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July 18, 2008

Ms. Marilyn Czimer Long, P.G.
Texas Commission on Environmental Quality
MC-137
State Lead Section
12100 Park 35 Circle
Austin, TX 78753

Subject: **Final Pilot Test Work Plan**
Jones Road Groundwater Plume Federal Superfund Site
Houston, Harris County, Texas
Shaw Project No. 131429

Dear Ms. Long:

Enclosed are three copies of the above referenced Work Plan. A hard copy of this Work Plan was also sent to Mr. Gary Baumgarten of EPA Region 6. An electronic version of this plan was e-mailed to the people on the distribution list of this letter.

Comments from TCEQ and EPA Region 6 on the revised draft Work Plan raised the concern that the volatile organic contaminant concentrations in the proposed pilot test area saturated zone may need further delineation. Shaw agrees with this. Additional data collected in the source area should be considered prior to conducting the pilot test. Chlorinated solvent concentrations in the proposed test interval from 22 to 37 feet below grade should be better defined in order to evaluate the effectiveness of the pilot test technologies. Additional data could be collected by a direct push soil and groundwater sampling program prior to pilot testing. If any of the future source area deep wells are being installed in or near the proposed pilot test areas, they present another opportunity to collect data.

If you have any questions or comments, please feel free to call me at (412) 858-3309.

Very truly yours,

Richard B. Wice, P.G. CHMM
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FINAL
PILOT TEST WORK PLAN
for
JONES ROAD GROUNDWATER PLUME FEDERAL SUPERFUND SITE
HOUSTON, HARRIS COUNTY, TEXAS

Shaw Project No. 131429

Prepared for:

State Lead Section
Remediation Division
Texas Commission on Environmental Quality

Prepared by:

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July 2008

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1.0 INTRODUCTION

Shaw Environmental, Inc. (Shaw) is pleased to present to the Texas Commission on Environmental Quality (TCEQ) this Revised Draft Pilot Test Work Plan for In Situ Chemical Oxidation (ISCO) and bioaugmentation technologies at the Jones Road Groundwater Plume Federal Superfund site (Jones Road), located in Houston, Texas. The pilot test technology applications in this Work Plan are for the shallow saturated zone soils and groundwater in the source area of the Jones Road site. This Plan was developed for the TCEQ under Work Order No. 153-0061, Amendment No. 1.

Based on the *Treatability Study Report* (Shaw, 2007), ISCO using potassium permanganate was found to be potentially effective in treating tetrachloroethene (PCE) and its daughter products in both the dissolved phase and as adhered to the soil matrix in the vadose zone and saturated zone as free product.. Bench-scale treatability study results were used to develop quantities and concentrations of sodium permanganate ($NaMnO_4$) for the field pilot test. $NaMnO_4$ is recommended instead of potassium permanganate ($KMnO_4$), since it has easier and has safer handling characteristics. The effectiveness of $NaMnO_4$ in treating PCE and its daughter products is the same as $KMnO_4$.

The ISCO pilot test will include the following tasks.

- Installation of two injection wells. ISCO radius of influence is 10 feet, so the injection wells will be spaced 20 feet apart.
- Installation of five monitor wells.
- Baseline groundwater monitoring of wells before injection.
- Injection of approximately 15,710 gallons (7,855 gallons per well) of two percent $NaMnO_4$ solution to treat a zone located 22 to 37 feet below ground surface (bgs).
- Sampling groundwater during and after injection using a bailer to check for purple color indicative of permanganate.
- Follow-up monitoring of groundwater after injection at two, four, and six month intervals after injection.

Based on the *Treatability Study Report* (Shaw, 2007), bioaugmentation was found to be potentially effective in treating PCE and its daughter products at the site. The bioaugmentation pilot test will include the following tasks.

- Installation of two injection wells. The injection wells will be spaced 10 feet apart to ensure a good distribution of bioaugmentation fluids.
- Installation of three monitor wells.
- Baseline groundwater monitoring of wells before injection
- Injection of approximately 13,548 gallons of emulsified oil substrate (EOS)
- Follow-up monitoring of the test zone to determine when conditions are optimal for the addition of SDC-9™ culture.
- Injection of approximately 75 Liters of SDC-9™ culture.
- Follow-up monitoring of groundwater after injection of SDC-9™ culture at two, four, and six month intervals.

This Work Plan covers the activities associated with the shallow application of ISCO and bioaugmentation in the source area. Shaw proposes to conduct these shallower source area saturated zone pilot tests first, in order to evaluate the effectiveness of delivery and reaction of ISCO and bioaugmentation at the site prior to undertaking full scale applications. Site conditions with a mix of silts, silty-clay, and sand lenses are regarded by Shaw and the TCEQ as challenges for in situ technology applications at the site. Original pilot test scoping called for different pilot test target depths. However, pilot testing in the shallow zone (22 to 37 feet bgs) only is recommended for logistical reasons (well installation difficulties in tight working areas), and to conserve drilling costs. Pilot testing in the shallow zone is also recommended, since successful ISCO/bioaugmentation application in the shallow zone would likely have similar results in deeper, more permeable groundwater bearing units. Pilot test target zone depths in the shallow saturated zone are based on the conceptual site model (CSM (Shaw, 2008). Based on the results of these pilot tests, mainly effective delivery, distribution of the sodium permanganate, bioaugmentation fluids and culture, and reduction in PCE, a full scale application may be implemented.

Prior to conducting the pilot tests, Shaw will amend the current *Site-Specific Health and Safety Plan* for $NaMnO_4$ and EOS handling and injections. Shaw will also review and amend the *Jones Road Field Sampling Plan*, if necessary. Shaw will also prepare TCEQ Class V injection well permit applications.

1.1 Site Description

The Jones Road site is located approximately one-half mile north of the intersection of Jones Road and FM 1960, outside the city limits of northwest Houston, Harris County, Texas. The vadose zone, shallow (for purposes of these tests, the shallow saturated groundwater zone is from

20 to 40 feet below grade), and deeper groundwater (starting at a depth of 60 feet) in this area has been impacted by chlorinated solvents including PCE, trichloroethene (TCE), dichloroethene (DCE) and vinyl chloride (VC), believed to be associated with operations conducted at the former Bell Dry Cleaners site located in the Cypress Center Shopping Center at 11600 Jones Road.

A comprehensive description of the Jones Road site background and site conditions may be found in the *CPT Report* (Shaw, 2004), *Draft Remedial Investigation Report* (Shaw, 2006), and details of the Geoprobe® field investigation may be found in the *July 2006 Geoprobe® Investigation Report* (Shaw, 2007). Shaw also prepared a *Conceptual Site Model Report* (Shaw, May 2008).

