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# TECHNICAL MEMORANDUM

May 2006

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From: Dan Griffiths and Bruce Henry, Parsons

Subject: Preliminary Results for the Anoka County Park Organic Substrate Addition Pilot Test, Fridley, Minnesota

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This technical memorandum presents a summary of data collected during extended monitoring activities conducted at the vegetable oil injection pilot test during the Spring and fall of 2005, as well as relevant historic pilot test data. This technical memorandum has been prepared for the Naval Facilities Engineering Command (NAVFAC), Southern Division, and CH2M Hill Constructors (CCI) by the Parsons Corporation (Parsons).

## INTRODUCTION

During the reporting phase of this project it was determined that this pilot test was a success in that each of the data quality objectives (DQOs) were met and contaminant mass reduction was enhanced in the vicinity of the vegetable oil injection area. However, it was also determined that vegetable-oil-derived organic carbon was not effectively distributed within the pilot test area and that complete reductive dechlorination was only induced in a relatively small area (Parsons, 2004).

The activities associated with the extended monitoring program, presented in the work plan addendum technical memorandum dated January 6th 2005 and presented in this technical memorandum, were designed to improve the characterization of the pilot test area and to address the data gaps identified in the final work plan addendum (Parsons, 2005).

## EXTENDED MONITORING ACTIVITIES

Extended process monitoring activities at the vegetable oil pilot test site were conducted in accordance with the final work plan addendum (January 6th 2005), the Final Work Plan (Parsons, 2001a), final Quality Assurance Project Plan (QAPP), (Parsons, 2001b), and guidance provided by the United States Environmental Protection Agency (USEPA (1998)).

The extended process monitoring activities were conducted in three phases. The first phase consisted of a membrane interface probe (MIP) survey within the pilot test area to investigate the stratigraphy and vertical distribution of volatile organic compound (VOC) mass from the ground surface to a total depth of approximately 60 to 70 feet below ground surface (bgs). The second phase used the data generated during the MIP survey to place eight new monitoring wells and ten soil borings within approximately 100 feet of the injection area. The third phase began after the new monitoring well clusters are

installed and consisted of a groundwater sampling event at the newly installed wells, existing pilot test wells, and selected existing monitoring wells located outside of the pilot test area. A second groundwater sampling event was conducted approximately 7 months after the first event, in November 2005. The data collected during the field activities associated with the extending monitoring of the vegetable oil pilot test area are presented in the following subsections.

## MEMBRANE INTERFACE PROBE SURVEY

An MIP survey was conducted within the pilot test area in order to improve the characterization of the stratigraphy and distribution of VOCs in the subsurface. During the MIP survey it was determined that an area of relatively high VOC concentrations is present in the proximity of the pilot test area, and that this area of high chlorinated VOC concentrations extends further than expected to the south and west. Therefore, all of the contingency MIP borings and one additional MIP boring were installed for a total of 38 MIP points (Figure 1). In addition, it was discovered that the direct push equipment employed during the MIP survey was capable of drilling deeper than expected. Thus, select MIP borings were advanced to a maximum depth of 70 feet below ground surface (bgs) instead of the proposed maximum depth of 50-60 feet. This data indicates that the direct push drilling technology is a viable drilling method at Anoka County Park to depths of at least 70 feet.

During the course of the MIP survey, discrete groundwater samples were collected from the background MIP location and sixteen MIP locations drilled within or in close proximity to the injection area. A total of 45 discrete groundwater samples were collected from select vertical intervals corresponding to high and low chlorinated VOC concentrations and areas where high flame ionization detector (FID) readings were observed. The discrete groundwater samples were collected at each location using direct push discrete sampling equipment. Each sample was collected directly from the aquifer formation through the sampling point without purging a significant quantity of groundwater. These samples were analyzed for VOCs via USEPA Method 8260B, total organic carbon (TOC) via USEPA method SW9060, and methane, ethane, and ethene via Microseeps Internal standard operating procedure (SOP) AM-20GAX in order to qualitatively validate the MIP results. The data set generated from the analysis of these samples was used in conjunction with data generated during the MIP program and the soil sampling program to determine the extent of the area directly impacted by vegetable oil and to investigate the distribution of CAH reductive dechlorination products within the injection area. The completed MIP borings are summarized in Table 1. The MIP profiles generated during this program are attached to this technical memorandum as Appendix A.

## SOIL BORING INSTALLATIONS

A total of ten soil borings were installed as part of the extended monitoring activities related to the vegetable oil pilot test. Seven soil borings (PES-SB-1 through PES-SB-7) were advanced in the immediate vicinity of the three injection wells. These soil borings

were used to collect stratigraphic, geochemical, mineralogical, and microbial data in the vicinity of each injection well and to determine the extent of the injection area. Three additional soil borings (PES-SB-8 through PES-SB-10) were installed immediately downgradient of the injection area in order to investigate anomalies in the geophysical data set generated by the United States Geological Survey (USGS). The completed soil boring installation activities are summarized in Table 2 and are presented in detail in the following subsections. Boring logs prepared during drilling are presented in Appendix A.

## MONITORING WELL INSTALLATIONS

A total of eight new monitoring wells were installed using hollow stem auger (HSA) drilling techniques during the extended monitoring program. One of the proposed monitoring wells (PES-MW-13A) is located approximately 55 feet upgradient of MS-46S and approximately 65 feet upgradient of the injection area (Figure 2). The data collected from this location is representative of soil and groundwater that have not been impacted by the injected vegetable oil and iron tracers. The remaining seven monitoring wells were installed south and downgradient from the injection area as shown on Figure 2. Proposed monitoring well clusters PES-MW-10, PES-MW-12, PES-MW-14 consist of two wells installed at two vertical intervals within the shallow drift aquifer (Figure 2), while monitoring wells PES-MW-11A and PES-MW-13A consist of single wells installed slightly below the bottom of the silt/clay unit (Figure 2). The new monitoring wells, with the exception of PES-MW-13A, were installed to investigate potential vegetable oil impacts in a more southerly direction from the injection area and to investigate the potential for vertical groundwater flow. The installation details associated with the new monitoring wells are summarized in Table 2.

Each monitoring well installed during the extended monitoring program was constructed of 2-inch inside diameter (ID) schedule 40 polyvinyl chloride (PVC) casing and 0.020-inch slot screen. Each monitoring well was installed with approximately 10 feet of factory slotted screen which was flush threaded to the appropriate length of solid casing. A filter pack consisting of clean size 10-20 silica sand was installed from the bottom of each borehole to approximately 2 feet above the top of the screen interval. A 2-foot thick pure bentonite seal was installed above the sand pack, and a concrete-bentonite sanitary seal was installed from the top of the bentonite seal to ground surface. The installation details associated with the new monitoring wells are summarized in Table 2.

During drilling and well installation activities, soil samples were collected from the screen interval of each proposed monitoring well and shipped to an offsite laboratory for analysis. The boring logs compiled during the extended monitoring program are included as Appendix B. Select boring logs have been complied and presented in three dimensions on a fence diagram presented as Figure 3. Groundwater elevation data collected during the November 2005 sampling event is presented on Figure 4.

## MEMBRANE INTERFACE PROBE SURVEY RESULTS

The MIP rig employed at Anoka County Park was provided and operated through a subcontract by KB Labs Incorporated. KB Labs' MIP rig was equipped with approximately 70 feet of direct push rod with a heating block on the bottom. As the MIP rod was advanced, a heating block at the tip of the probe heated the soil and groundwater in the immediate vicinity of the probe tip. As the heating block heated the soil and groundwater, the resultant "soil gas" was drawn through a membrane and into an inert gas loop where it was drawn through a series of detectors at ground surface. The detectors included an electron capture detector (ECD) to detect total chlorinated VOCs, a photoionization detector (PID) to detect total VOCs, and an FID to detect methane and less volatile organic compounds that are not detected by the PID. In addition, a dipole array was installed in the MIP probe which collected electrical conductivity data from the soil matrix. Using this suite of detectors, a complete vertical profile of relative soil grain size, total chlorinated and non-chlorinated VOC concentrations, and methane concentrations was generated for each MIP location. The MIP locations are depicted on Figure 2.

During the course of the MIP survey it was discovered that the soil conductivity logs that were being produced by the dipole array did not match up to soil boring logs collected during the installation of the pilot test system in 2001. After the new soil borings and monitoring wells were installed the soil conductivity profiles were compared to the newly generated boring logs and the historic logs. The newly generated boring logs matched the historic logs relatively well. However, the soil conductivity logs did not match the new or historic boring logs. Therefore, we conclude that the soil conductivity logs collected during the MIP survey do not represent stratigraphic conditions at the site and will not be used for any purpose.

The data collected during the MIP survey indicates that the concentration of total VOCs present beneath the pilot test area is insufficient to cause a deflection on the PID instrument associated with the MIP system. There were no PID detections in any of the profiles collected with the exceptions of MIP-31 and MIP-36. Therefore, the MIP discussion with regard to VOC concentrations will be based on data collected with the ECD. The MIP profiles are attached to this technical memorandum as Appendix A.

### ELECTRON CAPTURE DETECTOR DATA

The ECD data collected during the MIP survey is summarized on Table 3, is depicted on Figure 5, and is presented in detail in Appendix A. The complete data set collected by KB labs was also provided under a separate cover (KB Labs, 2005). Review of the horizontal distribution of ECD response indicates that elevated concentrations of chlorinated VOCs are present throughout the pilot test area. Elevated concentrations of chlorinated ethenes were detected at all MIP locations, indicating that the VOC "hot spot" was not bounded in any direction during the MIP survey.

Review of the vertical distribution of ECD response indicates that at most MIP locations installed upgradient of PES-MW-10A/B, elevated concentrations of chlorinated solvents were present below approximately 28 to 30 feet bgs and above 40 to 42 feet bgs. The exceptions to this observation include MIP points MIP-3, MIP-6, MIP-10, MIP-11, and MIP-14. Downgradient of PES-MW-10A/B the ECD data collected at the majority of the MIP points indicate that elevated concentrations of chlorinated VOCs are present below a depth of approximately 35 feet bgs and do not extend below approximately 50 feet bgs. In some cases elevated concentrations of chlorinated VOCs extended below the bottom of the total advancement depth of the point. Therefore, the vertical distribution of elevated chlorinated VOC concentrations is not completely defined at these locations.

Immediately after the completion of the MIP survey, discrete groundwater samples were collected from direct push borings installed immediately adjacent to a selection of MIP bore holes. The discrete groundwater samples were collected in an effort to quantify the ECD and FID response data collected during the MIP survey. The ECD response and associated discrete sampling data are summarized in Table 4. Generally the ECD response for a given depth compares relatively well to the associated total chlorinated VOC concentration as reported by the discrete sampling results within each borehole, with the exception of results from MIP-5, MIP-8, and MIP-19. However, the correlation of ECD response to discrete sampling data does not hold up between boreholes as indicated by the variability in the correlation factor data presented on Table 4. These observations indicate that the ECD response data appears to be a useful tool to qualitatively determine the vertical distribution of chlorinated solvents within a particular borehole. However, the ECD data does not appear to be a very useful tool to determine the horizontal distribution of chlorinated VOC concentrations except in a very qualitative "presence-absence" way. Therefore, the distribution of ECD response data with respect to the size of the detections will not be discussed, as this data does not appear to correlate to changes in chlorinated VOC concentrations.

## FLAME IONIZATION DETECTOR DATA

The FID response data generated during the MIP survey (Table 4 and Appendix B) is representative of concentrations of methane and other less volatile organic compounds that are not detected by the PID or the ECD. Thus, FID response can be considered to be indicative of the presence of organic material in the subsurface because the presence of methane can be inferred to result from the biodegradation of organic matter. Organic material in the subsurface at the pilot site consists of a combination of naturally occurring organic material in the soil matrix as well as vegetable oil injected as part of the pilot test. Therefore, the FID data collected during the MIP survey is representative of both naturally occurring as well as vegetable oil derived organic carbon. However, vegetable oil was injected at relatively high concentration at this site so it was expected that the response to vegetable oil derived organic carbon would be much larger than the response to naturally derived organic carbon signature.

