Existing Soil Borings and Monitor Wells

Soil Boring: **MS**

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: **128125** Sheet 1 of 2

Project Location: **Hobbs, NM**		Logged By: **B.Camacho**	Approved: **L.Teague**
Drilling Contractor: **Gemini Technical Services**		Date Started: **7/14/05**	Date Finished: **7/14/05**
Drilling Equipment: **CME-75**	Driller: **Richard**	Total Boring Depth: (feet) **48.0**	Depth to Static Water: (feet)
Drilling Method: **Hollow Stem Auger**	Borehole Diameter: **8"**	TOC Elevation:	Ground Elevation:
Sampling Method: **Split Spoon**		Diameter and Type of Well Casing:	
Comments:		Slot Size:	Filter Material:
		Development Method:	

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
			▨	Fill -select backfill material.					
2			▨						
4			▨						
6			▨						
8			▨						
10			▨						
12			▨						
14			▨						
16			▨						
18			▨		2261	☒	2		
20		SP		SAND (SP); Dark gray; moist; fine to medium grained sand; contains 1/4" to 1/2" diameter nodules of fine lithified sandstone nodules, hydrocarbon odor					
22									
24					3503	☒	2		Sampled MS-24-25'
26									
28									
30				Black; slightly moist; SAA, black stained, strong hydrocarbon odor	2672	☒	2		
32									

Soil Boring: **MS**

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: **128125** Sheet **2** of **2**

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
34		SW	⠿	SAND (SW); Black; dry; fine grained sand; contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules, hydrocarbon odor	1931	☒	2		
36			⠿						
38			⠿						
			⠿		1679	☒	2		
40			⠿						
42			⠿						
44			⠿	SAA, moist, hydrocarbon odor	1256	☒	2		
46	▽		⠿	SAA, dark gray, wet					
48									Sampled MS-45-46'
									Boring was plugged with a bentonite-cement grout.

Soil Boring: **ES**

Project Name:	**BJ Services Company, U.S.A. - Fracmaster Facility**	Project Number:	**128125**	Sheet	1 of 2

Project Location: **Hobbs, NM**		Logged By: **B.Camacho**	Approved: **L.Teague**
Drilling Contractor: **Geoprojects International**		Date Started: **7/12/05**	Date Finished: **7/12/05**
Drilling Equipment: **CME-75**	Driller: **Richard**	Total Boring Depth: (feet) **56.0**	Depth to Static Water: (feet)
Drilling Method: **Hollow Stem Auger**	Borehole Diameter: **8"**	TOC Elevation:	Ground Elevation:
Sampling Method: **Split Spoon**		Diameter and Type of Well Casing: **2" Schedule 40 PVC**	
Comments: **Temporary Well Installed**		Slot Size: **0.010**	Filter Material: **20/40**
		Development Method: **Bailer**	

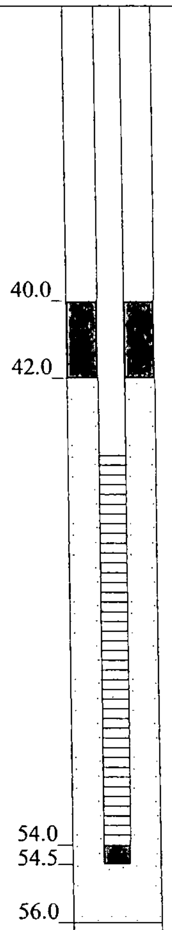
Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
				Fill - cobbles, gravel, sand, silt, etc.	0	☒	2		Temporary well was installed
2 4		SP		SAND (SP); Dark brown; moist; fine to medium grained sand; contains 1/2" to 2" diameter nodules of medium grained lithified sandstone.					
6 8		SM		SILTY SAND (SM); Tan; slightly moist; contains 1/4" to 1/2" diameter of lithified siltstone nodules	5.4	☒	2		
10 12		SP		SAND (SP); Black; dry; medium to coarse grained sand; stained, strong hydrocarbon odor	625	☒	2		
14 16 18				SAA, moist	1329	☒	2		Sampled ES-14-15'
20					1201	☒	2		No backfill, just PVC riser pipe
22 24				SILTSTONE; Black; dry; hydrocarbon odor					
26 28		SP		SAND (SP); Black; slighlty moist; fine to medium grained sand; hydrocarbon odor	1028	☒	2		
30 32		SM		SILTY SAND (SM); Black; dry; fine grained sand; contains 1/2" diameter nodules of very fine lithified sandstone nodules, hydrocarbon odor	1013	☒	2		

Soil Boring: ES

Project Name: BJ Services Company, U.S.A. - Fracmaster Facility **Project Number:** 128125 Sheet 2 of 2

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID
34		SW		SAND (SW); Black; moist; fine grained sand; contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules, hydrocarbon odor	682	☒	2	
36								
38								
40					502	☒	2	
42								
44					663	☒	2	
46								
48	▽							
50				SAA, wet	42.4	☒	2	
52								
54								
56								

Soil Boring Remarks



Bentonite Seal

Sampled ES-47-48'

20/40 Silica filter pack

0.01 slotted PVC screen

Boring was plugged with a bentonite-cement grout.