1.2 Pilot Test Objectives

The Jones Road site pilot test objective is to evaluate an in situ remedial technology application that may effectively remediate the chlorinated solvents in the saturated shallow zone in and around the source area of the site. Pilot tests determine if the technology is applicable in the field and provide information necessary for planning a full scale application. At the Jones Road site, data collected during the ISCO and bioaugmentation pilot test will be evaluated to determine if these technologies are viable in the field and what will be required for a full scale implementation.

Specific objectives of the ISCO pilot test include:

- Evaluation of the ISCO application and distribution effectiveness of $NaMnO_4$ in the shallow saturated zone;
- Evaluation of the ISCO application effectiveness in destroying PCE and its daughter products;
- Evaluation of PCE and daughter products to rebound after the application. At the Jones Road site, slow time-release desorbtion of PCE from clay and silty clay layers was recognized as a strong possibility.

Specific objectives of the bioaugmentation pilot test include:

- Evaluation of bioaugmentation substrate and culture distribution in the shallow saturated zone;
- Evaluation of bioaugmentation application effectiveness in reducing PCE and its daughter products to ethene.
- Evaluation of the longevity of groundwater parameter changes (groundwater reducing condition longevity) from the application of EOS.

- Evaluation of PCE and daughter products to rebound after the application. At the Jones Road site, slow time release dissolution of PCE from clay and silty clay layers was recognized as a strong possibility.

2.0 TREATMENT TECHNOLOGY DESCRIPTION

The following section describes the treatment technologies that will be applied as part of this pilot test.

2.1 ISCO

Chemical oxidation using potassium or sodium permanganate is widely used in drinking water treatment applications. ISCO using sodium or potassium permanganate is also used to remediate hazardous waste sites with soil and groundwater contaminated with chlorinated volatile organic compounds (VOCs). ISCO technology has been applied to a wide range of site soils, from clays to sands. The greater the clay content, the more closely spaced injection points and multiple applications of oxidant may be needed. Ideally, any in situ technology application is best suited at sites with moderate permeabilities and lower fine (silt/clayey) content. PCE and TCE are well-suited for oxidation by permanganate. Permanganate reacts rapidly with nonconjugated (i.e., nonaromatic) double bonds in chlorinated ethenes, and oxidizes the chlorinated ethenes to carbon dioxide and chloride ions. The reaction between PCE and permanganate is shown below.

$$3C_2Cl_4 + 4MnO_4^- + 4H_2O \rightarrow 6CO_2 + 4MnO_2 + 12Cl^- + 8H^+$$

Insitu permanganate oxidation involves the injection (by gravity or under pressure) of sodium or potassium permanganate solution into the subsurface. Oxidant is delivered to the subsurface using injection probes, treatment wells, soil mixing, hydraulic fracturing, or vertical or horizontal wells.

The effectiveness of ISCO with permanganate depends on three factors: 1) the kinetics of the reaction between the permanganate and the contaminants; 2) the contact between the oxidant and the contaminants, and 3) competitive reaction of permanganate with other reduced/oxidizable species. If the contaminants targeted are reactive (e.g., chlorinated ethenes), and if sufficient oxidant is added (to overcome the demand from other reduced species, as well as naturally occurring organic matter), the limiting factor to the successful application is the transport of the oxidant to the contaminated area, but not the reaction itself. Clayey silts at Jones Road will somewhat complicate oxidant transport and distribution in the subsurface. The oxidation of contaminants by permanganate is essentially an instantaneous reaction. If the permanganate contacts the contaminant, a reaction will occur. Significant oxidation is observed in as little as a few hours after addition.

2.2 Bioaugmentation

Prior to adding organism to the subsurface for bioaugmentation, biostimulation may be done. In situ anaerobic biostimulation involves stimulating the degradation of indigenous microbial

populations by introducing electron donor (substrate) and/or nutrients into the subsurface. These materials can be delivered to the subsurface using injection probes, treatment walls, soil mixing, pneumatic fracturing, or vertical or horizontal wells. The assumption with this approach is that the indigenous microbial population contains DHC, but the native DHC are unable to maintain high levels of degradation due to unfavorable oxidation-reduction potential, insufficient nutrient (e.g., nitrogen, phosphorous) levels, insufficient microbial levels, and/or lack of electron donor. For the Jones Road site, the bench-scale treatability study test indicated that microbial populations will need to be added.

Bioaugmentation is similar to biostimulation, except that it involves the delivery of microorganisms (in addition to substrate and nutrients) to the subsurface to stimulate biological degradation. These organisms can be cultured directly from site material, or can be obtained from an outside source. Evidence of biological degradation found at a site, such as the presence of daughter products of the degradation of the target contaminants and suitable geochemical conditions may be indicative of an active microbial population. Site soil collected from the area of the site where degradation appears to be occurring, or where these organisms appear to be present, can often be enriched in the laboratory to select the population responsible for degradation. The bacterial culture can then be grown in the laboratory to produce large batches of active microorganisms that are then added to the subsurface, along with appropriate substrate and nutrient.

Alternate sources of active microbial cultures of DHC have been obtained from sites where DHC are naturally occurring. There are several cultures available to Shaw, most notably our SDC-9™ culture, which has been shown to completely and rapidly degrade PCE to ethene using lactate as an electron donor. For this pilot test the SDC-9™ culture will be used for bioaugmentation.

3.0 TEST LOCATION AND TEST ZONE

The proposed locations for the Jones Road pilot tests are shown on Figure 1. The ISCO pilot test will be conducted in an area near monitor well MW-01. The test area measures approximately 20 feet wide by 30 feet long. Extra area will be needed for equipment. Shaw will attempt to minimize the area used and time on site in order to reduce the impact to local plaza businesses and visitors of the Cypress Center Shopping Center. It is estimated that well installation will take three to five days and the ISCO application will take five to ten days. The bioaugmentation pilot test will be conducted in the north alley immediately adjacent to the former dry cleaning building (see Figure 1). This is a narrow area with limited access. The test area measures approximately 15 feet wide by 35 feet long. Equipment will be stored in the alley way. Working in this area should not disrupt Cyprus Center Shopping Center businesses and visitors. It is estimated that well installation will take approximately three to five days and the bioaugmentation EOS application will take approximately five to ten days. Adding the SDC-9™ culture will take part of one day.

All equipment and materials for the pilot tests will be stored in a secure manner to protect property and the public. All waste generated during the pilot test will be stored in secure, labeled drums in accordance with site protocols and TCEQ requirements. Drums will be stored in the field on the east side of the Cypress Center Shopping Center.