Relatively low FID detections in the range of approximately 1E+05 to 6E+05 microvolts (uV) were observed sporadically throughout the pilot test area at locations

that are unlikely to be impacted by vegetable oil derived organic carbon (i.e., cross gradient points MIP-18 and MIP-36, as well as downgradient points MIP-27, MIP-32, and MIP-37). These observations indicate that the FID detector was detecting organic carbon that is likely to be naturally occurring, with a response of approximately 6E+05 uV. Within and downgradient from the injection area FID detections were much higher, ranging from approximately 1E+06 uV to 1E+07 uV, indicating that the vegetable oil derived organic carbon is responsible for an increase in FID response of approximately one to two orders of magnitude.

Relatively high FID detections were observed in a large area which includes the injection area and extends southwest as far down gradient as MIP-26 (Figure 6). This relatively large area corresponds roughly to the area of elevated TOC discussed in later sections (Figure 9). The coincidence of the area of elevated FID readings and the area of elevated TOC concentrations indicates that the FID was likely detecting dissolved phase organic carbon, dissolved methane, as well as non-aqueous phase vegetable oil. Thus, the area of elevated FID detections represents an area that is impacted by vegetable oil derived organic carbon, both directly and indirectly.

The vertical distribution of FID detections at all locations is highly heterogeneous. Within the un-impacted locations this heterogeneity indicates that naturally occurring organic carbon is present only within particular vertical intervals. For example, at MIP-36 (Appendix A) elevated FID readings are limited to two very narrow vertical intervals located at 28 feet and 30 feet bgs. Review of the boring log from PES-BG-2, located approximately 8 feet away, indicates that these vertical intervals consist of silty sand which is slightly finer than the fine to medium sand present above and below this vertical interval. This fine grained unit likely contains higher concentrations of naturally occurring organic carbon than the surrounding sands, which would result in a higher FID reading. Large ECD peaks are also present in the MIP-36 profile at the same depth intervals indicating that the fine grained unit contains elevated concentrations chlorinated VOCs as well as TOC. The heterogeneous distribution of FID peaks in borings within the injection area indicates that the injected vegetable oil also has a heterogeneous vertical distribution.

## SOIL SAMPLING RESULTS

Continuous soil samples were collected from the soil borings and monitoring well borings from the ground surface to the bottom of each borehole. Boring logs were prepared by an experienced field geologist at each boring location. The boring logs compiled during the extended monitoring program are included as Appendix B.

A total of 36 soil samples were collected during drilling activities and analyzed for VOCs via USEPA method 8260B. Soil samples were collected from soil borings PES-SB-1, PES-SB-2, and PES-SB-3 to characterize the soil conditions in the immediate vicinity of the injection wells. At each soil boring location, subsurface soils impacted by vegetable oil were typically stained dark brown or black and smelled of degrading vegetable oil. At soil boring PES-SB-1 and PES-SB-3, the soil was heavily impacted by

vegetable oil from a depth of approximately 33 feet bgs to 39 feet bgs and from 39 feet to 48 feet bgs, respectively. These impact intervals correspond to the closest injection well screen intervals (PES-INJ-01 and PES-INJ-03, respectively). At soil boring PES-SB-2, which was installed immediately adjacent to PES-INJ-02, vegetable oil impacts extended from just below the top of the PES-INJ-02 injection interval at 40 feet to 6 feet below the bottom of the PES-INJ-02 injection interval at 50 feet. At all locations vegetable oil impacts were more pronounced in coarser, more transmissive units, indicating that the injection fluids migrated predominantly through the more permeable sand units.

Soil borings PES-SB-4 and PES-SB-5, were drilled upgradient of PES-INJ-2 to define the upgradient edge of the injection area, while PES-SB-6, and PES-SB-7 were drilled down gradient of PES-INJ-2 to define the down gradient edge of the injection area. Evidence of vegetable oil impact was not observed in PES-SB-4 and PES-SB-5, indicating that the injected vegetable oil did not travel more than approximately 8 to 10 feet upgradient during or after injection. This conclusion is contradicted somewhat by the high FID detections at MIP-02 (installed approximately 25 feet upgradient of PES-SB-5). On the downgradient side of the injection area vegetable oil impacts were observed at PES-SB-6, PES-SB-7, PES-SB-8, and PES-SB-9 indicating that vegetable oil or high concentrations of vegetable oil derived organic carbon migrated as far down gradient as approximately 23 feet. Impacts were observed in these wells primarily as soil intervals with mild to moderate degrading vegetable oil odor. Impacts were observed at these downgradient locations as deep as approximately 55 feet bgs (PES-SB-9). Two intervals containing "weak to mild odor" were observed during drilling at PES-MW-10B at 50 feet bgs and 53 feet bgs. These observations may indicate that these depth intervals were impacted by vegetable oil or high concentrations of vegetable oil derived organic carbon. These observations indicate that during and potentially shortly after injection the vegetable oil or high concentrations of vegetable oil derived organic carbon continued to spread laterally along the coarser more transmissive units as far down gradient as approximately 23 to 25 feet. This data does not indicate that the injected vegetable oil spread vertically (upward or downward) to a significant extent.

The boring logs compiled during the drilling activities were combined with the historic boring logs and used to develop a fence diagram which depicts the stratigraphic data collected during drilling in three dimensions (Figure 3). Review of the boring log data and the fence diagram indicates that the stratigraphy beneath the pilot test site is relatively consistent on a large scale. The soil beneath the pilot test area consists predominantly of fine to medium sand and silty sand which extends from approximately 5 feet bgs to below the maximum drilling depth of 70 feet bgs. At approximately 30 feet bgs there is a fine grained of unit of variable thickness which consists predominantly of silt and clay. This fine grained unit ranges in thickness from less than one foot to a maximum of approximately 6 feet and is continuous throughout the pilot test area. There are also a number of smaller, less continuous, fine grained units present beneath the pilot test area. In particular, there appears to be a relatively large, thin silt/clay unit present at a depth of approximately 60 feet beneath and downgradient from the injection area. It is

likely that these fine grained units impact and therefore to some extent control groundwater flow characteristics locally within the pilot test area.

## TOTAL ORGANIC CARBON ANALYSES IN SOIL

During drilling operations soil samples were collected from soil borings drilled within the injection area and from outside the injection area in order to determine the spatial extent of soils impacted by vegetable oil and to compare the TOC content of impacted soils and un-impacted soils. The soil TOC results are summarized in Table 5. Soil TOC concentrations measured at the background boring PES-MW-13A ranged from approximately 330 mg/kg to approximately 830 mg/kg, indicating that there is naturally occurring organic carbon present within the soil matrix. This concentration range compares well with soil TOC data collected prior to the injection of the vegetable oil in 2001, indicating that PES-MW-13A has not been impacted by vegetable oil derived organic carbon.

TOC concentrations in soil collected within the injection area ranged from approximately 300 mg/kg to a maximum of 6,200 mg/kg. The high concentrations of TOC detected in the injection area were detected in vertical intervals that were visibly impacted by vegetable oil, indicating that significant vegetable oil derived organic carbon remains within the injection area to drive biological processes, including reductive dechlorination. TOC concentrations within the injection area vary widely between boreholes and even vertically within individual boreholes. This vertical and horizontal variation indicates that vegetable oil derived TOC is distributed heterogeneously within the injection area.

At locations PES-SB-7 and PES-MW-12B soil samples were collected from silty clay or clay units and analyzed for TOC (as well as a number of other parameters discussed in later sections). The silty clay unit sampled at PES-SB-7 was located at a depth of approximately 32 to 34 feet bgs, while the cohesive clay unit sampled at PES-MW-12B was located at 62 to 63 feet bgs. The clay units at both locations and depths contained high concentrations of TOC (2,900 mg/kg at PES-SB-7 and 5,900 mg/kg at PES-MW-12B). There is no evidence of vegetable oil impact between 32 and 34 feet bgs at PES-MW-7 and PES-MW-12B is located several hundred feet downgradient of the injection area and is thus unlikely to be impacted by vegetable oil. Thus, the high concentration of TOC present in the silt units at PES-SB-7 and PES-MW-12B likely to be naturally occurring. Groundwater samples were collected in close proximity to these sampling intervals (MIP-14 at 36 ft bgs for PES-SB-7 and MW-12B) and analyzed for TOC as well as a number of other parameters. TOC concentrations in groundwater at these locations were relatively low, below 8 mg/L in both cases, indicating that the high concentration of naturally occurring TOC present in the soil matrix is insoluble and thus not bioavailable to drive biological processes (including reductive dechlorination). This data indicates that these fine grained units are capable of absorbing significant amounts of contaminant mass and may serve as secondary sources of contaminant mass over time.

## PLFA AND MICROBIAL POPULATION CHARACTERIZATION ANALYSES IN SOIL

Biomass is represented by the total amount of phospholipid fatty acids (PLFA) present and provides a quantitative measure of the viable microbial biomass present. Elevated concentrations of biomass are an indicator of enhanced microbial activity and are an indirect indicator of changes in food supply (organic carbon) or changes in environmental conditions. The microbial population can also be identified through targeted gene detection analysis in order to determine if the microbial population present in a particular location is capable of dechlorinating chlorinated solvent mass and to what extent. A series of soil samples were collected from the injection area, upgradient of the injection area, and downgradient from the injection area in order to compare the microbial populations (both total population and which microbes are present) in each area. These samples were analyzed for total microbial biomass (PLFA) as well as targeted gene detection to determine the presence or absence of 4 phylogenic groups (Eubacteria, methanogens, sulfate and iron reducing bacteria, and methanotrophs); four bacterial genera that are known to be capable of dechlorinating chlorinated solvents (*Dehalococcoides* (DHC), *Desulfuromonas* (DSM), *Dehalobacter* (DHB), and *Desulfitobacterium* (DSB) and one additional genera that is known to dechlorinate tetrachloroethene (PCE) and trichloroethene (TCE) to *cis*-1,2-dichloroethene (DCE) (*Geobacter* (GEO)). In addition, two functional genes which identify particular species of DHC were identified and quantified. The BAV1 vinyl chloride reductase (BVC) functional gene is indicative of the species BAV1 which was isolated and identified by Frank Löffler's group at the Georgia Institute of Technology (He et. al., 2003) as a species of DHC that is capable of completely dechlorinating TCE to ethene. The second functional gene, also isolated and identified by Frank Löffler's group (He et. al., 2003), is TCE R-dase (TCER) which has been shown to be indicative of a DHC species that is capable of dechlorinating TCE completely. A third strain of methanotrophic bacteria was also identified and quantified through the analysis for soluble methane monooxygenase (sMMO). sMMO is an enzyme that is produced by methanotrophic bacteria when TCE is being broken down to non-toxic organic hypoxides through a destructive process called cometabolic oxidation (He et. al., 2003).

A total of 14 samples were collected and analyzed for targeted gene detection and PLFA, while an additional 9 samples were collected and analyzed for PLFA only. The PLFA and targeted gene detection analysis results are presented in Table 6. 11 of the 23 samples collected were impacted by vegetable oil or high concentrations of vegetable oil derived organic carbon as evidenced by visual and olfactory observations reported during drilling operations (Appendix B). The total biomass measured in the impacted samples was approximately two orders of magnitude higher than the total biomass measured in the un-impacted samples. The observed increase in microbial biomass is a result of an increase in microbial food supply supplied by the injected vegetable oil. The increased biomass is paralleled by increases in all of the identified phylogenic groups. Each phylogenic group increased by approximately one to four orders of magnitude with the largest increases observed in the sulfate/iron reducers and methanotrophs. This data

indicates that the injected substrate was successful in promoting anaerobic microbial population development within and downgradient from the injection area.

DHC and DHB were positively identified in nearly all samples analyzed including both vegetable oil impacted and non-impacted samples. The population of DHC in the impacted samples was approximately one order of magnitude higher than the population measured in the non-impacted samples while DHB populations in the impacted samples were approximately two to three orders of magnitude higher than background. DSM was positively identified in only one sample (PES-SB-6). DSB was positively identified in approximately half of the samples analyzed and does not appear to be affected by the presence or absence of vegetable oil. GEO was also detected at concentrations near the method detection limit in the impacted samples but not in the un-impacted samples. This data indicates that several microbial strains that are known to be capable of dechlorinating VOC mass are present naturally in site soils and that the injected vegetable oil has been effective at increasing the populations of DHC, DHB, and to a lesser extent GEO. Thus, the microbial population within the pilot test area is capable of completely dechlorinating chlorinated VOC mass.