Soil Boring: **NS**

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: **128125** Sheet **1** of **2**

Project Location: **Hobbs, NM**		Logged By: **B.Camacho**	Approved: **L.Teague**
Drilling Contractor: **Geoprojects International**		Date Started: **7/13/05**	Date Finished: **7/13/05**
Drilling Equipment: **CME-75**	Driller: **Richard**	Total Boring Depth: (feet) **36.0**	Depth to Static Water: (feet)
Drilling Method: **Hollow Stem Auger**	Borehole Diameter: **8"**	TOC Elevation:	Ground Elevation:
Sampling Method: **Split Spoon**		Diameter and Type of Well Casing:	
Comments:		Slot Size:	Filter Material:
		Development Method:	

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
				Fill - cobbles, gravel, sand, silt, etc.	0	☒	2		
		SP		SAND (SP); Tan; dry; fine to medium grained sand; contains caliche rock					
2									
4		SM		SILTY SAND (SM); Tan; slightly moist; contains 1/2" diameter of lithified siltstone nodules	0	☒	2		
6									
8									
10					0	☒	2		
12									
14		SP		SAND (SP); Tan; moist; medium to coarse grained sand; contains >1/2" diameter of medium grained sandstone nodules	0	☒	2		
16									
18									
20					0	☒	2		
22				SANDSTONE; Pinkish brown; dry; >1" diameter nodules of very fine lithified sandstone					
24		SP		SAND (SP); Dark gray; moist; fine to medium grained sand; contains <1/4" diameter of fine grained sandstone nodules	47	☒	2		Sampled NS-24-25'
26									
28									
30					9.3	☒	2		
32		SW		SAND (SW); Light gray; slightly moist; fine grained sand; contains 1/4" to 1/2" diameter nodules of very					

Soil Boring: NS

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: 128125 Sheet 2 of 2

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
			░	fine lithified sandstone nodules					
34			░		7.1	☒	2		Sampled NS-34-35'
36									
									Boring was plugged with a bentonite-cement grout.

Soil Boring: **SS**

Project Name: BJ Services Company, U.S.A. - Fracmaster Facility	Project Number: 128125	Sheet 1 of 1	
Project Location: Hobbs, NM		Logged By: B.Camacho	Approved: L.Teague
Drilling Contractor: Gemini Technical Services		Date Started: 7/14/05	Date Finished: 7/13/05
Drilling Equipment: CME-75	Driller: Richard	Total Boring Depth: (feet) 31.0	Depth to Static Water: (feet)
Drilling Method: Hollow Stem Auger	Borehole Diameter: 8"	TOC Elevation:	Ground Elevation:
Sampling Method: Split Spoon		Diameter and Type of Well Casing:	
Comments:		Slot Size:	Filter Material:
		Development Method:	

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
				Fill - cobbles, gravel, sand, silt, etc.	0		2		
2		SP		SAND (SP); Tan; dry; fine to medium grained sand					
4 6 8		SM		SILTY SAND (SM); Tan; slightly moist; contains 1/4" diameter of lithified siltstone nodules	0		2		
10 12		SP		SAND (SP); Pinkish brown; moist; medium to coarse grained sand; contains >1/2" diameter of medium grained sandstone nodules	0		2		
14				SANDSTONE; Pinkish brown; dry; >1" diameter nodules of very fine lithified sandstone	0		2		
16 18		SP		SAND (SP); Tan; moist; fine to medium grained sand; contains 1/4" to 1/2' diameter of fine grained sandstone nodules	0		2		
20 22		SW		SAND (SW); Pinkish brown; slightly moist; fine grained sand; contains <1/4" diameter nodules of very fine lithified sandstone nodules					
24 26 28				SAA, dry	0		2		Sampled SS-30-31'
30				SAA, moist	0		2		Boring was plugged with a bentonite-cement grout.

Soil Boring: **WS**

Project Name:	BJ Services Company, U.S.A. - Fracmaster Facility	Project Number:	128125	Sheet 1 of 2	
Project Location:	Hobbs, NM	Logged By:	B.Camacho	Approved:	L.Teague
Drilling Contractor:	Geoprojects International	Date Started:	7/13/05	Date Finished:	7/13/05
Drilling Equipment:	CME-75 Driller: Richard	Total Boring Depth: (feet)	51.0	Depth to Static Water: (feet)	
Drilling Method:	Hollow Stem Auger Borehole Diameter: 8"	TOC Elevation:		Ground Elevation:	
Sampling Method:	Split Spoon	Diameter and Type of Well Casing:			
Comments:		Slot Size:		Filter Material:	
		Development Method:			

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
				Fill - cobbles, gravel, sand, silt, etc.	0	☒	2		
		SP		SAND (SP); Tan; dry; fine to medium grained sand; contains caliche rock					
4				SAA, Pinkish brown, slightly moist	0	☒	2		
6		SM		SILTY SAND (SM); Dark brown; slightly moist; contains 1/2" diameter of lithified siltstone nodules					
10		SP		SAND (SP); Pinkisk brown; moist; medium to coarse grained sand; contains >1/2" diameter of medium grained sandstone nodules	0	☒	2		
14				SAA, Dark brown, dry	0	☒	2		
16				SANDSTONE; Light gray; dry; >1" diameter nodules of very fine lithified sandstone					
					4582	☒	2		Sampled WS-19-20'
20		SP		SAND (SP); Tan; moist; medium to coarse grained sand					
24				SAA, black stained, strong hydrocarbon odor	2528	☒	2		
30		SM		SILTY SAND (SM); Dark gary; dry; fine grained sand; hydrocarbon odor	1805	☒	2		
32									