The test zone for the pilot studies was selected as 22 to 37 feet bgs. This zone is shown on Figure 2. Figure 2 is a CPT cross section from the recent source area conceptual site model work (Shaw, 2008). The ISCO test is located near CPT-05 and CPT-01. The closest CPT point to the bioaugmentation pilot test area is CPT-06. Data from Geoprobe® Boring GP-3, adjacent to the test area, was also reviewed. From a depth of 22 to 34 feet, the lithology is silty-clay, clay, and sandy silty lenses. A clay layer is present at a depth of approximately 34 feet. From 35 to 37 feet, a sand layer is present. Sodium permanganate and EOS will be injected at their respective test sites across the entire 15-foot interval. The permanganate and EOS solutions will mostly travel in the more permeable sand and silty-sand lenses. It is within those layers that the PCE is most likely present in greater amounts and more readily able to migrate.

Figure 3 shows the layout of the ISCO pilot test. Two injection points, JR-IN1 and JR-IN2 will be used to inject sodium permanganate. JR-IN1 and JR-IN2 will be located approximately 20 feet apart. JR stands for Jones Road and IN stands for injection well. Five wells, JR-PT1 through JR-PT5 will be installed to monitor the dispersion of the sodium permanganate and to collect baseline and follow-up groundwater samples. PT stands for pilot test monitor well. Existing monitor well MW-01 (total depth approximately 35 feet) will also be used for baseline monitoring, permanganate dispersion monitoring, and follow-up monitoring. Monitor wells are

located at various distances and angles from the injection points. The pattern should allow for effective monitoring of the test.

Figure 4 presents the layout of the bioaugmentation pilot test on the north side of the former dry cleaners. Due to the narrow working area and limited access, the array for this pilot test is an in-line layout. Two bioaugmentation injection points, JR-IN3 and JR-IN4 will be used to inject the EOS and follow-up SDC-9™ culture. JR-IN3 and JR-IN4 will be located approximately 10 feet apart. A closer spacing is being used here, as opposed to the ISCO test, since the CPT study shows less developed sand stringers in this test area shallow saturated target zone. Three wells, JR-PT6 through JR-PT8 will be installed to monitor the dispersion of the EOS and SDC-9™ culture and to collect baseline and follow-up monitoring groundwater samples.

3.1 Well Installation

The monitor wells and injection wells will be installed using hollow-stem auger (HSA) drilling methods. Well drilling and installation will be performed by a Texas licensed driller. A Shaw geologist will supervise the well installation work. The geologist will be licensed in Texas or under the direct supervision of a Texas licensed geologist. Continuous soil cores will be collected from all the borings for lithological description purposes. The monitor wells and injection wells will be constructed using nominal 2-inch diameter poly vinyl chloride (PVC) pipe. Total depth will be approximately 38 feet. A 15 foot long, 2-inch diameter Schedule 40 slotted PVC screen (with 0.010-inch slots) will be set from 22 to 37 feet bgs across the test zone. The remainder of the well will be completed with 2-inch diameter PVC riser pipe. A 20/40 grade sand pack will be installed from the well total depth to 2 feet above the top of screen. A 1-foot thick 6/10 sand pack will be placed above the 20/40 sand pack to prevent grout intrusion and inhibit migration of $NaMnO_4$ upward. A 3 -foot thick bentonite well seal will be placed above the grout. The remaining annular space will be filled with bentonite grout or seal. The wells will be completed as flush mounts, so they will not interfere with vehicular traffic. Traffic grade flush-mount vaults will be used. Injection wells JR-IN1, JR-IN2, JR-IN3, and JR-IN4 may utilize larger and deeper flush mount well vaults in order to allow for the installation of injection piping, gauges, and controls. Well locations and elevations will be surveyed by a Texas licensed surveyor. Figure 5 shows a typical well completion. Figure 6 shows the typical injection wellhead.

3.2 Well Development

Following installation, each of the four injection wells and eight newly installed observation monitor wells will be developed. The monitor well development will consist of establishing a well connection with the aquifer by surging, pumping and removing fine-grained materials.

3.3 Baseline Sampling

Baseline sampling of the eight newly installed monitor wells and one existing well (MW-01) will provide additional saturation zone contaminant delineation, baseline conditions, and will be used to monitor groundwater conditions during and after the pilot test applications. In the ISCO test area, baseline groundwater samples will be analyzed using EPA Method 8260B for volatile organic compounds and EPA Method 610 for sodium. In the bioaugmentation pilot test area, baseline groundwater samples will be analyzed for volatile organics using EPA Method 8260B, sulfate, nitrite, methane, ethane, ethene, iron and manganese (analytical methods provided in Section 4.2.3). In addition to laboratory analysis, groundwater samples in both pilot test areas will be checked in the field for dissolved oxygen, chloride, oxidation-reduction potential (ORP), hydrogen potential (pH), temperature, and specific conductance. If soil cores show signs of gross contamination (staining, strong odors); they may be sent to a laboratory for VOC analysis.

4.0 PILOT TEST SET-UP AND TREATMENT

The following sections describe the procedures that Shaw will use for the pilot tests.

At this time, exact details of the equipment and instrumentation are not known. During pilot tests, many items are obtained at local suppliers or off the shelf from plumbing and instrument supply houses. Some items like the EOS dosimeter may be rented. Shaw may also use equipment we own from other sites where similar test or technology applications have been conducted. Shaw will submit to TCEQ a final, detailed description of the equipment and instruments being used, along with any test layout modifications and procedures prior to starting injection activities.

4.1 ISCO Pilot Study

The Jones Road ISCO source area treatment will consist of injecting a $NaMnO_4$ solution into the shallow zone at a depth between 22 and 37 feet bgs over an approximate 20 by 30 foot area located in the parking lot south of the former dry cleaner (Figure 1). Approximately 15,710 gallons of a two percent solution of $NaMnO_4$ will be injected into the two injection wells (JR-IN1 and JR-IN2). The total gallons of permanganate needed were determined by assuming a 23 percent pore volume in the 20 foot x 30 foot x 15 foot thick pilot test target treatment zone. $NaMnO_4$ will be injected at a flow rate of approximately two to four gallons per minute (gpm). The $NaMnO_4$ will be distributed equally (if field conditions allow) to both injection points.

4.1.1 Injection System Set-up

Following injection and monitor well installation and baseline groundwater sample collection, Shaw will mobilize to the site and prepare for the $NaMnO_4$ source area treatment. $NaMnO_4$ is a strong oxidant, and therefore, personal protective equipment must be worn at all times when working around the operating injection systems as detailed in the Site Specific Health and Safety Plan (to be modified, as needed).

An injection system consisting of a two point manifold, $NaMnO_4$ eductor system, a 50 kilowatt (kW) generator, twelve 55-gallon drums of $NaMnO_4$, a mixing tank, and PVC piping and associated pumps, valves, and fittings, will be mobilized to and assembled in the vicinity of the proposed injection wells JR-IN1 and JR-IN2. An alternative approach may be to use Carrus Chemicals Mobilix™ Portable Liquid Feeder Unit for the pilot test.