During the functional gene portion of the targeted gene detection analysis BVC was detected at low concentrations in nearly all of the impacted samples and in approximately one half of the un-impacted samples. TCER was also detected at low concentrations in three of the impacted samples and in only one of the un-impacted samples. sMMO was also detected in all but one of the impacted samples and in four of seven of the un-impacted samples. Moderate to high concentrations of sMMO (with respect to the un-impacted samples) were detected at locations PES-SB-1, PES-SB-7, and PES-MW-10B, indicating that it is possible that chlorinated solvent mass is being destroyed by methanotrophic bacteria through cometabolic oxidation at these locations.

During the April 2005 sampling event groundwater samples were collected from a selection of monitoring wells and submitted to Microbial Insights Inc. for targeted gene detection analysis. The results of the targeted gene detection in groundwater analyses are summarized in Table 6 for easy comparison to the soil results. Comparison of targeted gene detection results in water and soil from similar locations (e.g., PES-SB-2 to PES-INJ-2, PES-SB-7 to PES-MW-1, PES-MW-10B soil to PES-MW-10A water, PES-SB-4 to MS-46S, and PES-MW-10B soil to PES-MW-10B water) provides an insight into the relative representativeness of groundwater samples. Soil samples are considered to be most representative of the true microbial population present because the bulk of the microbial population grows on the soil matrix. Groundwater samples are generally considered to provide a good approximation of the microbial population and are generally preferred over soil samples due to the ease and low cost associated with groundwater sampling in comparison to soil sampling. However, review of Table 6 indicates that on this site groundwater samples are biased low and do not represent the microbial population present in the subsurface.

## VOLATILE ORGANIC COMPOUND ANALYSES IN SOIL

A total of 36 soil samples were collected during drilling activities and analyzed for VOCs via US EPA method 8260B (Table 5). TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and acetone were the only VOCs that were detected at concentrations above the method detection limit. VOC concentrations varied widely across the site, both vertically and horizontally. TCE concentrations ranged from non detect to 7,700 µg/kg (PES-SB-2) while *cis*-1,2-DCE and trans-1,2-DCE concentrations ranged from non detect to 2,100 µg/kg and 91 µg/kg, respectively. Samples that were impacted by vegetable oil, as indicated by visual and olfactory inspection, contained substantial concentrations of *cis*-1,2-DCE, and in some cases *trans*-1,2-DCE, indicating that at least partial dechlorination is occurring.

VOC samples were collected from several intervals at locations PES-SB-1, PES-SB-4, PES-SB-7, PES-MW-10B, PES-MW-11A, PES-MW-13A, and PES-MW-14B. At each location soil samples were collected from fine grained units, typically silty sands or clays, and coarser units, typically fine to medium sands, in an effort to determine which units contained higher VOC concentrations. At all locations sampled the finer grained, lower permeability units contained higher concentrations of VOCs than the coarser grained units. For example, at PES-SB-7 a clay unit located at 32 to 34 feet bgs contained 2,100 µg/kg of TCE while a sand unit immediately below (34 to 36 feet bgs) contained only 50J µg/kg. This phenomena is repeated at PES-MW-10B where a silt unit at 36 to 42 feet bgs contains 1,600 µg/kg of TCE while a sand unit at 49 feet bgs contains no detectable concentrations of TCE. This data indicates that the VOC concentrations are higher in the fine grained silt/clay units and that these soils may contain as much, or more, contaminant mass than the more transmissive sand units. Thus, the fine grained units will likely serve as secondary sources of contaminant mass for some time.

The removal of TCE mass from the silty clay units beneath the NIROP site will be an extremely slow process because removal rate will be limited by the rate of diffusion, which is typically several orders of magnitude slower than advective-dispersive processes. Thus, the application of a remedial option in the more permeable unit(s) will not accelerate site cleanup time significantly because the time to achieve MCLs on this site is dependant on the rate at which contaminant mass diffuses out of the fine grained units, not on the rate at which the remedial option of choice destroys contaminant mass.

## AQUEOUS AND MINERAL INTRINSIC BIOREMEDIATION ASSESSMENT ANALYSES IN SOIL

Aqueous and Mineral Intrinsic Bioremediation Assessment (AMIBA) analyses consist of analyses for chromium extractable sulfides, acid extractable sulfides, weak acid extractable iron, strong acid extractable iron, weak and strong acid extractable manganese, and total oxidized iron (Kennedy *et al.*, 2000). This suite of analyses, in addition to bioavailable ferric iron and bioavailable manganese, is designed to assess the potential for a reductive dechlorination pathway known as biogeochemical reductive dechlorination (BiRD) and to assess the potential for abiotic degradation through

mineralization. The BiRD process is termed "biogeochemical" because microbial processes are used to facilitate geochemical conditions that cause the precipitation of mineral ferrous iron monosulfide (FeS) in the aquifer matrix. The primary microbial processes that are necessary to produce FeS are iron reduction and sulfate reduction. In a normal aquifer system, both of these processes occur in the presence of sufficient organic carbon, ferric iron, and sulfate. These processes are occurring within the pilot test area due to the presence of vegetable-oil-derived organic carbon.

A total of 11 samples were collected for AMIBA analysis. 6 of the 11 samples collected were impacted by vegetable oil or high concentrations of vegetable oil derived organic carbon as evidenced by visual and olfactory inspection. Comparison of the impacted and non-impacted sample sets indicates that bioavailable iron, bioavailable manganese, and chromium extractable sulfide have been depleted slightly in the impacted samples. This data indicates that the impacted soil matrix has been depleted of bioavailable metals and sulfide, and therefore the capacity for abiotic degradation has been reduced slightly. However, the observed reduction in these species is relatively small in relation to the total mass present in the un-impacted samples. Therefore, the impacted soils' capacity to support abiotic degradation may remain relatively unchanged.

Review and comparison of all of the bioavailable iron and the strong acid extractable iron data is interesting and provides some insights into the relationship between the total mass of iron present in the soil (represented by strong acid extractable iron), and how much of that iron mass is accessible to the microbial community for use. In most of the samples collected strong acid extractable iron concentrations are one to nine times higher than the respective bioavailable iron concentration. This relationship is likely related to that fact that iron mineral dissolution is related to the surface area accessible to the microbial population and the microbial population present within a particular sample. It is also important to understand that the mass of bioavailable iron is rate dependant in that iron will continue to be stripped over time. Thus, as the time scale of the bioavailable iron analysis is extended, more of the total iron present in the soil matrix will become bioavailable. The time scale for the current bioavailable iron data set was 30 days. If the analysis time scale were extended for a much longer period of time most or all of the total iron present in the soil could become bioavailable. Therefore, the limiting factor on this site may be sulfide because the total sulfide mass in the soil matrix (as represented by chromium extractable sulfide) has been depleted by approximately 56% in the first 30 months following injection.

## GROUNDWATER SAMPLING RESULTS

### SITE HYDROLOGY

During the groundwater sampling event in November 2005 a round of groundwater elevation measurements was collected within the pilot test area as well as a number of monitoring wells installed outside of the pilot test area. The data collected during this round (Table 8) was used to develop a groundwater potentiometric surface map which is depicted on Figure 4. The groundwater mound in the park, historically known as the

"stagnation zone", is clearly evident in the 2005 potentiometric surface map and continues to control groundwater flow in the pilot test area.

Groundwater elevation data collected at the newly installed monitoring wells (PES-MW-10A, PES-MW-11A, PES-MW-12A, PES-MW-13A, and PES-MW-14A) have resulted in the improvement of the definition of the groundwater potentiometric surface within the pilot test area. Groundwater flow is interpreted to be more southerly in and immediately downgradient from the injection area than previous interpretations. This more southerly flow appears to continue to monitoring wells PES-MW-9 and PES-MW-11A where groundwater flow appears to turn to a more westerly heading.

The reinterpretation of the groundwater potentiometric surface did impact interpreted groundwater flow direction. However, the slope of the groundwater potentiometric surface map remained similar to past interpretations. In 2005 (April and November) the groundwater surface was relatively flat in the upgradient portion of the pilot test area (upgradient of monitoring well PES-MW-3) and in the downgradient portion of the pilot test area (downgradient of PES-MW-4. The groundwater surface between well PES-MW-3 and well PES-MW-4 slopes strongly to the south-southwest. This stair-step pattern in the groundwater surface is likely a result of the discontinuous silt unit that has been detected in the area during drilling operations (Figure 3).

Historically, vegetable oil thickness measurements have also been collected during each process monitoring round. Since injection measurable vegetable oil thicknesses have been detected routinely at PES-INJ-02 and PES-INJ-03 and sporadically at PES-INJ-01. During more recent sampling events the vegetable oil thickness measured in PES-INJ-3 has been greater than that measured in PES-INJ-1 and PES-INJ-2. During the 2005 sampling events separate phase vegetable oil was not detected at PES-INJ-01 and PES-INJ-02, while vegetable oil was detected at PES-INJ-03 (the thickness of the vegetable oil could not be determined during the November round). The observed decrease in measurable vegetable oil at PES-INJ-03 and the absence of measurable vegetable oil at PES-INJ-01 and PES-INJ-02 indicates that the vegetable oil is being gradually consumed.

Table 9 presents the results of pre- and post-injection aquifer testing and estimates of groundwater seepage velocity. The geometric mean for hydraulic conductivity values measured for PES-MW1 and the injection wells in the upgradient portion of the study area (upgradient of PES-MW-8 and PES-MW-9) was 177 feet per day (ft/day) (0.062 centimeters per second [cm/sec]). Hydraulic conductivity measurements conducted in wells PES-MW-3, PES-MW-8, and PES-MW-9 indicate that a zone of low hydraulic conductivity, relative to the injection area and the area around the contingency wells, is present in the vicinity of these well locations. The geometric mean for hydraulic conductivity values measured at PES-MW-3, PES-MW-8, and PES-MW-9 was 29.6 ft/day (0.010 cm/sec). The only location tested downgradient from this zone of lower conductivity prior to injection was PES-CW1. The hydraulic conductivity calculated for PES-CW-1 was approximately 196 ft/day (0.069 cm/sec). Mean groundwater flow

velocities, calculated from data collected prior to injection, ranged from approximately 438 feet per year (ft/yr) to 2,545 ft/yr.

Comparison of the pre-injection aquifer testing data with the post-injection aquifer testing data (Table 9) indicates that values of hydraulic conductivity calculated immediately after injection for the injection wells was approximately an order of magnitude lower than pre-injection values of hydraulic conductivity for these same wells. This decrease in hydraulic conductivity was likely due to the presence of vegetable oil within the aquifer matrix that effectively lowers the relative permeability of the aquifer matrix.

Values of hydraulic conductivity calculated from data collected 1 year after injection are similar to those calculated from the pre-injection testing round. This indicates that the decrease in hydraulic conductivity observed immediately after injection was transient, and that the hydraulic conductivity of the aquifer matrix in the vicinity of the injection wells (PES-MW-1) has returned to baseline conditions. This may be due to a lowering of residual oil saturation due to degradation and/or migration and dispersion of the vegetable oil.

A second post-injection round of slug testing was conducted during the April 2003 process monitoring event. Slug test data collected in April 2003 indicate that the hydraulic conductivity within the injection wells is very low relative to the baseline sampling event. This decrease in hydraulic conductivity within the injection wells is due to the presence of vegetable oil within the well casings and within the aquifer matrix surrounding the wells. The low hydraulic conductivities measured within the injection wells is also likely due to microbial growth (biofouling) within and around the injection wells. Immediately downgradient from the injection area (PES-MW-1, PES-MW-6, and PES-MW-7) hydraulic conductivities measured in April 2003 are similar to those measured during the baseline event (Table 9). These data indicates that the decrease in hydraulic conductivity is limited to the area immediately surrounding the injection wells.

Six of the new monitoring wells were installed in two well clusters (PES-MW-10A/B, PES-MW-12A/B, and PES-MW-14A/B) in order to determine if vertical groundwater flow is a significant factor within the pilot test area. The vertical hydraulic gradient was calculated at each monitoring well cluster by dividing the difference in head by the vertical interval between the wells within each cluster. The vertical hydraulic gradient at monitoring well clusters PES-MW-10 and PES-MW-14 were both weak (approximately 0.004 ft/ft) and upward indicating that there may be a small component of upward flow in the vicinity of these well clusters. The vertical gradient at cluster PES-MW-12 was very small (0.002 ft/ft) and in the downward direction.

## VOLATILE ORGANIC COMPOUND ANALYSES IN GROUNDWATER

Groundwater VOC data is the primary line of evidence in determining the success of the vegetable oil pilot test. During the first extended monitoring program process monitoring round all of the original pilot test monitoring wells, the eight newly installed

monitoring wells, and seven monitoring wells outside of the pilot test area were sampled for VOCs. Table 10 presents the latest round of VOC data as well as historic data for the previously sampled monitoring wells.