Soil Boring: **WS**

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: 128125 Sheet 2 of 2

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Soil Boring Remarks
34		SW		SAND (SW); Black; dry; fine grained sand; contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules, hydrocarbon odor	2398	☒	2		
36									
38									
40				SAA, dark gray, moist	1024	☒	2		
42									
44					1247	☒	2		
46									
48									Sampled WS-48-49'
50	▼			SAA, wet	876	☒	2		
									Boring was plugged with a bentonite-cement grout.

BROWN AND CALDWELL

Monitoring Well: **MW-1**

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility**	Project Number: **128125**	Sheet 1 of 2

Project Location: **Hobbs, NM**		Logged By: **B.Camacho**	Checked By: **R.Rexroad**
Drilling Contractor: **Geoprojects International**		Date Started: **2/21/06**	Date Finished: **2/22/06**
Drilling Equipment: **CME-75**	Driller: **Richard**	Total Boring Depth: (feet) **65.0**	Depth to Static Water: (feet) **49.00**
Drilling Method: **Hollow Stem Auger**	Borehole Diameter: **8"**	TOC Elevation: **103.21**	Ground Elevation:
Sampling Method: **Split Spoon**		Diameter and Type of Well Casing: **2" Schedule 40 PVC**	
Comments:		Slot Size: **0.010**	Filter Material: **20/40**
		Development Method: **Bailer**	

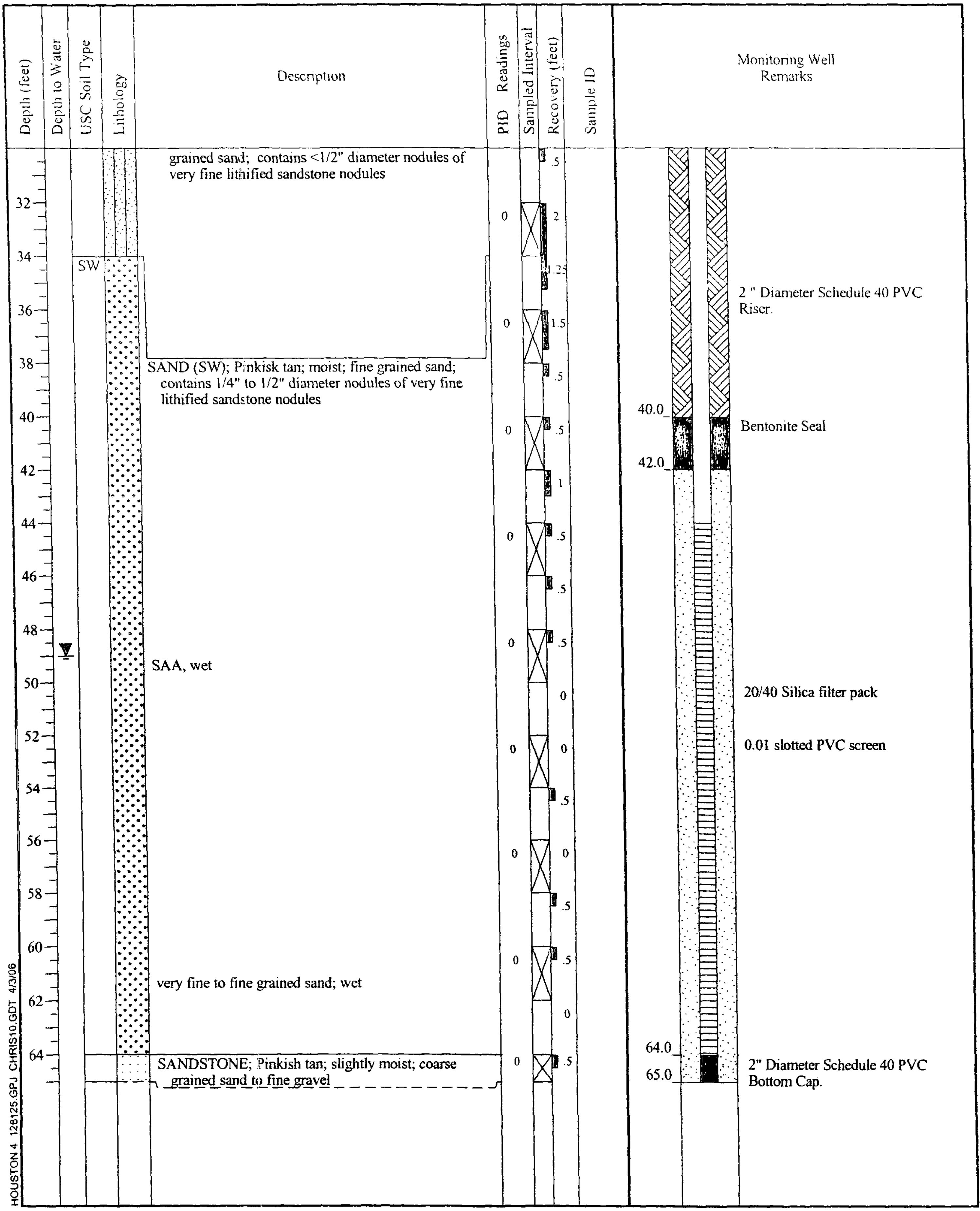
Depth (feet)	Depth to Water	USC Soil Type	Description	PID Readings	Recovery (feet)	Sample ID	Monitoring Well Remarks
0			Fill - cobbles, gravel, sand, silt, etc.	0	2		3X3 Above-grade completion.
		SC	CLAYEY SAND (SC); Dark brown; slightly moist; medium grained sand; contains caliche rock				
2					1.5		
4				6	2		
6			Tan; moist		2		
8				14	2		
9		SP	SAND (SP); Tan; loose; slightly moist; fine to medium grained sand; poorly sorted; contains <1/4" diameter nodules of fine lithified sandstone nodules				
10					1		
12				11	1.5		
14					.5		
16			SANDSTONE; Pinkish; dry; hard	15	1.5		
18		SP	SAND (SP); Pinkish tan; moist; fine to medium grained sand; contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules		1.5	19-20	Sampled MW-1-19-20'
20				19	1.25		Bentonite-cement grout.
22					1.5		
24				2	1.5		
26					1		
28				0	1.5		
		SM	SILTY SAND (SM); Tan; medium dense; moist; fine				