Once the injection system is assembled and tested with potable water, the injection system components will be enclosed in a taped off exclusion zone.

4.1.2 Permanganate Solution Development and Injection

The eductor system's vacuum wand or an inline liquid mixing meter/pump will be used to transfer the liquid $NaMnO_4$ into solution with clean potable water for delivery to the injection well manifold. The solution will be injected simultaneously into injection wells JR-IN1and JR-IN2 at a flow rate starting at 0.5 gpm and increased to 2 gpm or greater per well. During injection, flow rates and injection pressures will be monitored, recorded, and adjusted, as needed. Injection pressure will range from 10 to 15 pounds per square inch (psi). The following steps are necessary for the injection of permanganate into the Jones Road shallow zone:

1. Record the time, depth to water in the ISCO monitor wells, and the flow totalizer readings.

2. Begin $NaMnO_4$ injection starting with the two injection wells (JR-IN1 and JR-IN2) at approximately 0.5 gpm for each of the two injection points. Injection pressure at wellheads should not exceed 20 psi (>20 psi may force permanganate to surface).

3. Monitor and record the depth to water elevations in the pilot test monitor wells in order to avoid flow of permanganate to the surface.

4. Throughout each day's injection using dedicated bailers at each well, check water color (purple) for the presence of $NaMnO_4$. The injection rate can be reduced once purple groundwater is observed.

5. Continue injection of $NaMnO_4$ solution, while monitoring depth to water elevations.

6. Increase injection flow in 0.5 gpm increments while monitoring groundwater levels and wellhead pressure until the maximum flow of 2 to 4 gpm per well is achieved.

Based on eight hours of injection per day, using two wells at a flow rate of 2 gpm (4 gpm total), it will take approximately 65 hours to complete the injection.

At the end of the injection phase of the project, all surface equipment will be removed from the site, and public access will be restored. All waste generated during well installation work and baseline sampling will be disposed in accordance with established project procedures and TCEQ requirements.

4.1.3 Follow-up Monitoring

After injection, a follow-up monitoring program will be conducted. As will be performed during the test, one week after injection, water samples will be bailed from the pilot test wells to check color. Permanganate has a distinct purple color and it is general practice that visual confirmation

of purple is indicative of the presence of permanganate. The purple may be visible as a purple tint in water to total purple. Any sign of purple means permanganate is present. This will result in the destruction of chlorinated solvents in contact with the permanganate. After it is spent, permanganate may appear yellowish or brown in water or as a stain on soil. Based on the amount of $NaMnO_4$ being injected, Shaw anticipates a strong purple presence in the pilot test wells. At one and three month intervals after injection, groundwater samples will be collected for VOC analysis using EPA Method 8260B and EPA Method 610 for sodium. This data will be used to evaluate the immediate effects of the ISCO application. Six months after the ISCO application, another round of sampling of the ISCO observation wells will be conducted. Samples will be analyzed for VOCs and sodium. Groundwater samples will also be checked in the field for dissolved oxygen, chloride, ORP, temperature, and specific conductance. In addition, groundwater samples will also be collected from the injection wells (JR-IN1and JR-IN2). This sampling and analysis will be performed to provide data on the effectiveness of ISCO and to evaluate whether VOC rebound is occurring.

4.2 Bioaugmentation Pilot Study

The Jones Road bioaugmentation source area treatment will consist of injecting EOS solution into the shallow zone at a depth between 22 and 37 feet bgs over an approximate 15 foot wide by 35 foot long area located in the alley north of the building (Figure 1). Approximately 13,548 gallons of EOS will be injected into the two injection wells (JR-IN3 and JR-IN4). EOS is a food grade emulsified soybean oil and lactate substrate. The total gallons of EOS needed were determined by assuming a 23 percent pore volume in the 15 foot x 35 foot x 15 foot thick pilot test target treatment zone. EOS will be injected at a flow rate of approximately two to four gallons per minute (gpm). The EOS will be distributed equally (if field conditions allow) to both injection points.

4.2.1 Injection System

Following injection and monitor well installation and baseline groundwater sample collection, Shaw will mobilize to the site and prepare for the EOS source area treatment. EOS is a food grade material. However, personal protective equipment, mainly glove and eye protection, must be worn at all times when working around the operating injection systems as detailed in the Site Specific Health and Safety Plan (to be modified, as needed).

An injection system consisting of a two point manifold, EOS eductor system, a 50 kilowatt (kW) generator, 30 to 40 55-gallon drums of EOS, and PVC piping and associated pumps, valves, and fittings, will be mobilized to and assembled in the vicinity of the proposed injection wells JR-IN3 and JR-IN4. A potable water source or a storage tanker will be needed to mix with the EOS.

Once the injection system is assembled and tested with potable water, the injection system components will be enclosed in a taped off exclusion zone.

4.2.2 EOS Solution Development and Injection

A dosimeter (suction-flow operated pumping device rented from EOS provider) will be used to transfer the liquid EOS into solution with clean potable water for delivery to the injection well manifold. The solution will be injected simultaneously into injection wells JR-IN3and JR-IN4 at a flow rate starting at 0.5 gpm and increased to 2 gpm or greater per well. During injection, flow rates and injection pressures will be monitored, recorded, and adjusted, as needed. Injection pressure will range from 10 to 15 psi. The following steps are necessary for the injection of permanganate into the Jones Road shallow zone:

1. Record the time, depth to water in the bioaugmentation monitor wells, and the flow totalizer readings.

2. Begin EOS injection starting with the two injection wells (JR-IN3 and JR-IN4) at approximately 0.5 gpm for each of the two injection points. Injection pressure at wellheads should not exceed 20 psi (>20 psi may force EOS to the surface).

3. Monitor and record the depth to water elevations in the pilot test monitor wells to avoid the flow of EOS to the surface.

4. Continue injection of EOS solution, while monitoring depth to water elevations.

5. Increase injection flow in 0.5 gpm increments while monitoring groundwater levels and wellhead pressure until the maximum flow of 2 to 4 gpm per well is achieved.

Based on eight hours of injection per day, using two wells at a flow rate of 2 gpm (4 gpm total), it will take approximately 56 to 60 hours to complete the injection.