Review of the entire VOC data set indicates that TCE remains the most commonly detected contaminant across the site and that TCE is typically present at greater concentration than any other contaminant compound within each monitoring well. TCE concentrations have been decreasing at all of the wells (except for the newly installed wells) since 2002. *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, and 1,1-DCA have also been detected routinely during the last 36 months at much lower concentrations than TCE. VC, acetone, and 2-butanone have also been detected sporadically both historically and during the most recent sampling event in November 2005.

TCE concentrations detected during the baseline sampling event, conducted prior to vegetable oil injection, are depicted on Figure 7. Review of groundwater analytical data (summarized in Table 10) from the baseline sampling event in November 2001 indicates that four contaminants were detected at concentrations above associated method detection limits: PCE, TCE, *cis*-1,2-DCE, and *trans*-1,2-DCE. PCE was detected at only one location (GWMS-47S) at a low concentration of 0.92 micrograms per liter (ug/L). TCE was detected at elevated concentrations at all wells within the pilot test area, except GWMS-27S, with a maximum concentration of 20,000 ug/L detected at location MS-46S (see Figure 1 for well locations). TCE concentrations were generally highest (>1,000 µg/L in most cases) in the upgradient portions of the pilot test area, east of PES-MW-4. TCE concentrations detected in the downgradient portions of the pilot test area were significantly lower, generally below 300 µg/L, with the exception of PES-CW-1 (630 ug/L). *cis*-1,2-DCE, a breakdown product of TCE, was detected at most locations at concentrations significantly less than TCE. This data suggests that limited degradation of TCE to *cis*-1,2-DCE occurred naturally at the site prior to vegetable oil injection.

Review of groundwater analytical data (Table 10) collected after vegetable oil injection indicates that TCE concentrations detected in groundwater have been variable over time, but generally have declined at the three injection wells (PES-INJ-1, PES-INJ-2, and PES-INJ-3) and at all of the pilot test wells with the exception of GMW-27S. At the majority of these wells TCE concentrations increased initially, typically peaking during the May or August 2002 sampling rounds, then decreased through November 2005. TCE concentrations detected during the most recent sampling event in November of 2005 are depicted on Figure 8. Comparison of the pre-injection plume map presented in Figure 7 to the most recent plume map presented in Figure 8 indicates that TCE concentrations have decreased substantially since injection, with the largest decreases observed in and downgradient from the injection area.

2-butanone and acetone have been detected sporadically at elevated concentrations during all of the process monitoring events in several wells including PES-INJ-1, PES-INJ-2, PES-INJ-3, PES-MW-6, PES-MW-7, PES-MW-8, and PES-MW-9. Concentrations of both analytes were relatively low during the first round of process monitoring with a maximum concentration of 490 µg/L for 2-butanone and 240 µg/L for

acetone. During later process monitoring rounds concentrations of 2-butanone and acetone were highly variable and in some cases relatively high. However, 2-butanone and acetone have never been detected at concentrations approaching the MPCA Health Risk Limits of 4,000 µg/L for 2-butanone and 700 µg/L for acetone outside of the injection area and monitoring wells PES-MW-7 and PES-MW-9.

VC has not been detected at concentrations above the method detection limit in any of the contingency wells (PES-CW1, PES-CW2, PES-CW3, GWMS-47S), or the new downgradient monitoring well cluster PES-MW-12A/B, during the course of the pilot test.

## GEOCHEMICAL ANALYSES IN GROUNDWATER

Biodegradation of organic carbon, whether natural or anthropogenic, brings about measurable changes in the chemistry of groundwater in the affected area. Concentrations of compounds used as electron acceptors (e.g., dissolved oxygen [DO], nitrate, sulfate, and carbon dioxide) are depleted, and byproducts of electron acceptor reduction (e.g., carbon dioxide, ferrous iron, sulfide, reduced manganese, and methane) are elevated. By measuring these changes, it is possible to evaluate what biological processes are occurring at a particular site. The geochemical data collected during the course of the pilot test is presented in Table 11.

During the Spring 2005 sampling event TOC concentrations sufficient to support reductive dechlorination (>20 milligrams per liter (mg/L) (USEPA, 1998)) were detected at the injection wells and at monitoring wells PES-MW-4, PES-MW-7, PES-MW-10A, and PES-MW-14A. The TOC data set collected from the monitoring wells during the Spring 2005 sampling round was combined with the TOC data set collected during the discrete sampling program (also in the Spring of 2005) and used to develop a TOC contour map (Figure 9). The TOC data depicted on Figure 9 indicates that there is a relatively large area of elevated TOC present to the south and southwest of the injection area. Within the relatively large area impacted by elevated (>10 mg/L) TOC concentrations is a smaller core of highly elevated TOC concentrations (>50 mg/L) which extends as far down gradient as PES-MW-4 and PES-MW-14A. TOC concentrations within this area are present at concentrations sufficient to drive reductive dechlorination (USEPA, 1998). The TOC mass depicted on Figure 9 is most likely related to and derived from the vegetable oil injected as part of this pilot test. Comparison of the TOC plume map depicted in Figure 9 with the TCE plume map depicted in Figure 8 indicates that the area of high TOC concentration in Figure 9 roughly corresponds to the area of low TCE concentrations (<50 µg/L) in Figure 8.

Between the April 2005 and November 2005 sampling events TOC concentrations decreased at most locations sampled and the horizontal extent of TOC concentrations exceeding 10 mg/L decreased significantly (Figure 10). The reductions in TOC concentrations observed downgradient of the injection area are not likely to be a result of or indicative of organic carbon depletion in the injection area because TOC concentrations in the injection area increased at PES-INJ-03 during the same time period.

It is more likely that the observed reductions in TOC concentrations downgradient of the injection area are related to seasonal fluctuations in groundwater flow and TOC transport rates.

At monitoring locations where TOC concentrations are elevated (the injection wells, PES-MW-7, PES-MW-10A, and PES-MW-14A) geochemical conditions are moderately to strongly reducing as indicated by the presence of elevated concentrations ferrous iron, reduced manganese, sulfide, and methane. The presence of these reduced species indicates that iron reduction, manganese reduction, sulfate reduction and methanogenesis are occurring at, or in close proximity to, these locations. These reducing conditions are conducive to anaerobic biological processes including anaerobic reductive dechlorination.

Ethane and ethene concentrations present in wells known to be un-impacted by vegetable oil (MS-27S, MS-47S, PES-CW-1, PES-CW-2, PES-CW-3) range up to approximately 35 nanograms per liter (ng/L) and 50 ng/L, respectively. During the Spring 2005 sampling event ethane concentrations at least twice the concentration measured in non-impacted wells (70 ng/L) were detected in the injection wells and in monitoring wells MS-45S, MS-46S, PES-MW-1, PES-MW-7, PES-MW-10A, PES-MW-11A, PES-MW-12B, PES-MW-14A, and PES-MW-14B. During the same sampling event ethene concentrations at least twice the concentration measured in un-impacted wells (100 ng/L) were detected in the injection wells and in monitoring wells PES-MW-1, PES-MW-6, PES-MW-10A, PES-MW-12B, PES-MW-14A, and PES-MW-14B. This data indicates that complete reductive dechlorination may be occurring at these locations or immediately upgradient of these locations (in the case of PES-MW-1 and PES-MW-6). Methane, ethene, and ethane samples were not collected during the November 2005 sampling event.

## GROUNDWATER SAMPLING RESULTS FROM MS-53PC

Monitoring well MS-53PC was redeveloped and one groundwater sample collected as recommended in the August 2003 Report (CCI, 2003). In April of 2005, the TOC concentration in MS-53 PC was 110 mg/L and the total VFA concentration was 792 mg/L (Table 12). Background concentrations of TOC as measured during the baseline event were below 5 mg/L and VFA concentrations measured at wells upgradient of the injection system are below 4 mg/L. Therefore, the high concentrations of TOC and VFAs measured at MS-53PC indicate that this well was impacted with vegetable oil during injection. However, TCE was the only VOC detected in MS-53PC in April 2005 and it was detected at a concentration of 0.83J µg/L, which is lower than the TCE concentration detected during the June 2003 sampling event. The concentration of TCE detected in MS-53-PC during the June 2003 sampling event was 2.1 and 1.19 µg/L in the screened interval. This suggests that, although monitoring well MS-53PC was impacted during the vegetable oil injection, the TCE concentration at this well did not increase. No further action is recommended for monitoring well MS-53PC.

## SUMMARY

During the Spring 2005 field program a total of 38 MIP points were installed with 48 discrete groundwater samples collected to confirm or further investigate the data collected during the MIP program. After the MIP program was complete 8 new wells and 10 new soil borings were installed to investigate the soil conditions within and downgradient from the injection area to improve the definition of groundwater flow conditions in the pilot test area and to investigate geochemical and VOC conditions in the area south of the injection wells. Following the completion of the drilling program a full round of groundwater sampling was conducted.

During the course of the MIP program it was found that direct push drilling is well suited for drilling activities at Anoka County Park. The direct push rig deployed in support of this project was capable of reaching depths of up to approximately 75 feet below ground surface and was limited by the supply of drilling rod and not by the capabilities of the rig. It is also likely small diameter monitoring wells could be installed in addition to the MIP work, soil sampling, and discrete groundwater sampling conducted during this project. Small diameter monitoring wells could be installed in lieu of standard monitoring wells during future drilling programs at a fraction of the cost due to cost savings related to decreased mobilization and drilling costs, decreased investigation derived waste production, and decreased well material costs.

Groundwater elevation data collected during the 2005 program from the existing pilot test wells, the newly installed pilot test wells, and a selection of wells installed outside of the pilot test area indicates that groundwater flow near the injection area is more southerly than previously interpreted. As a result, the effects of the injected vegetable oil are migrating with groundwater flow in a more south-southwest direction. This newly interpreted groundwater flow regime is supported by the TOC plume maps presented on Figures 9 and 10 and the November 2005 plume map presented on Figure 8. The groundwater elevation data collected in 2005 from the newly installed monitoring well clusters also indicates that there is the potential for upward vertical groundwater flow at wells PES-MW-10 and PES-MW-14, and downward groundwater flow at PES-MW-12.

The ECD data collected during the MIP survey indicates that chlorinated VOC mass is present in the subsurface between approximately 28 feet and 42 feet bgs in the upgradient portion of the pilot test area (upgradient of PES-MW-10) and between approximately 35 feet and 50 feet bgs downgradient of PES-MW-10. This distribution was confirmed by discrete groundwater sampling conducted immediately after the completion of the MIP program. The VOC in soil data collected during the drilling program further indicates that VOC concentrations in the finer grained, less transmissive units are significantly higher than VOC concentrations present in the coarser grained, more transmissive units. This data indicates that significant contaminant mass is present in the fine grained silt-clay units. Thus, any remedial strategies implemented in this area that are designed primarily to remove/destroy contaminant mass should be targeted to the finer grained units present between approximately 30 feet and 50 feet bgs where the majority of the contaminant mass resides. In addition, groundwater flow and contaminant migration

within the fine grained units are likely to be controlled by diffusion based mechanics as apposed to the more permeable units where advective flow mechanics likely control contaminant migration. As a result, the success of any remedial option chosen for application within this area will be dependant upon the rate at which contaminant mass diffuses out of the fine grained units.

The TOC in soil data and observations collected during the drilling program indicate that the injected vegetable oil was distributed heterogeneously both vertically and horizontally within the injection area. TOC concentrations in soil detected within the injection area ranged from approximately 2,000 to 6,000 mg/kg, indicating that significant vegetable oil derived organic carbon mass remains in the system to drive biological degradation processes. TOC data collected in groundwater during the discrete sampling program and during the groundwater sampling program indicates that a relatively large area of elevated TOC concentrations was present around the injection area and extended approximately 80 feet to the south-southwest during the April 2005 sampling event. TOC concentrations in this area were high enough to support reductive dechlorination (>20 mg/L (USEPA, 1998)). During the November 2005 sampling event this area of elevated TOC was smaller than in April 2005, possibly as a result of seasonal fluctuations in groundwater flow and TOC transport. Geochemical conditions within this area of elevated TOC (the injection wells, PES-MW-1, PES-MW-4, PES-MW-7, PES-MW-10A, and PES-MW-14A) are indicative of anaerobic geochemical conditions capable of supporting reductive dechlorination. The TOC data collected in April 2005 also indicates that monitoring well MS-53PC was inadvertently impacted by vegetable oil during injection activities in 2001.