HOUSTON 4 128125.GPJ CHRIS10.GDT 4/3/06

BROWN AND CALDWELL

Monitoring Well: MW-1

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: **128125** Sheet 2 of 2



grained sand; contains <1/2" diameter nodules of very fine lithified sandstone nodules

SAND (SW); Pinkisk tan; moist; fine grained sand; contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules

SAA, wet

very fine to fine grained sand; wet

SANDSTONE; Pinkish tan; slightly moist; coarse grained sand to fine gravel

2 " Diameter Schedule 40 PVC Riser.

Bentonite Seal

20/40 Silica filter pack

0.01 slotted PVC screen

2" Diameter Schedule 40 PVC Bottom Cap.

HOUSTON 4 128125.GPJ CHRIS10.GDT 4/3/06

This log should not be used separately from the original report

BROWN AND CALDWELL

Monitoring Well: MW-2

Project Name:	BJ Services Company, U.S.A. - Fracmaster Facility	Project Number:	128125	Sheet 1 of 2	
Project Location:	Hobbs, NM	Logged By:	B.Camacho	Checked By:	R.Rexroad
Drilling Contractor:	Geoprojects International	Date Started:	2/22/06	Date Finished:	2/22/06
Drilling Equipment:	CME-75 Driller: Richard	Total Boring Depth: (feet)	65.0	Depth to Static Water: (feet)	49.00
Drilling Method:	Hollow Stem Auger Borehole Diameter: 8"	TOC Elevation:	102.05	Ground Elevation:	
Sampling Method:	Split Spoon	Diameter and Type of Well Casing:	2" Schedule 40 PVC		
Comments:		Slot Size:	0.010	Filter Material:	20/40
		Development Method:	Bailer		

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Monitoring Well Remarks
0				Fill - cobbles, gravel, sand, silt, etc.	0	☒	2		3X3 Above-grade completion.
		SM		SILTY SAND (SM); Tan; moist; fine grained sand; contains caliche rock					
2							1.5		
4		SP		SAND (SP); Pinkish tan; loose; slightly moist; fine to medium grained sand; poorly sorted; contains 1/2" to 1" diameter nodules of very fine lithified sandstone nodules	0	☒	1.5		
6							1		
8					0	☒	1		
10							1.5		
12					0	☒	2		
14							2	14-15	
16					0	☒	1.5		
17				SANDSTONE; Pinkish; dry; hard					
18		SP		SAND (SP); Pinkish tan; moist; fine to medium grained sand			1		Sampled MW-2-14-15' Bentonite-cement grout.
20					0	☒	1.25		
22							.5		
23				contains <1/4" diameter nodules of very fine lithified sandstone nodules					
24					0	☒	1.5		
26							1.25		
28					0	☒	1.5		
29		SW		SAND (SW); Pinkisk tan; moist; fine grained sand;					