Before and after the injection of the EOS, subsurface conditions will be monitored for dissolved oxygen (DO) and oxidation/reduction potential (ORP). A field probe will be used to check DO and ORP once a week after EOS injection. Once the DO and ORP indicate reducing conditions, Shaw will inject approximately 75 Liters of SDC-9™ culture. The culture will be split between the two injection wells. A nitrogen purge will be applied to the wells during injection to displace oxygen in the well in order to avoid damage to the anaerobic culture. The amount of time before SDC-9™ culture can be injected will depend on how quickly EOS creates reducing conditions in the shallow saturated zone. Based on prior pilot test experience, approximately two to four weeks should be sufficient time for aquifer conditioning. If pH adjustments are needed,

additional time and materials may be required before SDC-9™ can be injected. Shaw will notify TCEQ if pH is not in range for optimal testing.

At the end of the permanganate and EOS injection phases of the project, all surface equipment will be removed from the site and public access will be restored. All waste generated during well installation work and baseline sampling will be disposed in accordance with established project procedures and TCEQ requirements.

4.2.3 Follow-up Monitoring

After EOS injection, a follow-up monitoring program will be conducted. As mentioned in Section 4.2.2, DO and ORP readings will be collected on a weekly basis until conditions are suitable for the SDC-9™ culture injection. At one and three month intervals after injection, groundwater samples will be collected for VOC analysis using EPA Method 8260B, iron and manganese using EPA Method 6010, methane, ethane, and ethene using EPA Method 381.0-RSK-175, and sulfate and nitrate using EPA Method 300-0. This data will be used to evaluate the immediate effects of the bioaugmentation application. Six months after the bioaugmentation application, another round of sampling of the bioaugmentation wells will be conducted. Samples will be analyzed for the same parameters as the one month and three month events. Based on the results of the three month sampling event, the timing for the final six month event may be increased. This may occur if degradation rates are slow and more time may be needed to evaluate trends.

Groundwater samples will also be checked in the field for dissolved oxygen, chloride, ORP, temperature, and specific conductance. In addition, groundwater samples will also be collected from the injection wells (JR-IN3 and JR-IN4). This sampling will be performed to evaluate whether VOC rebound is occurring.

5.0 PILOT TEST SUMMARY REPORT

Upon completion of the ISCO and bioaugmentation pilot test, Shaw will prepare a Pilot Test Summary Report. The Pilot Test Summary Report will document all the field activities, NaMnO4 and EOS injection rates and amounts, field observations, baseline, and follow-up well sampling results. Major items that will be discussed in the Pilot Test Summary Report include effectiveness of the injections and degradation/destruction of PCE and its daughter products. The Pilot Test Summary Report will present the following information:

- Introduction and brief site/pilot test background discussion.
- Description of the remedial technologies being pilot tested. Pilot test data will help evaluate technology, cost-effectiveness, and viability of a full scale field application.
- Pilot test objectives.
- Description of the pilot test from field sample collection through follow-up sampling analysis tests. Pilot test results will be described and evaluated. A comparison of expected results and actual results (deviations, if any) will be provided and explained.
- Field boring logs and well construction diagrams.
- Photographic documentation of various stages of the project, including soil boring cores and $NaMnO_4$ color in water samples over time.
- Field pilot test layout figures.
- Summary of monitoring results.
- Suitability of the technologies for full scale application will be discussed.
- Supporting relevant data management, health and safety, and residual waste management issues.
- Summary of results, including conclusions and discussion on future full-scale applications of the technology will be provided.
- Factors that may impact a possible full-scale technology application will be discussed.
- Planning and implementation of full-scale technology application will be discussed, along with recommendations for procurement, implementation specifications, and future costs.

The above bullet list also serves as a tentative outline of the Pilot Test Summary Report. Data tables, figures, and analytical data will also be presented within the text or as supporting appendices.

Pilot test data will be used to determine dosages, best application method, and evaluation parameters to determine the effectiveness of a full scale application. A separate Analytical Report will be prepared for the six month sampling event. This report will summarize the six month event, discuss any rebound effects, and discuss and confirm initial report recommendations that may need to be revised based on VOC rebound and changes in shallow saturated zone conditions.

6.0 SCHEDULE

Once Shaw receives TCEQ work order approval to conduct the pilot studies, Shaw anticipates being in the field approximately 60 days after notice to proceed. During that 60 day period, Shaw will prepare the TCEQ Class V injection well authorization documents. Although this is a Superfund Site, and TCEQ is performing the work, a Class V authorization letter from the Underground Injection Control Group is needed, based on Shaw's experience in Texas. Procurement and preparation activities will also be conducted during the first 60 days. Field work, including well installation, baseline sampling, and injections, should occur over a period of two months. Follow-up sampling of the ISCO and bioaugmentation work will occur one and three months after injection. Based on sampling at one and three months after pilot test injections (for bioaugmentation this means SDC-9™ injection – not just EOS), Shaw anticipates having the initial Pilot Test Summary Report to TCEQ five to six months after the pilot test injections.

Follow-up sampling will also occur six months after injections. As stated in Section 5.0, Shaw will provide a six month sampling follow-up monitoring report and final recommendation for full scale applications under separate cover from the initial report.

7.0 REFERENCES

Shaw , 2004 *Jones Road CPT Study*, April 29, 2004

Shaw, 2006, *Jones Road Remedial Investigation Report*, (being revised).