Targeted gene detection analysis of soil samples collected during the 2005 program indicates that DHC and DHB were positively identified in nearly all samples analyzed including both vegetable oil impacted and un-impacted samples. The population of DHC in the impacted samples was approximately one order of magnitude higher than the population measured in the non-impacted samples, while DHB populations in the impacted samples were approximately two to three orders of magnitude higher than background. Dechlorinating bacteria DSB, DSM, and GEO were also positively identified at lower concentrations. Thus, the microbial population within the pilot test area is capable of completely dechlorinating chlorinated VOC mass. In addition, moderate to high concentrations of sMMO (with respect to the un-impacted samples) were detected at locations PES-SB-1, PES-SB-7, and PES-MW-10B, indicating that it is possible that chlorinated solvent mass is being destroyed by methanotrophic bacteria through cometabolic oxidation at these locations. This data indicates that several microbial strains that are known to be capable of dechlorinating chlorinated VOC mass are present naturally in site soils, that the injected vegetable oil has been effective at increasing the populations of DHC, DHB, and to a lesser extent GEO. The injected vegetable oil has also been successful in promoting contaminant mass destruction through cometabolic oxidation. Samples of groundwater were also collected for targeted gene detection analysis. Comparison of the targeted gene detection data collected in soil

and in groundwater indicates that the analysis of groundwater from this site does not adequately represent the microbial population in the subsurface.

A total of 11 samples were collected for AMIBA analysis during the 2005 drilling program. Comparison of the impacted and un-impacted sample sets indicates that bioavailable iron, bioavailable manganese, and chromium extractable sulfide have been depleted slightly in the impacted samples. This data indicates that the impacted soil matrix has been depleted of bioavailable metals and sulfide and therefore the capacity for abiotic degradation has been reduced slightly. However, the observed reduction in these species is relatively small in relation to the total mass present in the un-impacted samples. Therefore, the impacted soils' capacity to support abiotic degradation remains relatively unchanged.

Groundwater VOC data collected during the 2005 sampling rounds indicate that VOC concentrations continued to decrease both within and outside of the pilot test area. Comparison of the pre-injection TCE plume map presented on Figure 7 and the November 2005 TCE plume map presented on Figure 8 indicates that TCE concentrations decreased most dramatically within and down gradient from the pilot test area. Review of the VOC data presented in Table 10 and geochemistry data presented in Table 11 indicates that at locations were adequate TOC is present partial, potentially complete, reductive dechlorination is occurring. Elevated ethane and ethene concentrations at these locations further indicates that complete reductive dechlorination may be occurring. These observations indicate that the vegetable oil pilot has been successful in enhancing VOC mass destruction beneath Anoka County Park.

Data collected during the most recent round of field activities indicates that significant contaminant mass is present as sorbed mass located in the fine grained silt/clay units beneath the park. As a result of the presence of this sorbed contaminant mass, the remedial time frame and effectiveness associated with any remedy designed to remove contaminant mass from the subsurface (including organic substrate addition) will be dependant upon the rate at which the contaminant mass diffuses out of the silt/clay units and into the more transmissive sand units where it can be removed or destroyed. Theoretically the rate at which contaminant mass diffuses out of the finer grained units could be maximized by removing the contaminant mass from the more transmissive units and thereby increasing the steepness of the contaminant concentration gradient from the less permeable unit to the more permeable unit. However, the time frame necessary for contaminant mass to diffuse out of the fine grained units is likely to be on the order of hundreds of years. Therefore, it is unlikely that any remedial technology will be successful in significantly accelerating the time it will take to reach remedial goals at the site because contaminant mass will continue to diffuse out of the fine grained units for some time to come.

Since the remedial time frame for groundwater contamination at Anoka County Park appears to be fixed by the diffusion rate from the fine grained units it is likely that the attainment of the remedial goal to remove or destroy all contaminant mass from the subsurface will be technically unattainable within a reasonable period of time. However,

the remedial goal to protect potential contaminant receptors by limiting contaminant mass loading to those receptors remains as a potentially attainable remedial goal at the site. The success of the vegetable oil pilot test indicates that the substrate addition technology is a viable technology to meet this remedial goal. The data collected during the course of this pilot test has shown that the injected vegetable oil has been effective at immobilizing contaminant mass through the partitioning of contaminant mass into the immobile vegetable oil (Parsons, 2004) as well as enhancing the destruction of contaminant mass through biologically supported degradation processes. The ability of vegetable oil to immobilize contaminant mass has the potential to reduce contaminant loading in the short term while the ability of organic substrate addition to promote biologically mediated contaminant mass destruction will reduce contaminant mass loading in the long term.

Parsons suggests that the Navy continue to perform limited groundwater monitoring in the pilot test area in order to track the future progress of the pilot test and to define the life cycle of the injected substrate. Future sampling events could be combined with the base wide sampling events in order to decrease the monitoring costs and to produce site wide sampling rounds that are internally comparable. The sampling locations and analytical parameters could be scaled back to only those locations and parameters important for tracking the progress of the pilot test (Table 13). It is recommended that the following sampling be retained and repeated approximately annually in order to continue to track the effectiveness of the system and to track the depletion of the vegetable oil derived organic carbon:

**TABLE 13**
**RECOMMENDATIONS FOR FUTURE ANNUAL SAMPLING**
**NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY**
**ANOKA COUNTY PARK**
**FRIDLEY, MINNESOTA**

| Well Identification | Well Stabilization Parameters [a/] | VOCs (8260B) | TOC (SW9060) |
|---|---|---|---|
| PES-INJ-03 | X | X | X |
| PES-MW-4 | X | X | X |
| PES-MW-5 | X | X | X |
| PES-MW-7 | X | X | X |
| PES-MW-9 | X | X | X |
| PES-MW-10A | X | X | X |
| PES-MW-11A | X | X | X |
| PES-MW-12A | X | X | X |
| PES-MW-13A | X | X | |
| PES-MW-14A | X | X | X |
| PES-CW-2 | X | X | |
| PES-CW-3 | X | X | |
| MS-46S | X | X | |
| MS-47S | X | X | |

[a/] Well stabilization parameters include dissolved oxygen, temperature, pH, oxidation reduction potential, and turbidity.

In addition it is recommended that a slightly expanded sampling program be implemented during the site wide sampling round immediately prior to a five year ROD review in order to prepare a more complete representation of "current" site conditions. Parsons recommends that PES-MW-1 and PES-MW-6 be added to the pre-ROD review sampling protocol in order to assess groundwater conditions immediately downgradient from the injection area. Parsons also recommends that the B interval wells be added at well clusters PES-MW-10, PES-MW-12, and PES-MW-14 in order to assess water quality downgradient from and slightly below the injection area.

**TABLE 14**
**RECOMMENDATIONS FOR SAMPLING PRIOR TO A 5-YEAR ROD REVIEW**
**NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY**
**ANOKA COUNTY PARK**
**FRIDLEY, MINNESOTA**

| Well Identification | Well Stabilization Parameters [a/] | VOCs (8260B) | TOC (SW9060) |
|---|---|---|---|
| PES-MW-1 | X | X | X |
| PES-MW-6 | X | X | X |
| PES-MW-10B | X | X | X |
| PES-MW-12B | X | X | X |
| PES-MW-14B | X | X | X |

Note: Sampling recommendations presented in this table are in addition to the sampling recommendations presented in Table 13.

[a/] Well stabilization parameters include dissolved oxygen, temperature, pH, oxidation reduction potential, and turbidity.

During the coming months the NIROP team will be required to make a series of decisions regarding the future of remedial activities at Anoka County Park. These decisions will be made based upon the results of the vegetable oil pilot test, research being conducted by the USGS with regard to the hydraulic system, and the impact of the extraction system currently operating on site. The vegetable oil pilot test has been successful in enhancing the destruction of chlorinated solvent mass in the subsurface and has thus been successful in reducing the overall toxicity of the groundwater plume. Vegetable oil has also been shown to be effective at stripping contaminant mass from the soil matrix through its surfactant properties and immobilizing contaminant mass through its preferential partitioning properties (Parsons, 2004). Therefore, Parsons recommends that organic substrate addition in general and vegetable oil injection specifically be considered as a future remedial option at this site.

In 1990 the record of decision (ROD) for groundwater at the NIROP facility was signed. The ROD specified that contaminated groundwater located offsite and downgradient of the NIROP facility in Anoka County Park would be allowed to dissipate naturally (TTNUS, 2005). During the 1998 5-year ROD review it was determined that VOC concentrations in Anoka County Park were not decreasing as rapidly as expected

and it was recommended that the Navy determine what could be done to reduce residual groundwater contamination in Anoka County Park (TTNUS, 2005). As a result of this recommendation the Navy embarked on this organic substrate addition pilot test program. In addition, the Navy started a groundwater extraction system expansion program in order to more fully capture the VOC plume emanating from the NIROP facility. Over the last several years of groundwater monitoring in Anoka County Park VOC concentrations at wells installed within and outside of the pilot testing area have been decreasing (TTNUS, 2006). The VOC concentration decreases observed outside of the pilot test area are likely a result of more complete capture afforded by the expanded extraction system and natural attenuation mechanisms active in the Park (TTNUS, 2006). Since VOC concentrations in Anoka County Park have been decreasing over the last several years, Parsons suggests that the Navy continue to monitor VOC concentrations at wells installed in the Park to determine if the VOC concentration reductions are sustainable. If VOC concentrations continue to decrease in the Park then the tenants of the ROD should be fulfilled and active remediation in the Park may be unnecessary to be protective of identified potential contaminant receptors. In the event that VOC concentrations in the Park increase significantly over a significant period of time the NIROP partnering team could re-consider the need for more active remediation measures.

In the event that a more active approach becomes warranted, Parsons suggests that future active remedial activities at Anoka County Park be designed to reduce the potential impact to receptors and therefore reduce the environmental risk and impact associated with the contaminant mass remaining in the subsurface instead of attempting to remove or destroy all of the remaining contaminant mass. To this end Parsons suggests that the NIROP team limit future remedial activities at the site to defined contaminant hot spots or source areas instead of attempting to treat large areas (for example attempting to treat an area within a particular interpreted VOC concentration contour). The control or elimination of contaminant mass present as hot spots will allow the environmental risk associated with the site to be reduced most significantly and most efficiently in terms of cost and in terms of impact to activities and access to the site.