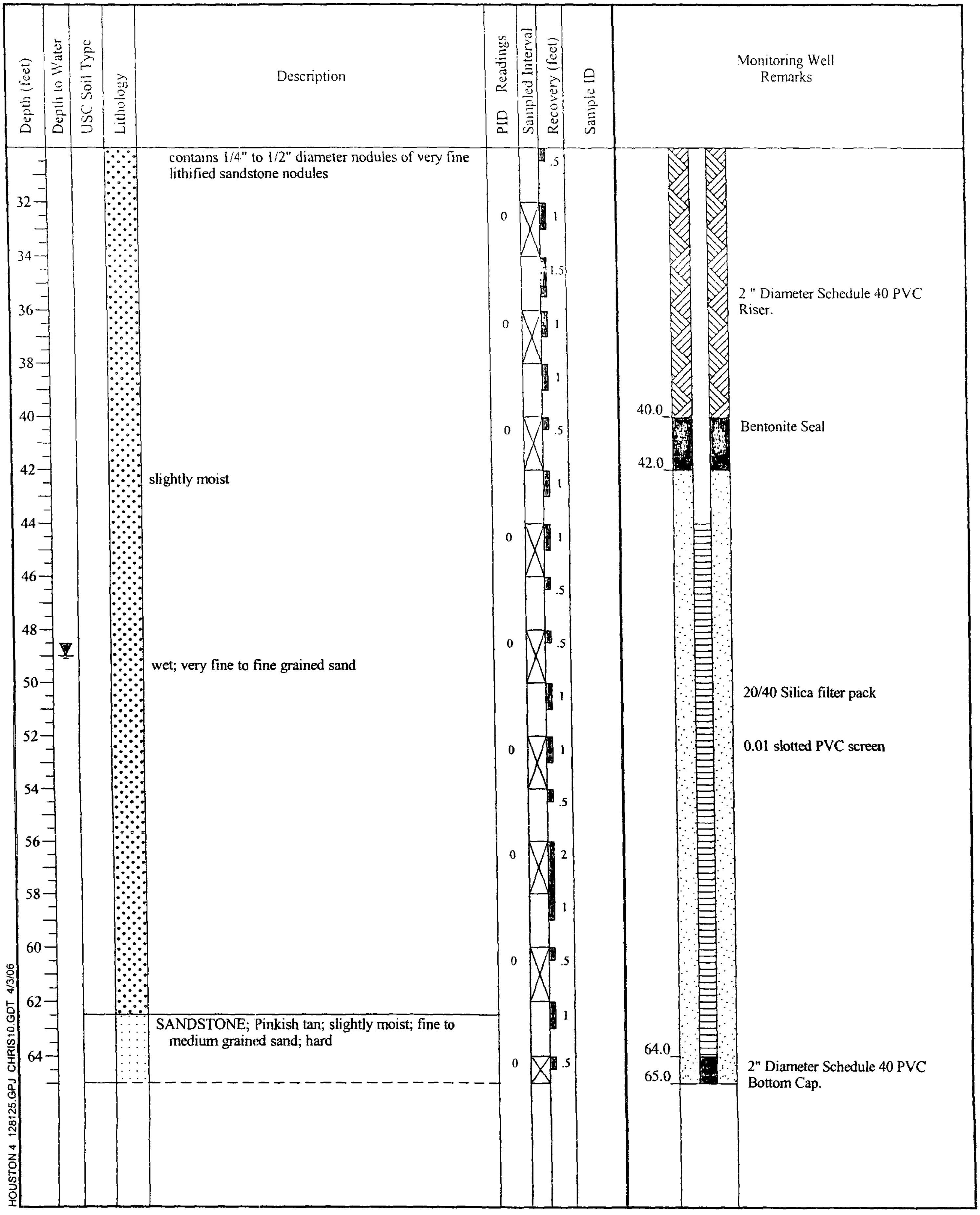
BROWN AND CALDWELL

Monitoring Well: **MW-2**

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility**

Project Number: **128125**

Sheet 2 of 2



contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules

slightly moist

wet; very fine to fine grained sand

SANDSTONE; Pinkish tan; slightly moist; fine to medium grained sand; hard

2 " Diameter Schedule 40 PVC Riser.

Bentonite Seal

20/40 Silica filter pack

0.01 slotted PVC screen

2" Diameter Schedule 40 PVC Bottom Cap.

HOUSTON 4 128125.GPJ CHRIS10.GDT 4/3/06

Monitoring Well: MW-3

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility**
Project Number: 128125
Sheet 1 of 2

Project Location: **Hobbs, NM**		Logged By: **B.Camacho**	Checked By: **R.Rexroad**
Drilling Contractor: **Geoprojects International**		Date Started: 2/21/05	Date Finished: 2/21/05
Drilling Equipment: CME-75	Driller: Richard	Total Boring Depth: (feet) 64.0	Depth to Static Water: (feet) 48.00
Drilling Method: **Hollow Stem Auger**	Borehole Diameter: 8"	TOC Elevation: 102.41	Ground Elevation:
Sampling Method: **Split Spoon**		Diameter and Type of Well Casing: **2" Schedule 40 PVC**	
Comments:		Slot Size: **0.010**	Filter Material: **20/40**
		Development Method: **Bailer**	