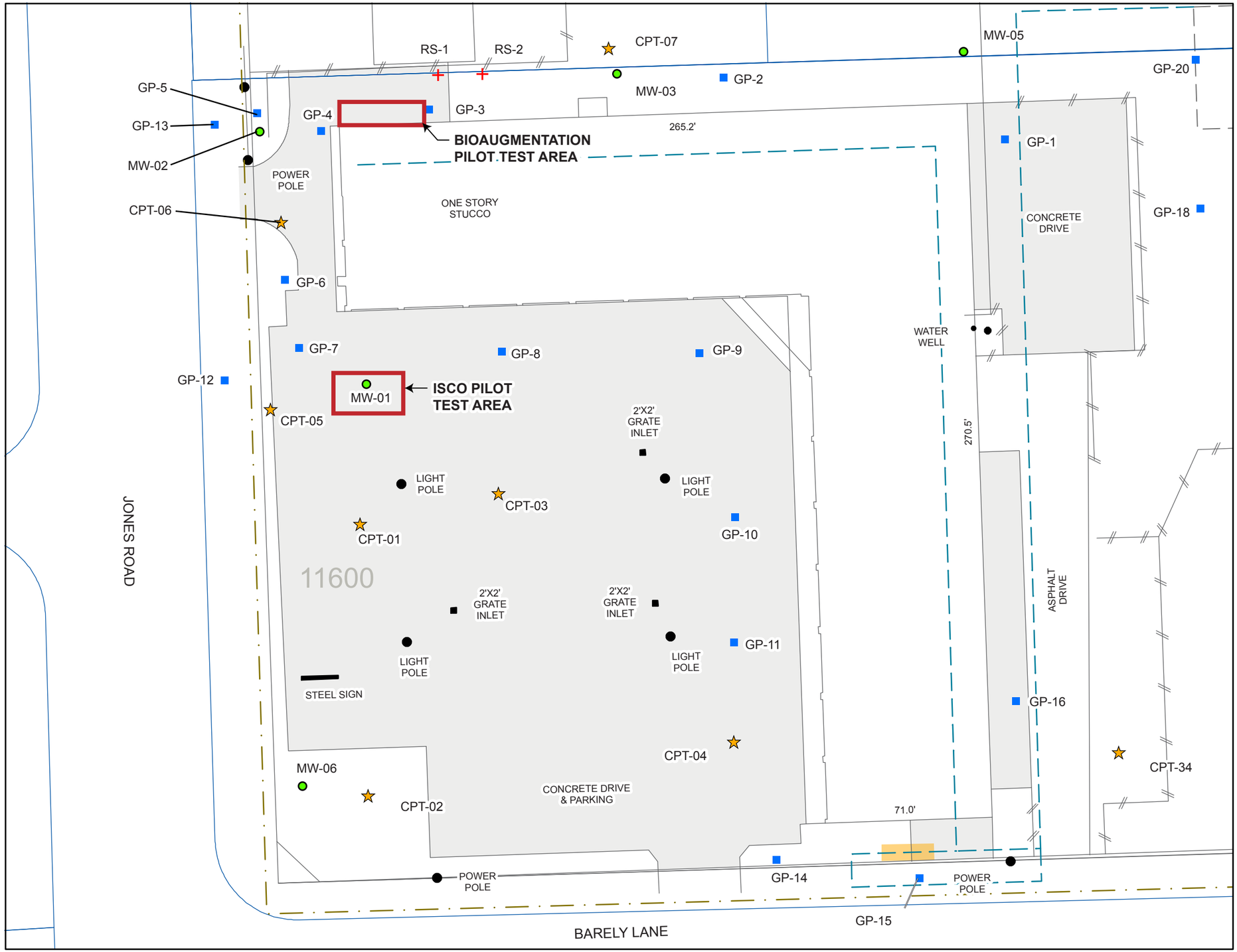
Shaw, 2006, *Jones Road Site Treatability Study Work Plan*, October 12, 2006.

Shaw, 2007, *July 2006 Geoprobe® Investigation*, January 24, 2007.

Shaw, 2007, *Final Treatability Study Report*, October 16, 2007.

Shaw, 2008 , *Source Area Conceptual Site Model*, May 8, 2008

FIGURES



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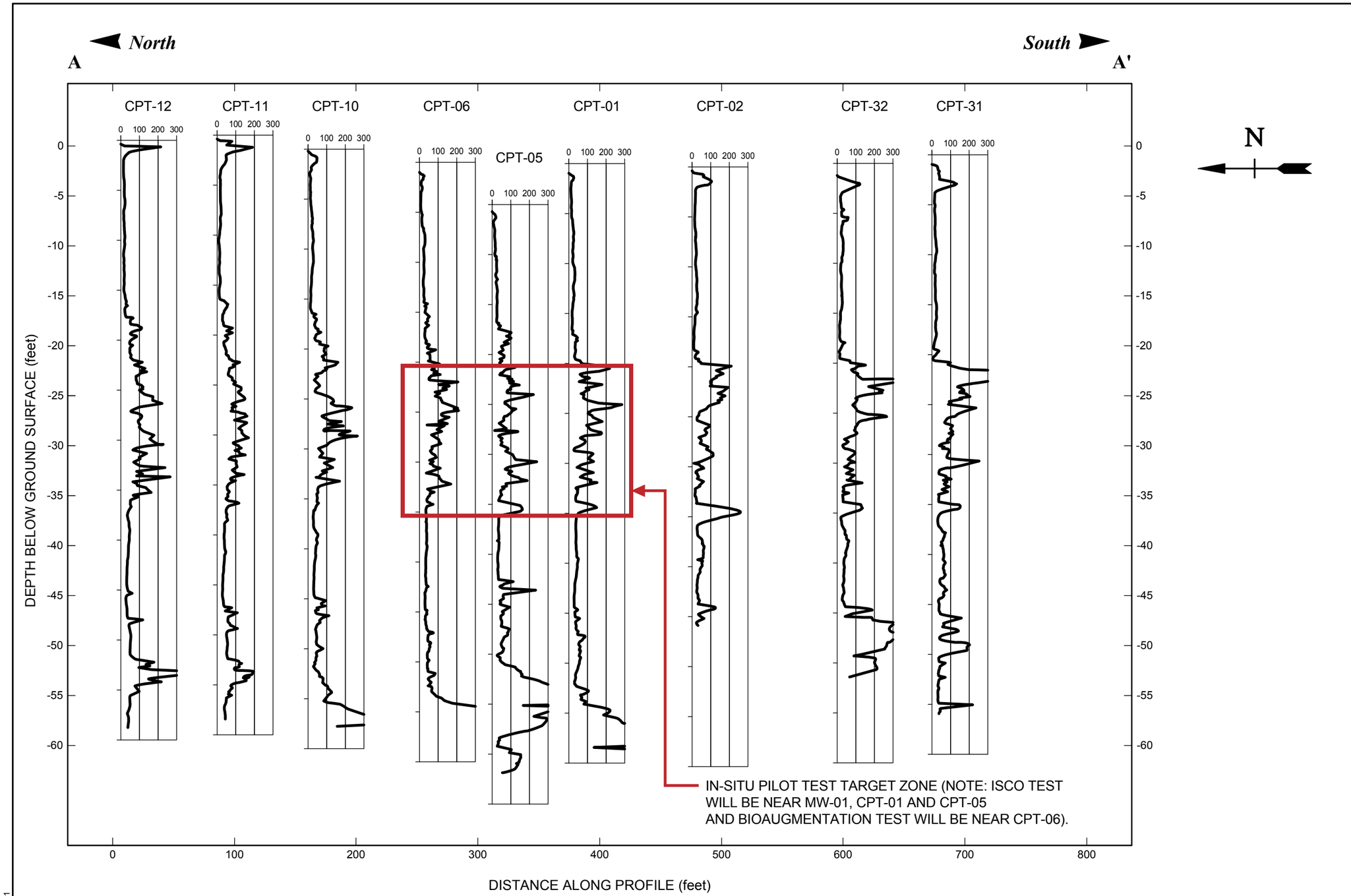
(from the Texas Commission on Environmental Quality)