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# TABLES

# TABLE 1
## SUMMARY OF MEMBRANE INTERFACE PROBE POINT INSTALLATIONS
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Well/Borehole Identification | Well/Boring Diameter (Inches) | Total Depth (feet bgs)[a/] | Ground Surface Elevation (feet amsl)[b/] | Elevation Top of Casing (feet amsl) | Survey Northing (State Plane) | Survey Easting (State Plane) |
|---|---|---|---|---|---|---|
| MIP-1 | 1 | 60 | NM[c/] | NM | 1,077,426.77 | 2,810,933.36 |
| MIP-2 | 1 | 60 | NM | NM | 1,077,392.94 | 2,810,924.37 |
| MIP-3 | 1 | 60 | NM | NM | 1,077,386.69 | 2,810,892.06 |
| MIP-4 | 1 | 55 | NM | NM | 1,077,389.93 | 2,810,890.64 |
| MIP-5 | 1 | 60 | NM | NM | 1,077,393.87 | 2,810,889.35 |
| MIP-6 | 1 | 60 | NM | NM | 1,077,385.27 | 2,810,882.59 |
| MIP-7 | 1 | 74 | NM | NM | 1,077,387.07 | 2,810,908.80 |
| MIP-8 | 1 | 60 | NM | NM | 1,077,382.04 | 2,810,914.14 |
| MIP-9 | 1 | 61 | NM | NM | 1,077,378.44 | 2,810,910.70 |
| MIP-10 | 1 | 60 | NM | NM | 1,077,374.97 | 2,810,906.82 |
| MIP-11 | 1 | 60 | NM | NM | 1,077,393.04 | 2,810,910.18 |
| MIP-12 | 1 | 60 | NM | NM | 1,077,378.63 | 2,810,925.62 |
| MIP-13 | 1 | 70 | NM | NM | 1,077,367.15 | 2,810,898.56 |
| MIP-14 | 1 | 62 | NM | NM | 1,077,364.96 | 2,810,894.05 |
| MIP-15 | 1 | 60 | NM | NM | 1,077,354.34 | 2,810,904.24 |
| MIP-16 | 1 | 60 | NM | NM | 1,077,348.53 | 2,810,893.98 |
| MIP-17 | 1 | 60 | NM | NM | 1,077,351.98 | 2,810,908.44 |
| MIP-18 | 1 | 60 | NM | NM | 1,077,378.73 | 2,810,935.81 |
| MIP-19 | 1 | 60 | NM | NM | 1,077,340.37 | 2,810,897.87 |
| MIP-20 | 1 | 60 | NM | NM | 1,077,322.76 | 2,810,900.43 |
| MIP-21 | 1 | 70 | NM | NM | 1,077,314.20 | 2,810,903.44 |
| MIP-22 | 1 | 60 | NM | NM | 1,077,215.88 | 2,810,882.20 |
| MIP-23 | 1 | 70 | NM | NM | 1,077,347.80 | 2,810,907.97 |
| MIP-24 | 1 | 60 | NM | NM | 1,077,343.98 | 2,810,907.95 |
| MIP-25 | 1 | 60 | NM | NM | 1,077,323.60 | 2,810,884.91 |
| MIP-26 | 1 | 60 | NM | NM | 1,077,308.01 | 2,810,878.27 |
| MIP-27 | 1 | 60 | NM | NM | 1,077,292.13 | 2,810,865.27 |
| MIP-28 | 1 | 60 | NM | NM | 1,077,383.47 | 2,810,925.54 |
| MIP-29 | 1 | 60 | NM | NM | 1,077,258.88 | 2,810,896.58 |
| MIP-30 | 1 | 60 | NM | NM | 1,077,281.18 | 2,810,903.57 |
| MIP-31 | 1 | 67 | NM | NM | 1,077,311.17 | 2,810,911.70 |
| MIP-32 | 1 | 62 | NM | NM | 1,077,305.95 | 2,810,929.81 |
| MIP-33 | 1 | 60 | NM | NM | 1,077,345.89 | 2,810,925.22 |
| MIP-34 | 1 | 60 | NM | NM | 1,077,354.24 | 2,810,924.29 |
| MIP-35 | 1 | 66 | NM | NM | 1,077,213.64 | 2,810,866.11 |
| MIP-36 | 1 | 60 | NM | NM | 1,077,377.46 | 2,810,925.30 |
| MIP-37 | 1 | 67 | NM | NM | 1,077,271.25 | 2,810,921.46 |
| MIP-38 | 1 | 61 | NM | NM | 1,077,308.49 | 2,810,952.02 |

[a/] feet bgs indicates depth in feet below ground surface.

[b/] feet amsl indicates elevation in feet above mean sea level.

[c/] NM indicates elevation not measured.

# TABLE 2
## SUMMARY OF MONITORING WELL AND SOIL BORING CONSTRUCTION
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Well/Borehole Identification | Completion Date | Well/Boring Diameter (Inches) | Screened Interval/TD (feet bgs)[a/] | Ground Surface Elevation (feet amsl)[b/] | Elevation Top of Casing (feet amsl) | Survey Northing (State Plane) | Survey Easting (State Plane) |
|---|---|---|---|---|---|---|---|
| **Newly Installed Monitoring Wells** | | | | | | | |
| PES-MW-10A | 4/1/2005 | 2/8 | 45.0 - 55.0 | NM[d/] | 832.17 | 1,077,342.33 | 2,810,904.47 |
| PES-MW-10B | 3/31/2005 | 2/8 | 65.0 - 75.0 | NM | 832.11 | 1,077,345.35 | 2,810,906.36 |
| PES-MW-11A | 3/29/2005 | 2/8 | 45.0 - 55.0 | NM | 832.28 | 1,077,320.34 | 2,810,900.39 |
| PES-MW-12A | 4/5/2005 | 2/8 | 35.0 - 45.0 | NM | 833.89 | 1,077,205.43 | 2,810,881.86 |
| PES-MW-12B | 4/5/2005 | 2/8 | 55.0 - 65.0 | NM | 833.80 | 1,077,208.68 | 2,810,882.56 |
| PES-MW-13A | 3/28/2005 | 2/8 | 35.0 - 45.0 | NM | 832.15 | 1,077,420.00 | 2,810,927.99 |
| PES-MW-14A | 4/4/2005 | 2/8 | 45.0 - 55.0 | NM | 831.74 | 1,077,291.98 | 2,810,872.98 |
| PES-MW-14B | 4/4/2005 | 2/8 | 65.0 - 75.0 | NM | 831.84 | 1,077,295.69 | 2,810,871.97 |
| **Newly Installed Soil Borings** | | | | | | | |
| PES-SB-1 | 8/29/2000 | NA[c/]/8 | 60 | NM | NA | 1,077,385.69 | 2,810,895.57 |
| PES-SB-2 | 8/29/2000 | NA/8 | 60 | NM | NA | 1,077,373.21 | 2,810,905.91 |
| PES-SB-3 | 9/7/2000 | NA/8 | 60 | NM | NA | 1,077,359.27 | 2,810,907.97 |
| PES-SB-4 | 9/7/2000 | NA/8 | 60 | NM | NA | 1,077,379.96 | 2,810,914.05 |
| PES-SB-5 | 9/9/2000 | NA/8 | 60 | NM | NA | 1,077,376.71 | 2,810,909.98 |
| PES-SB-6 | 9/7/2000 | NA/8 | 60 | NM | NA | 1,077,368.49 | 2,810,898.43 |
| PES-SB-7 | 9/7/2000 | NA/8 | 60 | NM | NA | 1,077,365.37 | 2,810,894.23 |
| PES-SB-8 | 9/9/2000 | NA/8 | 60 | NM | NA | 1,077,357.14 | 2,810,883.76 |
| PES-SB-9 | 9/9/2000 | NA/8 | 60 | NM | NA | 1,077,357.62 | 2,810,895.39 |
| PES-SB-10 | 9/9/2000 | NA/8 | 60 | NM | NA | 1,077,353.26 | 2,810,903.79 |

[a/] feet bgs indicates depth in feet below ground surface.

[b/] feet amsl indicates elevation in feet above mean sea level.

[c/] NA indicates data not available.

[d/] NM indicates elevation not measured.

# TABLE 3
## SUMMARY OF MIP SURVEY DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Location | Depth Range (ft bgs)[a] | Peak depth(s) (ft bgs) | ECD peak hit (uV)[b] | FID range (ft bgs) | FID peak depth (ft bgs) | FID peak (uV) |
|---|---|---|---|---|---|---|
| **MIP Points Upgradient of MPES-MW-10A/B** | | | | | | |
| MIP-01 | 30.5-49.0 | 32.0-36.0 | 3.50E+05 | NA[c] | NA | ND[d] |
| MIP-02 | 27.0-47.0 | 33.5 | 1.20E+06 | 26.7-28.5 | 26.5 | 1.80E+06 |
| | | 36.0 | 2.50E+05 | | 27.0 | 2.20E+06 |
| MIP-03 | 29.5-59.5 | 39.0 | 3.90E+05 | 30.5-32.5 | 31.0 | 8.00E+06 |
| | | 42.0 | 3.00E+05 | | | |
| | | 45.0 | 3.20E+05 | | | |
| | | 51.0 | 2.80E+05 | | | |
| MIP-04 | 38.0-53.0 | 32.5 | 4.00E+05 | NA | NA | ND |
| | | 35.0 | 3.50E+05 | | | |
| | | 37.5 | 5.20E+05 | | | |
| MIP-05 | 28.5-49.0 | 30.0 | 1.80E+06 | 30.0-32.0 | 30.0 | 4.80E+05 |
| | | 32.5 | 8.00E+05 | | | |
| MIP-06 | 34.5-TD (60) [e] | 37.0 | 3.00E+05 | 31.0-34.0 | 32.0 | 1.50E+06 |
| | | 48.0 | 3.90E+05 | | 33.0 | 9.00E+05 |
| | | 54.0 | 3.00E+05 | | | |
| MIP-07 | 27.5-46.0 | 27.5 | 8.00E+05 | 27.5 | 27.5 | 1.80E+05 |
| | | 31.0 | 7.00E+05 | | | |
| MIP-08 | 28.5-TD (60) | 37.0 | 1.00E+06 | 31.0 | 31.0 | 4.00E+05 |
| | | 39.0 | 1.00E+06 | | | |
| | | 41.0 | 9.00E+05 | | | |
| MIP-09 | 28.5-50.0 | 31.0 | 1.00E+06 | NA | NA | ND |
| | | 36.0 | 8.00E+05 | | | |
| MIP-10 | 36.0-52.0 | 41.0 | 2.00E+05 | 32.0 | 32.0 | 5.50E+05 |
| | | 43.0 | 2.00E+05 | | | |
| | | 50.0 | 1.50E+05 | | | |
| MIP-11 | 28.5-TD (60) | 44.0 | 7.00E+05 | NA | NA | ND |
| | | 51.5 | 1.00E+06 | | | |
| | | 56.5 | 6.00E+05 | | | |
| | | 59.0 | 6.00E+05 | | | |
| MIP-12 | 27.0-40.0 | 27.0 | 1.00E+06 | NA | NA | ND |
| | | 35.0 | 3.50E+06 | | | |
| MIP-13 | 31.0-51.0 | 33.0 | 1.70E+06 | 31.0-50.5 | 47.5 | 6.00E+06 |
| | | | | | 51.0 | 5.50E+06 |
| MIP-14 | 29.5-TD (62) | 36.0 | 5.00E+05 | 32.0-54.0 | 32.0 | 6.00E+05 |
| | | 49.0 | 4.00E+05 | | 38.0 | 6.00E+05 |
| | | 58.0 | 5.00E+05 | | 49.0 | 2.80E+06 |
| | | | | | 54.0 | 8.00E+05 |
| MIP-15 | 30.5-42.0 | 36.0 | 1.60E+06 | 54.0-57.0 | 54.0 | 5.00E+06 |
| | | | | | 56.0 | 3.00E+06 |
| MIP-16 | 30.5-42.0 | 34.0 | 1.50E+06 | 34.0-56.0 | 34.0 | 5.00E+05 |
| | | 36.0 | 2.30E+06 | | 53.0 | 2.00E+06 |
| | | | | | 56.0 | 3.00E+05 |
| MIP-17 | 30.0-52.5 | 32.5 | 8.00E+05 | NA | NA | ND |
| | | 39.0 | 7.00E+05 | | | |
| | | 42.0 | 6.00E+05 | | | |
| MIP-18 | 26.5-48.0 | 29.0 | 7.00E+05 | 28.0 | 28.0 | 1.50E+05 |
| | | 33.5 | 4.00E+05 | | | |
| | | 37.0 | 4.00E+05 | | | |
| MIP-23 | 30.0-48.0 | 35.5 | 2.50E+06 | NA | NA | ND |
| | | 40.0 | 2.00E+06 | | | |
| MIP-28 | 28.0-TD (60) | 35.0 | 6.00E+05 | 53.0-54.0 | 53.5 | 1.00E+05 |
| | | 42.0 | 5.50E+05 | | | |
| MIP-33 | 28.0-46.0 | 28.0 | 1.50E+06 | NA | NA | ND |
| | | 35.5 | 7.50E+05 | | | |
| | | 41.0 | 5.00E+05 | | | |