Depth (feet)	Depth to Water	USC Soil Type	Lithology	Description	PID Readings	Sampled Interval	Recovery (feet)	Sample ID	Monitoring Well Remarks
				Fill - cobbles, gravel, sand, silt, etc.	0		2		3X3 Above-grade completion.
		SC		CLAYEY SAND (SC); Tan; moist; medium to coarse grained sand; contains caliche rock					
2							1.5		
4				slightly moist; contains caliche rock	0		2		
6		SM		SILTY SAND (SM); Tan; moist; fine grained sand; calcareous nodules			1		
8					0		1		
10		SP		SAND (SP); Tan; loose; moist; fine to medium grained sand; poorly sorted; contains 1/2" to 1" diameter nodules of very fine lithified sandstone nodules			1		
12					0		1.5		
14							1		
				SANDSTONE; Pinkish brown; dry; hard					
16					0		1		
18		SP		SAND (SP); Pinkish tan; slightly moist; fine to medium grained sand; poorly sorted; contains <1/4" diameter nodules of very fine lithified sandstone nodules			.5		
20					0		1.5		Bentonite-cement grout.
				contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules					
22							.5		
24					0		.5		
26							1		
28				moist	0		1		

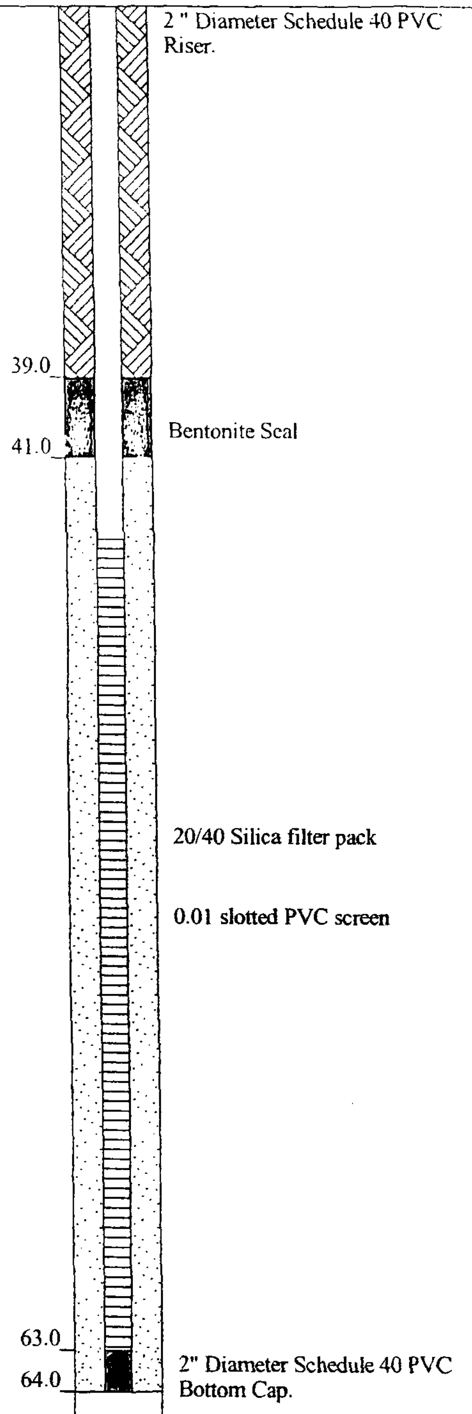
BROWN AND CALDWELL

Monitoring Well: MW-3

Project Name: **BJ Services Company, U.S.A. - Fracmaster Facility** Project Number: **128125** Sheet 2 of 2

Depth (feet)	Depth to Water	USC Soil Type	Description	PID Readings	Recovery (feet)	Sample ID
					1.5	
32						
				0	.5	
34						
					1	
36		SW	SAND (SW); Pinkisk tan; moist; fine grained sand; contains 1/4" to 1/2" diameter nodules of very fine lithified sandstone nodules			
				0	0	
38						
					.5	
40						
				0	0	
42						
					.5	
44						
				0	1	
46			slightly moist; contains <1/4" diameter nodules of very fine lithified sandstone nodules			
					.5	
48	▼		wet; very fine to fine grained sand			
				0	.5	
50						
					0	
52						
				0	0	
54						
					.5	
56						
				0	.5	
58						
					0	
60						
				0	.5	
62						
					1	
64						
				0	.5	

Monitoring Well Remarks



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APPENDIX B

Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures

United States Environmental Protection Agency
Office of Research and Development
Office of Solid Waste and Emergency Response
EPA/540/S-95/504
April 1996

EPA Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

by Robert W. Puls[1] and Michael J. Barcelona[2]

Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites. One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives. This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling.

For further information contact: Robert Puls, 405-436-8543, Subsurface Remediation and Protection Division, NRMRL, Ada, Oklahoma.

I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water. Large water-bearing units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased. This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic *units*. With time it became apparent that conventional water supply generalizations of *homogeneity* did not adequately represent field data regarding pollution of these subsurface resources. The important role of *heterogeneity* became increasingly clear not only in geologic terms, but also in terms of complex physical,

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[2] *University of Michigan*

Superfund Technology Support Center for Ground Water

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Technology Innovation Office
Office of Solid Waste and Emergency Response, US EPA, Washington, DC

Walter W. Kovalick, Jr., Ph.D.
Director

chemical and biological subsurface processes. With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and *aquitards* or low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths.