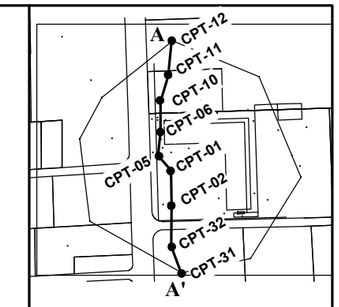
Explanation

- CPT location
- Well without filtration system
- Monitoring well (MW)
- Wells with filtration system installed (2006 data)
- Approximate Chicot Rotosonic well location 2006 (RS)
- Geoprobe location (GP)
- 11600 Property number
- Property boundary
- Ditch
- Fence
- Sewer line (approximate location)
- Septic field
- Concrete
- Septic tank and pump
- Pilot test area

0 75 FT
SCALE

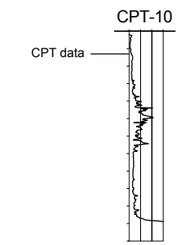
Figure 1
Proposed Location
In Situ Pilot Tests
Jones Road Superfund Site
Houston, Texas





Site Map Scale 1 inch equals 440 feet

Explanation



Tip Resistance (TSF)

Lithology Boundary

Approximate Lithology Boundary

CPT Cone Penetration Test

0 184.5

Horizontal Scale (feet)

Vertical Exaggeration: 6.5x

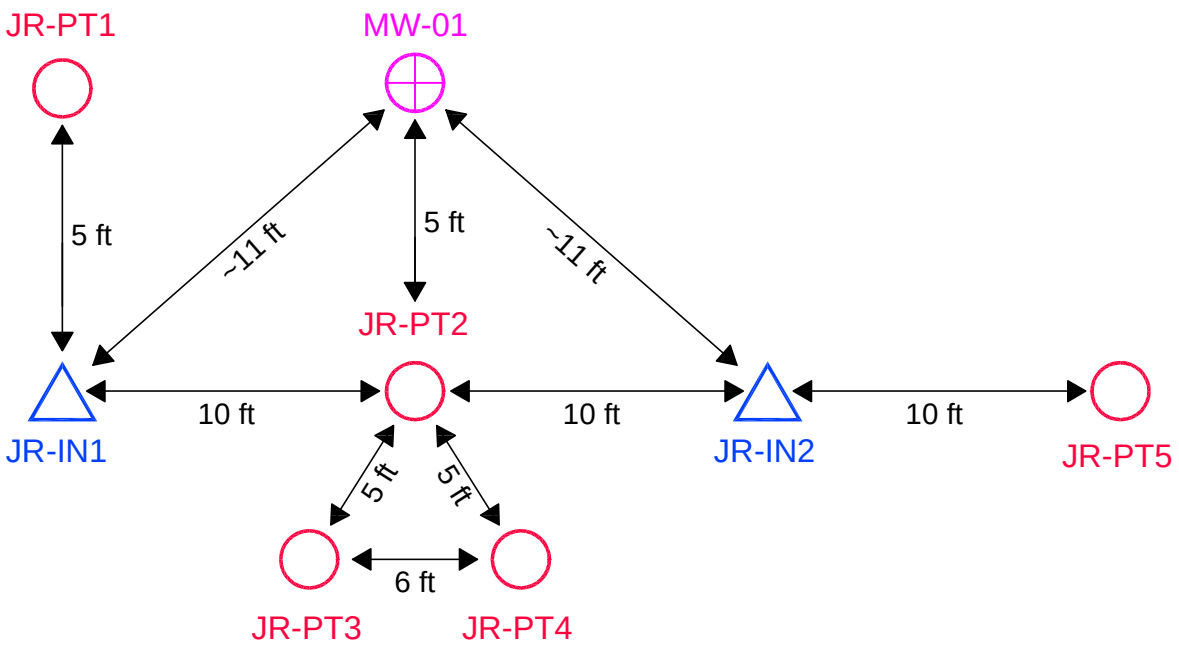
Shaw Environmental and Infrastructure
2790 Mosside Blvd.
Monroeville, PA 15146

Figure 2
Pilot Test Target Zone
Cross Section

Jones Road
Superfund Site
Houston TX

JOB NUMBER	PLATE NUMBER
128885	Plate A-1

131429.0100 B1



Explanation:

⊕	Existing Monitor Well
○	Proposed Monitor Well
△	Proposed Pilot Test Injection Well
JR	Jones Road
IN	Pilot Test Injection Well
PT	Pilot Test Monitor Well

Figure 3
Source Area
ISCO Pilot Test Layout Detail

prepared for:
TCEQ
Jones Road Superfund Site
Houston, Texas

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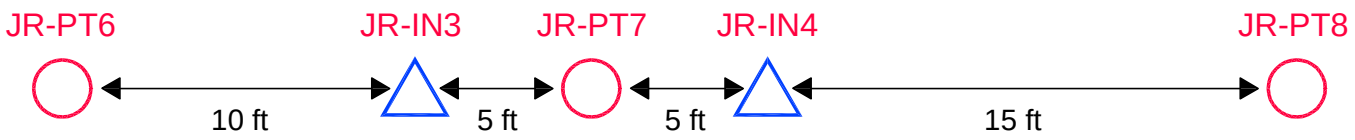

Explanation:

○	Proposed Monitor Well
△	Proposed Pilot Test Injection Well
JR	Jones Road
IN	Pilot Test Injection Well
PT	Pilot Test Monitor Well