## TABLE 3
## SUMMARY OF MIP SURVEY DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| | | | | | | |
|---|---|---|---|---|---|---|
| MIP-34 | 27.0-43.5 | 28.5 | 1.30E+06 | NA | NA | ND |
| | | 33.0 | 7.50E+05 | | | |
| MIP-36 | 27.5-33.0 | 28.5 | 8.00E+06 | 27.5-30.0 | 28.0 | 6.00E+05 |
| | | 30.5 | 5.50E+06 | | 30.0 | 6.00E+05 |
| | | 32.0 | 2.00E+06 | | | |
| **MIP Points Down Gradient of MPES-MW-10A/B** | | | | | | |
| MIP-19 | 31.0-TD (60) | 34.0 | 6.00E+05 | 38.0-54.0 | 42.5 | 4.00E+06 |
| | | 38.0 | 9.50E+05 | | 44.5 | 7.00E+06 |
| | | 44.5 | 8.00E+05 | | 49.0 | 2.00E+06 |
| | | 48.0 | 9.00E+05 | | 53.0 | 4.50E+06 |
| | | 55.0 | 4.00E+05 | | | |
| | | 58.0 | 8.00E+05 | | | |
| MIP-20 | 31.0-58.0 | 34.0 | 4.50E+05 | 55.5-57.0 | 56.0 | 7.50E+06 |
| | | 42.0 | 7.50E+05 | | 57.0 | 3.00E+06 |
| | | 58.0 | 3.50E+05 | | | |
| MIP-21 | 31.5-52.5 | 35.0 | 6.00E+05 | 47.5-58.0 | 55.0 | 8.50E+06 |
| | | 40.0 | 1.00E+06 | | 56.0 | 1.10E+07 |
| | | 42.5 | 1.80E+06 | | 57.5 | 5.00E+06 |
| | | 47.0 | 1.00E+06 | | | |
| MIP-22 | 33.0-TD (60) | 41.0 | 3.00E+05 | NA | NA | ND |
| | | 47.0 | 3.00E+05 | | | |
| | | 59.0 | 6.00E+05 | | | |
| MIP-24 | 31.0-48.0 | 34.0 | 1.20E+06 | 47.5-55 | 48.0 | 8.00E+05 |
| | | 36.0 | 1.70E+06 | | 52.5 | 2.10E+06 |
| | | 39.0 | 1.20E+06 | | 53.5 | 1.60E+06 |
| | | | | | 55.0 | 9.00E+05 |
| MIP-25 | 31.0-TD (60) | 34.0 | 3.20E+05 | 39.0-52.0 | 40.0 | 2.00E+05 |
| | | 39.0 | 3.80E+05 | | 44.0 | 1.55E+05 |
| | | 48.0 | 2.50E+05 | | 49.0 | 2.00E+05 |
| | | 56.0 | 2.00E+05 | | 52.0 | 3.00E+05 |
| MIP-26 | 31.0-51.0 | 35.0 | 5.80E+05 | 54.5-55.5 | 55.0 | 8.00E+06 |
| MIP-27 | 31.0-54.0 | 35.0 | 4.00E+05 | 35.0-41.0 | 38.5 | 1.50E+06 |
| | | 37.0 | 4.20E+05 | 50.0-57.5 | 57.0 | 2.10E+05 |
| | | 46.0 | 3.00E+05 | | | |
| MIP-29 | 44.0-59.0 | 49.0 | 7.00E+05 | NA | NA | ND |
| | | 55.0 | 5.50E+05 | | | |
| MIP-30 | 35, 38.0-58.0 | 35.0 | 5.00E+05 | 42.0-45.0 | 44.0 | 7.00E+05 |
| | | 47.0 | 3.20E+06 | | | |
| MIP-31 | 33.0-57.0 | 43.0 | 4.50E+06 | NA | NA | ND |
| | | 45.0 | 4.00E+06 | | | |
| | | 48.0 | 2.00E+06 | | | |
| MIP-32 | 31.5-56.0 | 40.0 | 5.00E+06 | 35.0, 40.0, 46.5 | 35.0 | 1.90E+05 |
| | | 47.0 | 4.00E+06 | | 40.0 | 2.00E+05 |
| | | | | | 46.5 | 1.80E+05 |
| MIP-35 | 43-TD (66) | 43.0 | 2.00E+05 | NA | NA | ND |
| | | 50.0 | 2.80E+05 | | | |
| | | 57.0 | 3.20E+05 | | | |
| | | 63.0 | 4.50E+05 | | | |
| | | 66.0 | 3.50E+05 | | | |
| MIP-37 | 38.0-62.5 | 47.0 | 6.00E+05 | 39.5-46.5 | 44.0 | 4.50E+05 |
| | | 51.0 | 5.00E+05 | | | |
| MIP-38 | 40.0-TD (61) | 41.0 | 3.00E+05 | NA | NA | ND |
| | | 43.0 | 3.70E+05 | | | |
| | | 45.0 | 9.00E+05 | | | |
| | | 48.0 | 7.50E+05 | | | |
| | | 53.0 | 5.00E+05 | | | |

[a] ft bgs - feet below ground surface
[b] uV = microvolts
[c] NA = not applicable
[d] ND = not detected
[e] TD = total depth

# TABLE 4
## SUMMARY OF MIP AND DISCRETE GROUNDWATER SAMPLING DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Date | Sampling Depth (ft bgs) | ECD Response (uV) | Correlation Factor (unitless) | Total Cl VOCs (µg/L) | PCE[a] (µg/L)[b] | TCE[a] (µg/L) | *cis-* 1,2-DCE[a] (µg/L) | *trans-* 1,2-DCE[a] (µg/L) | Vinyl Chloride (µg/L) | FID Response (uV) | TOC Concentration (mg/L) | Methane (µg/L) | Ethene (µg/L) | Ethane (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIP-01 | 14-Mar-05 | 30.0 | 3.00E+05 | 149 | 2,007 | 0.45 U | 1,900 | 49 | 51 | 0.52 J | ND | 4.6 | NA | NA | NA |
| | | 50.0 | 3.00E+05 | 1279 | 235 | 0.45 U | 220 | 6.6 | 3.2 | 0.18 U | ND | 3.9 | NA | NA | NA |
| MIP-03 | 14-Mar-05 | 31.0 | 1.56E+05 | 233 | 671 | 0.90 U | 38 | 610 | 12 | 3.4 | 8.00E+06 | 420 | NA | NA | NA |
| | | 39.0 | 3.42E+05 | 291 | 1,174 | 2.2 U | 940 | 170 | 44 | 0.9 U | ND | 14 | NA | NA | NA |
| | | 43.0 | 2.93E+05 | 439 | 667 | 1.1 U | 630 | 13 | 14 | 0.45 U | ND | 4.8 | NA | NA | NA |
| MIP-04 | 14-Mar-05 | 38.0 | 4.00E+05 | 277 | 1,444 | 2.2 U | 1300 | 65 | 59 | 0.90 U | ND | 4.4 | NA | NA | NA |
| | 14-Mar-05 | 43.0 | 3.20E+05 | 389 | 822 | 0.45 U | 790 | 13 | 14 | 0.18 U | ND | 4.7 | NA | NA | NA |
| | 15-Mar-05 | 50.0 | 2.00E+05 | 434 | 460 | 0.90 U | 430 | 16 | 6.2 | 0.36 U | ND | 10 | 26 | 2.9 | 3.0 |
| MIP-05 | 15-Mar-05 | 30.0 | 1.00E+06 | 1679 | 596 | 0.45 U | 520 | 40 | 31 | 0.18 U | 4.00E+05 | 1.7 | 2.7 | 0.36 | 0.55 |
| | | 40.0 | 3.61E+05 | 396 | 912 | 0.90 U | 860 | 19 | 25 | 0.36 U | ND | 1.7 | 9.3 | 0.85 | 0.75 |
| MIP-08 | 17-Mar-05 | 31.0 | 3.00E+05 | 187 | 1,607 | 9 U | 1,400 | 58 | 68 | 3.6 U | 4.00E+05 | 3.2 | 20 | 12 | 9.4 |
| | | 35.0 | 4.50E+05 | 263 | 1,710 | 9 U | 1,500 | 60 | 69 | 3.6 U | ND | 3.1 | 13 | 6.0 | 5.8 |
| | | 41.0 | 8.00E+05 | 783 | 1,022 | 4.5 U | 920 | 32 | 29 | 1.8 U | ND | 1.7 | 9.4 | 4.9 | 4.6 |
| | | 48.0 | 5.50E+05 | 1202 | 458 | 4.5 U | 400 | 9.6 | 7.4 | 1.8 U | ND | 1.9 | 15 | 7.0 | 7.8 |
| MIP-09 | 17-Mar-05 | 31.0 | 1.00E+06 | 596 | 1,678 | 2.2 U | 1,500 | 79 | 81 | 0.9 U | ND | 2.9 | 13 | 2.2 | 1.9 |
| | | 36.0 | 8.00E+05 | 421 | 1,899 | 4.5 U | 1,700 | 74 | 84 | 1.8 U | ND | 2.3 | 13 | 5.0 | 3.7 |
| | | 45.0 | 2.50E+05 | 526 | 476 | 2.2 U | 440 | 9.9 | 7.6 | 0.9 U | ND | 2.7 | 8.2 | 0.55 | 0.89 |
| MIP-10 | 17-Mar-05 | 32.0 | ND | None | 310 | 1.1 U | 280 | 10 | 9.8 | 0.45 U | 5.00E+05 | 2.4 | 83 | 0.24 | 0.36 |
| | | 43.0 | 2.50E+05 | 341 | 733 | 2.2 U | 680 | 17 | 18 | 0.9 U | ND | 3.1 | 15 | 1.6 | 1.6 |
| | | 48.0 | ND | None | 425 | 0.90 U | 400 | 9.6 | 7.4 | 0.36 U | ND | 150 | 14000 | 1.4 | 0.53 |
| MIP-13 | 16-Mar-05 | 33.5 | 2.00E+06 | 2494 | 802 | 0.45 U | 170 | 590 | 41 | 0.51 J | ND | 3.0 | 4900 | 9.4 | 7.6 |
| | | 43.0 | 2.50E+05 | 310 | 807 | 0.45 U | 160 | 630 | 14 | 2.2 | ND | 37 | 11000 | 0.90 | 0.49 |
| | | 47.5 | 2.00E+05 | 801 | 250 | 0.45 U | 4.5 | 240 | 3.8 | 0.96 J | 6.00E+06 | 130 | 20000 | 2.7 | 1.5 |
| MIP-14 | 16-Mar-05 | 36.0 | 4.50E+05 | 300 | 1,499 | 0.45 U | 120 | 1,300 | 66 | 6.5 | ND | 7.2 | 14000 | 15 | 11 |
| | | 42.0 | 1.00E+05 | 145 | 688 | 2.2 U | 630 | 25 | 15 | 0.9 U | ND | 1.8 | 4300 | 0.56 | 0.47 |
| | | 46.0 | 3.50E+05 | 1076 | 325 | 1.1 U | 300 | 10 | 4.7 | 0.45 U | ND | 2.0 | 70 | 15 | 16 |
| | | 49.0 | 4.00E+05 | 1607 | 249 | 0.45 U | 180 | 62 | 2.4 | 0.18 U | 2.50E+06 | 3.2 | 660 | 4.6 | 4.9 |
| MIP-15 | 17-Mar-05 | 36.0 | 1.50E+06 | 579 | 2,589 | 11 U | 2,300 | 99 | 89 | 4.5 U | ND | 3.2 | 53 | 0.41 | 0.52 |
| | | 42.0 | 2.50E+05 | 370 | 675 | 2.2 U | 630 | 15 | 12 | 0.9 U | ND | 3.1 | 1900 | 5.1 | 4.4 |
| | | 54.0 | ND | None | 158 | 0.45 U | 19 | 130 | 1.7 | 3.1 J | 5.00E+06 | 170 | 30000 | 4.9 | 8.5 |
| MIP-16 | 15-Mar-05 | 36.0 | 2.00E+06 | 1887 | 1,060 | 0.45 U | 850 | 150 | 54 | 0.4 J | ND | 2.2 | 3100 | 13 | 8.3 |
| | | 45.0 | ND | None | 323 | 0.45 U | 280 | 33 | 4.9 | 0.20 J | 2.50E+05 | 2.3 | 7000 | 13 | 14 |
| | | 53.0 | ND | None | 135 | 0.45 U | 71 | 57 | 2.3 | 0.18 U | 2.00E+06 | 4.6 | 1700 | 3 | 3.5 |
| MIP-17 | 15-Mar-05 | 39.0 | 7.50E+05 | 386 | 1,941 | 0.45 U | 1,800 | 66 | 67 | 0.53 J | ND | 1.7 | 15 | 13 | 5.2 |
| | | 42.0 | 6.00E+05 | 915 | 656 | 0.45 U | 620 | 14 | 12 | 0.90 U | ND | 2.3 | 560 | 12 | 12 |
| | | 46.0 | 3.50E+05 | 897 | 390 | 0.45 U | 370 | 8.6 | 6.5 | 0.18 U | ND | 2.4 | 230 | 3.7 | 3.9 |
| | | 50.0 | ND | None | 227 | 0.45 U | 200 | 19 | 3.6 | 0.18 U | ND | 3.8 | 7.5 | 1.1 | 1.0 |
| MIP-19 | 15-Mar-05 | 38.0 | 9.50E+05 | 766 | 1,240 | 0.45 U | 250 | 930 | 50 | 2.4 | 7.00E+05 | 5.8 | 18000 | 21 | 15 |
| | | 42.0 | 2.00E+05 | 322 | 621 | 0.45 U | 17 | 580 | 18 | 0.59 J | 2.00E+06 | 4.3 | 20000 | 3.6 | 2.8 |
| | | 47.0 | 5.00E+05 | 2670 | 187 | 0.45 U | 8.4 | 170 | 4.0 | 0.97 J | ND | 16 | 28000 | 6 | 7.3 |
| | | 52.0 | 2.00E+05 | 733 | 273 | 0.45 U | 23 | 240 | 4.8 | 0.93 J | 4.00E+06 | 5.6 | 17000 | 14 | 18 |
| MIP-21 | 15-Mar-05 | 43.0 | 1.80E+06 | 935 | 1,926 | 4.50 U | 1,500 | 330 | 55 | 1.8 U | ND | 1.9 | 1900 | 72 | 37 |
| | | 56.0 | ND | None | 151 | 0.77 J | 130 | 14 | 1.7 | 0.18 U | 1.00E+07 | 3.9 | 30 | 7.2 | 7.8 |
| MIP-23 | 15-Mar-05 | 36.0 | 2.50E+06 | 1427 | 1,752 | 0.45 U | 1,400 | 240 | 85 | 1.8 U | ND | 0.8 | 5000 | 24 | 6.7 |
| MIP-24 | 16-Mar-05 | 36.5 | 1.00E+06 | 516 | 1,939 | 0.45 U | 1,800 | 62 | 69 | 0.97 J | ND | 1.7 | 110 | 7.8 | 5.6 |
| | | 53.0 | ND | None | 179 | 0.45 U | 12 | 160 | 1.8 | 1.4 | 2.00E+06 | 230 | 19000 | 0.14 | 0.05 |
| MIP-31 | 16-Mar-05 | 43.0 | 4.00E+06 | 3460 | 1,156 | 0.45 U | 1,100 | 24 | 26 | 0.23 J | ND | 2.6 | 39 | 1.3 | 1.4 |
| MIP-32 | 16-Mar-05 | 40.0 | 1.00E+06 | 873 | 1,145 | 0.45 U | 1,100 | 20 | 17 | 1.8 U | 2.00E+05 | 18 | 39 | 48 | 47 |