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today: aquifer heterogeneity and colloidal transport. Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g., 3-6 m) typically installed at hazardous waste sites to detect and monitor plume movement over time. Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987; McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988; Penrose et al., 1990). Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third *phase* as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990; McCarthy and Degueldre, 1993; Backhus et al., 1993; U. S. EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm. The most commonly observed mobile particles include: secondary clay minerals; hydrous iron, aluminum, and manganese oxides; dissolved and particulate organic materials, and viruses and bacteria. These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the *total* mobile contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias *naturally* suspended particle concentrations.

Currently the most common ground-water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artifactual particles which produce an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques.

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic *push* technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential baseline data requirements. Detailed soil and geologic data are required prior to and during the installation of sampling points. This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended. With this information (together with other site characterization data) and a clear understanding of sampling objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with *hybrid* variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;

2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and

3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term *representativeness* applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

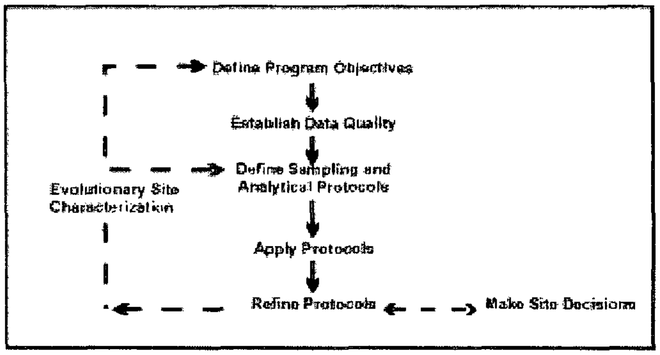

Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.

1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren't statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these *over-sampling* concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

C. Sampling Point Design and Construction

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program's data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

2) Flexibility of Sampling Point Design

In most cases *well-point* diameters in excess of 1 7/8 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that *short* (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. *Short*, of course, is relative to the degree of vertical water quality variability expected at a site.

3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than *direct-push* technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality *recovery* period.

III. Definition of Low-Flow Purging and Sampling

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point. Low-flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

A. Low-Flow Purging and Sampling

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min. The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques. The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used. Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval. Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling.

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques. If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled. At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective.

B. Water Quality Indicator Parameters

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity. Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization. Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging

In general, the advantages of low-flow purging include:

- samples which are representative of the *mobile* load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control;

- reduced stress on the formation (minimal drawdown);
- less mixing of stagnant casing water with formation water;
- reduced need for filtration and, therefore, less time required for sampling;
- smaller purging volume which decreases waste disposal costs and sampling time;
- better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are:

- higher initial capital costs,
- greater set-up time in the field,
- need to transport additional equipment to and from the site,
- increased training needs,
- resistance to change on the part of sampling practitioners,
- concern that new data will indicate a *change in conditions* and trigger an *action*.

IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors' (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986; Puls and Barcelona, 1989; Puls et. al. 1990, 1992; Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of *representative* ground-water samples include: mixing of the stagnant casing and *fresh* screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to sampling, it is recommended that an in-line water quality measurement device (e.g., flow-through cell) be used to establish the stabilization time for several parameters (e.g. , pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling:

- use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well;
- maximize tubing wall thickness, minimize tubing length;
- place the sampling device intake at the desired sampling point;
- minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
- make proper adjustments to stabilize the flow rate as soon as possible;
- monitor water quality indicators during purging;
- collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system.

B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer's recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing. Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation.

D. Pump Type

The use of low-flow (e.g., 0.1-0.5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site. Bailers are inappropriate devices for low-flow sampling.

1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and minimal disturbance of the sample across a range of *low* flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause *significant* drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be of a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other *grab* type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of *stagnant* water in the casing and the *dynamic* water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1991), U. S. EPA (1992), Parker (1994) and Thurnblad (1994).

E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over <u>any</u> other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screen with the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and resulting purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a *fix* for poor sampling practices, and field-filtering of certain constituents should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally *dissolved* [i.e., samples filtered with 0.45 µm filters]) concentrations of major ions and trace metals, 0.1 µm filters are recommended although 0.45 µm filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO_2 composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g. oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 µm). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer's recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, a filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within ± 0.1 for pH, ± 3% for conductivity, ± 10 mv for redox potential, and ± 10% for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

H. Sampling, Sample Containers, Preservation and Decontamination

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g., Fe^{2+}, CH_4, H_2S/HS^-, alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analytes of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U. S. EPA, 1992] or EPA SW-846 [U. S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

I. Blanks

The following blanks should be collected:

(1) field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.

(2) equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.

(3) trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

V. Low-Permeability Formations and Fractured Rock

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of the well screen. This may require repeated recovery of the water during purging while leaving the pump in place within the well screen.

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected; i.e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i.e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device.

A. Low-Permeability Formations (<0.1 L/min recharge)

1. Low-Flow Purging and Sampling with Pumps

a. "portable or non-dedicated mode" - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements). After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.

b. "dedicated mode" - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized. Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

2. Passive Sample Collection

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining "representative" samples. Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives.

B. Fractured Rock

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most "representative" samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or other geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in "dedicated mode" or use a passive sampling device which can isolate the identified water-bearing fractures.