Figure 4
Source Area
Bioaugmentation Pilot Test Layout Detail

prepared for:
TCEQ
Jones Road Superfund Site
Houston, Texas

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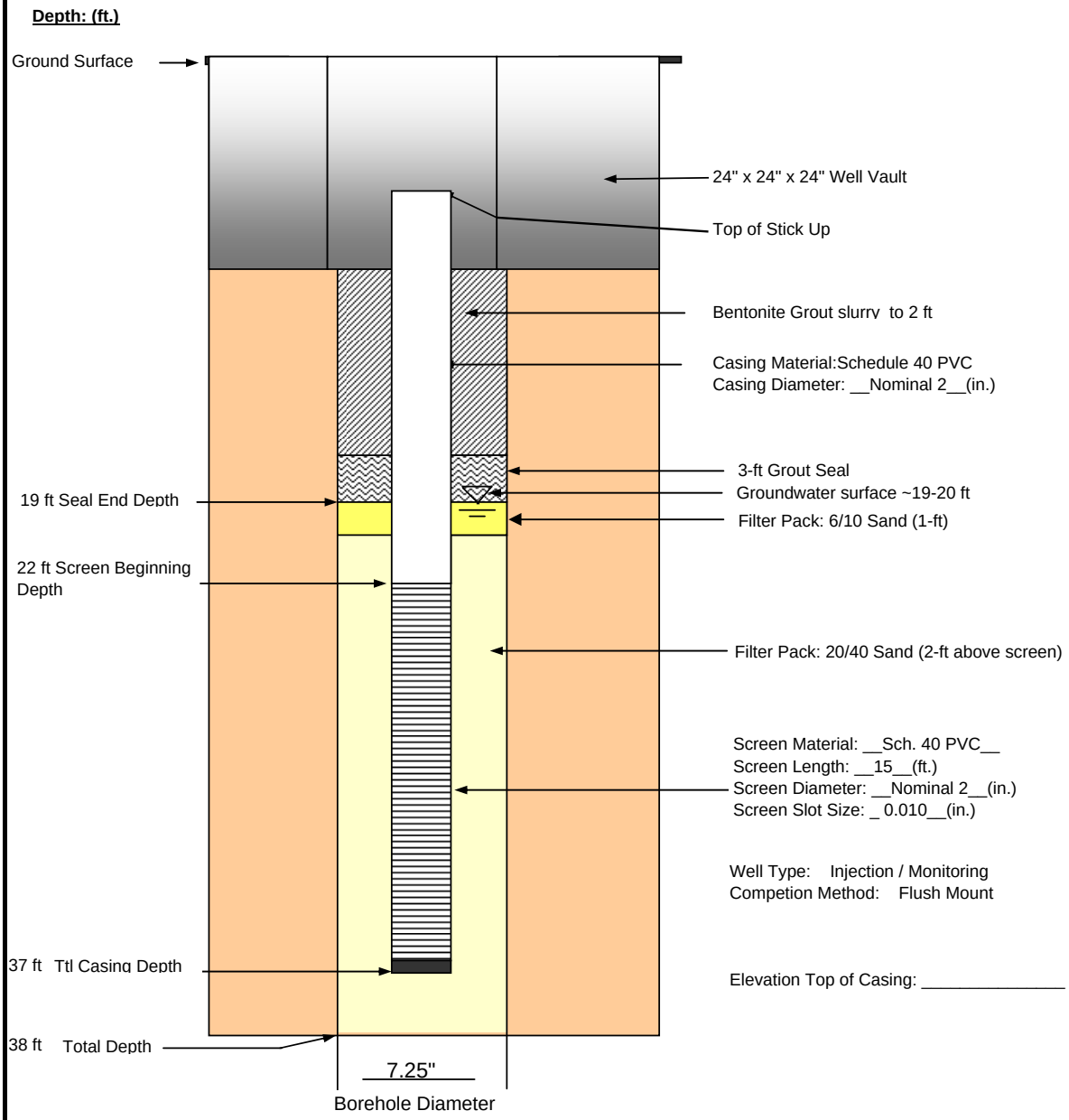
Figure 5
Injection Well Installation Detail

ISCO Pilot Test Well Design
Jones Road Superfund Site
Houston, Texas



Notes:
1) Drawing not to scale
2) See Figure 5 for well-head completion detail
3) Monitoring well construction the same with smaller vault and top of casing closer to ground surface

Injection Wellhead

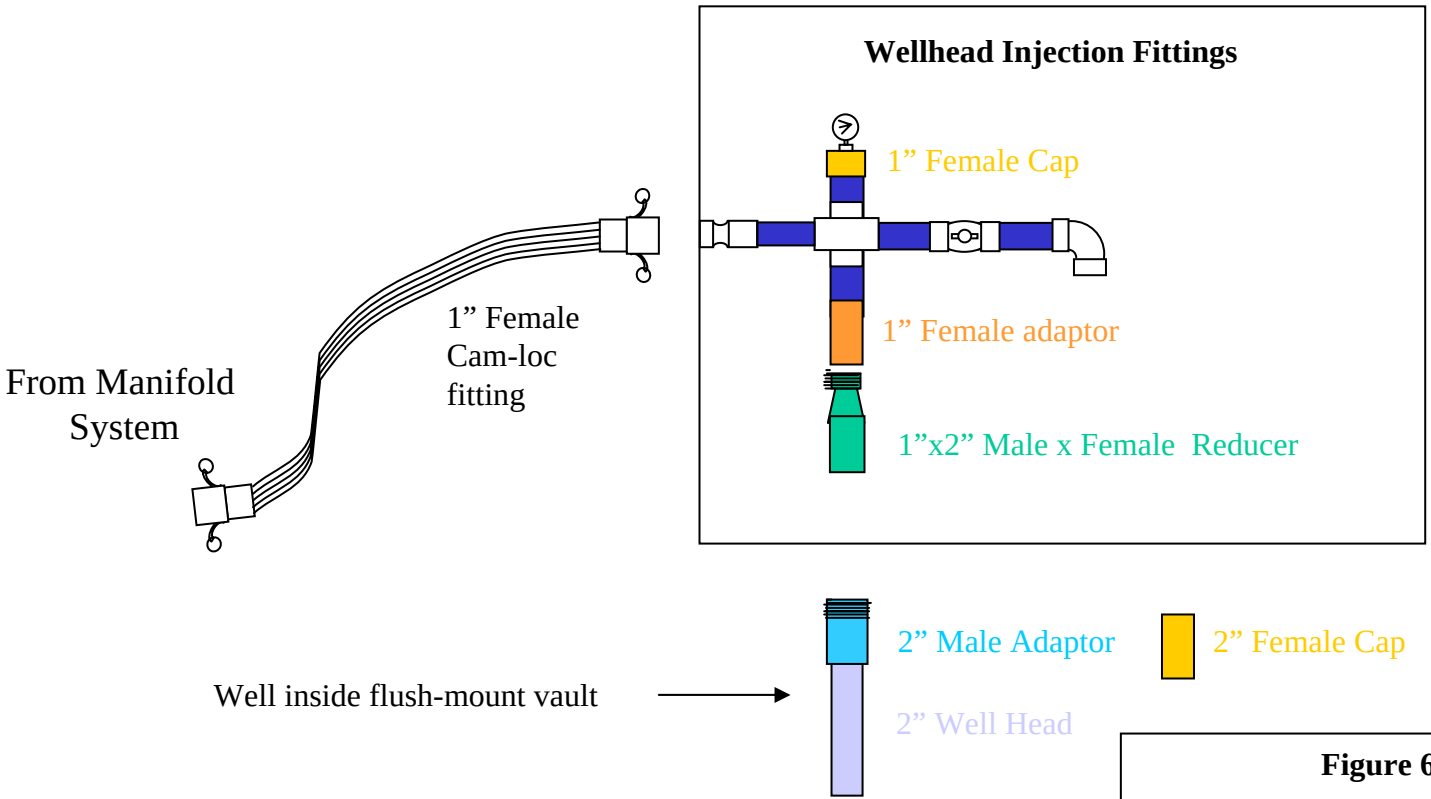


Figure 6

Typical Pilot Test

Injection Wellhead

Jones Road Superfund Site

Houston, Texas