VI. Documentation

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum: information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and "Ground Water Sampling Workshop -- A Workshop Summary" (U. S. EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the "useability" of the sampling data.

VII. Notice

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Figure 2. **Ground Water Sampling Log**

Project ______________ **Site** ______________ **Well No.** ____________ **Date** ________________________
Well Depth ___________ **Screen Length** _________ **Well Diameter** ________ **Casing Type** ___________
Sampling Device ______________ **Tubing type** ___________________ **Water Level** ________________
Measuring Point _________________ **Other Infor** ____

Sampling Personnel ____

Time	pH	Temp	Cond.	Dis.O_2	Turb.	[ ]Conc			Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3\pi\ r^3$

Figure 3. **Ground Water Sampling Log** (with automatic data logging for most water quality parameters)

Project ______________ **Site** ______________ **Well No.** ____________ **Date** ______________________

Well Depth ____________ **Screen Length** __________ **Well Diameter** _________ **Casing Type** __________

Sampling Device ______________ **Tubing type** ____________________ **Water Level** ________________

Measuring Point _________________ **Other Infor** ____

____

Sampling Personnel ____

Time	Pump Rate	Turbidity	Alkalinity	[ ] Conc	Notes

Type of Samples Collected

____

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: $Vol_{cyl} = \pi r^2 h$, $Vol_{sphere} = 4/3\pi r^3$

APPENDIX C

Groundwater Sampling Field Data Sheet

BROWN AND CALDWELL

GROUNDWATER SAMPLING FIELD DATA SHEET

WELL ID:____________

1. PROJECT INFORMATION

Project Number:__________ Task Number:________ Date:______________ Time:__________

Client:______________________________ Personnel:______________________________

Project Location:______________________________ Weather:______________________________

2. WELL DATA

Casing Diameter:________ inches | Type: ☐ PVC ☐ Stainless ☐ Galv. Steel ☐ Teflon® ☐ Other:__________

Screen Diameter:________ inches | Type: ☐ PVC ☐ Stainless ☐ Galv. Steel ☐ Teflon® ☐ Other:__________

Total Depth of Well:________ feet | From: ☐ Top of Well Casing (TOC) ☐ Top of Protective Casing ☐ Other:__________

Depth to Static Water:________ feet | From: ☐ Top of Well Casing (TOC) ☐ Top of Protective Casing ☐ Other:__________

Depth to Product:________ feet | From: ☐ Top of Well Casing (TOC) ☐ Top of Protective Casing ☐ Other:__________

Length of Water Column:________ feet Well Volume:________ gal Screened Interval (from GS):__________

Pump intake depth________ (from GS)

Note: 2-inch well = 0.16 gal/ft 4-inch well = 0.65 gal/ft

3. PURGE DATA

Purge Method: ☐ Bailer, Size:____ ☐ Bladder Pump ☐ 2" Submersible Pump ☐ 4" Submersible Pump ☐ Centrifugal Pump ☐ Peristaltic Pump ☐ Inertial Lift Pump ☐ Other:__________

Materials: Pump/Bailer ☐ Stainless ☐ PVC ☐ Teflon® ☐ Other:__________ ☐ Dedicated ☐ Prepared Off-Site ☐ Field Cleaned ☐ Disposable

Materials: Rope/Tubing ☐ Polyethylene ☐ Polypropylene ☐ Teflon® ☐ Other:__________ ☐ Dedicated ☐ Prepared Off-Site ☐ Field Cleaned ☐ Disposable

Was well purged dry? ☐ Yes ☐ No Pumping Rate:________ liters/min

Equipment Model(s)

1. ____________________
2. ____________________
3. ____________________

Time	Cum. Liters Removed	pH	Temp	Spec. Cond.	Eh	Dissolved Oxygen	Turbidity	Depth to Water (TOC)	Comments

4. SAMPLING DATA

Method(s): ☐ Bailer, Size:____ ☐ Bladder Pump ☐ 2" Submersible Pump ☐ 4" Submersible Pump ☐ Peristaltic Pump ☐ Inertial Lift Pump ☐ Other:

Materials: Pump/Bailer ☐ Stainless ☐ PVC ☐ Teflon® ☐ Other:__________ ☐ Dedicated ☐ Prepared Off-Site ☐ Field Cleaned ☐ Disposable

Materials: Tubing/Rope ☐ Polyethylene ☐ Polypropylene ☐ Teflon® ☐ Other:__________ ☐ Dedicated ☐ Prepared Off-Site ☐ Field Cleaned ☐ Disposable

Depth to Water at Time of Sampling:__________ Field Filtered? ☐ Yes ☐ No

Sample ID:__________ Sample Time:__________ # of Containers:______

Duplicate Sample Collected? ☐ Yes ☐ No ID:

Geochemical Analyses

Ferrous Iron: ________ mg/L

DO: ________ mg/L

Nitrate: ________ mg/L

Sulfate: ________ mg/L

Alkalinity: ________ mg/L

5. COMMENTS

Note: Include comments such as well condition, odor, presence of NAPL, or other items not on the field data sheet.

Gen\non-proj\forms\Field Data Sheet.xls\BC-liters

FORM GW-1 (Rev 2/26/02 - dg)

Signature