[a] PCE = tetrachloroethene; TCE = trichloroethene; DCE = dichloroethene; TCA = trichloroethane; DCA = dichloroethane.

[b] µg/L = micrograms per liter.

[c] U = Analyte was not detected at a concentration above the method detection limit.

[d] J = Analyte was detected at a concentration above the method detection limit and below the reporting limit

# TABLE 5
## SUMMARY OF SOIL ANALYTICAL DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Sample Date | Sample Depth (feet bgs)[a] | Stratigraphy | Total Organic Carbon (mg/kg)[d] | TCE[b] (µg/kg)[c] | *cis-* 1,2-DCE[b] (µg/kg) | *trans-* 1,2-DCE (µg/kg) | Vinyl Chloride (µg/kg) | 1,2-DCA[b] (µg/kg) | Carbon Tetrachloride (µg/kg) | Acetone (µg/kg) | 2-Butanone (µg/kg) | Bromomethane (µg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PES-SB-1 | 16-Mar-05 | 32 - 35 | Cohesive silt, mild odor, staining | **410** | **220** | **100** | 17 U | 17 U | 24 U | 19 U | 67 U | 84 U | 29 U |
| | 16-Mar-05 | 35 - 36 | Cohesive Silt, mild odor, staining | **830** | **510** | **490** | 17 U | 17 U | 24 U | 19 U | 67 U | 84 U | 29 U |
| | 16-Mar-05 | 37 - 38 | Sandy Silt, mild odor, staining | **330** | **80** | **2,100** | **83** | 17 U | 24 U | 19 U | 69 U | 87 U | 29 U |
| PES-SB-2 | 15-Mar-05 | 37 - 38 | Sandy silt, strong odor, heavy staining | **6,200** | **7,700** | **850** | **56 J**[e] | 17 U | 23 U | 20 U | 69 U | 87 U | 19 U |
| PES-SB-3 | 14-Mar-05 | 42 | Non-plastic silt with fine sand, moderate odor, staining | **1,700** | **2,400** | **610** | **75** | 17 U | 24 U | 19 U | 67 U | 84 U | 19 U |
| PES-SB-4 | 24-Mar-05 | 30 | Sandy silt, no odor, no staining | **480 J** | **1,000** | 22 U | **19 J** | 16 U | 24 U | 19 U | 65 U | 81 U | 28 U |
| | 24-Mar-05 | 31 | Sandy Silt, no odor, no staining | **3,700** | **710** | 23 U | 17 U | 17 U | 24 U | 19 U | 66 U | 83 U | 28 U |
| | 24-Mar-05 | 42 - 44 | Fine sand, no odor, no staining | **160 J** | **110** | 24 U | 17 U | 17 U | 23 U | 20 U | 69 U | 87 U | 29 U |
| PES-SB-5 | 7-Apr-05 | 42 - 44 | Fine - medium sand, no odor, no staining | **230 J** | **77** | 24 U | 17 U | 17 U | 25 U | 20 U | **130 J** | 87 U | 29 U |
| PES-SB-6 | 7-Apr-05 | 36 - 38 | Fine sand, strong odor | **550** | 23 U | **43 J** | 17 U | 17 U | 24 U | 19 U | 66 U | 84 U | 28 U |
| PES-SB-7 | 23-Mar-05 | 32 - 34 | Tight clay with medium sand | **2,800** | **2,100** | **57 J** | **91** | 18 U | 26 U | 20 U | 71 U | 90 U | 30 U |
| | 7-Apr-05 | 34 - 36 | Cohesive Sandy Silt, no odor | **340 J** | **50 J** | **210** | **18 U** | 18 U | 26 U | 20 U | 70 U | 88 U | 30 U |
| | 3-Mar-05 | 46 - 48 | Find sand, strong odor | **300 J** | 24 U | 24 U | 18 U | 18 U | 25 U | 20 U | 70 U | 88 U | 30 U |
| PES-SB-8 | 17-Mar-05 | 46 | Silt, no odor, some staining | **280** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | 17-Mar-05 | 48 - 50 | Fine Sand and Silt, mild odor | **230 J** | **81** | 24 U | 17 U | 17 U | 25 U | 19 U | 68 U | 85 U | 19 U |
| | 17-Mar-05 | 51 | Fine Sand and Silt, no odor | **280 J** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | 17-Mar-05 | 56 | Fine - coarse sand, no odor | **330 J** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PES-SB-9 | 7-Apr-05 | 34 - 36 | Fine sand with silt, mild-strong odor | **350 J** | **85** | **150** | 17 U | 17 U | 25 U | 19 U | 67 U | 85 U | 29 U |
| | 21-Mar-05 | 46 | Fine - medium sand with silt, mild odor, weak staining | **1,200** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | 21-Mar-05 | 51 | Silty sand, mild odor | **210 J** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | 21-Mar-05 | 56 | Fine - coarse silty sand, mild odor | **350 J** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PES-SB-10 | 22-Mar-05 | 51 | Fine sand, no odor | **290 J** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| | 22-Mar-05 | 56 | Fine - medium sand, no odor | **240 J** | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| PES-MW-10B | 31-Mar-05 | 36 - 38 | sandy silt, no odor | **610** | **1,600** | 22 U | **25 J** | 16 U | 23 U | 18 U | 64 U | 81 U | 27 U |
| | 31-Mar-05 | 40 - 42 | sandy silt, no odor | **1,000** | **1,600** | 23 U | **24 J** | 16 U | 24 U | 19 U | 65 U | 82 U | 28 U |
| | 31-Mar-05 | 49 - 50 | fine sand, no odor | **370 J** | 24 U | 24 U | 17 U | 17 U | 25 U | 20 U | 69 U | 87 U | 29 U |
| | 31-Mar-05 | 70 - 71 | Fine - medium sand, no odor | **220 J** | 24 U | 24 U | 17 U | 17 U | 25 U | 20 U | 68 U | 85 U | 29 U |
| PES-MW-11A | 29-Mar-05 | 42 - 44 | Sandy silt, no odor | **470 J** | **1,800** | 22 U | **26 J** | 16 U | 23 U | 18 U | 64 U | 81 U | 27 U |
| | 29-Mar-05 | 48 - 50 | fine sand, no odor | **310 J** | **100** | 24 U | 17 U | 17 U | 25 U | 20 U | 69 U | 87 U | 30 U |
| PES-MW-12B | 5-Apr-05 | 62 - 63 | Cohesive tight clay. no odor. | **5,900** | **190** | 25 U | 18 U | 18 U | 26 U | 20 U | **140 J** | 89 U | 30 U |
| PES-MW-13A | 28-Mar-05 | 26 [f] | Sandy silt, no odor | **610** | **200** | 22 U | 16 U | 16 U | 23 U | 18 U | 64 U | 80 U | 27 U |
| | 28-Mar-05 | 27 | sandy silt, no odor | **460 J** | **89** | 22 U | 17 U | 16 U | 23 U | 18 U | 64 U | 81 U | 27 U |
| | 28-Mar-05 | 42 | Fine sand, no odor | **330 J** | **59** | 23 U | 17 U | 17 U | 24 U | 19 U | 66 U | 84 U | 28 U |
| PES-MW-14B | 4-Apr-05 | 40 - 42 | Sandy silt, no odor | **580** | **220** | **130** | 16 U | 16 U | 23 U | 18 U | 63 U | 79 U | 27 U |
| | 4-Apr-05 | 42 | Sandy silt, no odor | **510** | **200** | **250** | **22 J** | 16 U | 23 U | 18 U | 64 U | 81 U | 27 U |
| | 4-Apr-05 | 68 - 70 | Fine sand, no odor | **370 J** | 23 U | 23 U | 17 U | 17 U | 24 U | 19 U | **360** | 84 U | 28 U |

[a] feet bgs = feet below ground surface.

[b] TCE = trichloroethene; DCE = dichloroethene; DCA = dichloroethane.

[c] µg/kg = micrograms per kilogram.

[d] mg/kg = milligrams per kilogram.

[e] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated value.

# TABLE 6
## SUMMARY OF PLFA AND TARGETED GENE DETECTION DATA IN SOIL AND GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| | | | | | | Dechlorinating Bacteria | | | | | DHC Functional Genes | | | Phylogenic Groups | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Location | Sample Date | Sample Depth (feet bgs)[a] | Stratigraphic Classification | Evidence of Organic Carbon Impact | Total Organic Carbon (mg/kg)[b] | DHC[c] (cells/gram)[d] | DSM[c] (cells/gram) | DHB[c] (cells/gram) | DSB[c] (cells/gram) | Geobacter (cells/gram) | BVC[c] (cells/gram) | TCER[c] (cells/gram) | sMMO[c] (cells/gram) | Eubacteria (cells/gram) | Methanogens (cells/gram) | Sulfate+Iron Reducers (cells/gram) | Methanotrophs (cells/gram) | Total Biomass (cells/gram) |
| **Soil Samples Impacted by Vegetable Oil** | | | | | | | | | | | | | | | | | | |
| PES-SB-1 | 16-Mar-05 | 32-35 | Silt | Mild Odor | 410 | 2.00E+04 | <1.75E+03[e] | 1.64E+07 | 5.32E+08 | 7.77E+03 | 4.33E+01 J | <8.76E+02 | 3.76E+05 | 4.73E+08 | 3.11E+07 | 7.92E+06 | 2.13E+09 | 1.21E+08 |
| PES-SB-2 | 15-Mar-05 | 37-38 | F-M Sand | Strong Odor | 6,200 | 9.76E+04 | <1.70E+03 | 2.73E+07 | <1.70E+03 | 6.70E+02 | 2.47E+03 | 3.01E+02 J | 7.36E+02 | 2.26E+09 | 1.09E+04 | 1.48E+06 | 4.98E+09 | 1.29E+07 |
| PES-SB-3 | 14-Mar-05 | 42 | Silty Fine Sand | Moderate Odor, Staining | 1,700 | 1.20E+03 | <1.82E+03 | 4.47E+07 | <1.82E+03 | <1.37E+03 | 2.19E+01 J | 2.40E+02 J | 1.23E+03 J | 1.62E+09 | 6.61E+06 | 3.50E+07 | 7.95E+09 | 1.09E+08 |
| PES-SB-6 | 23-Mar-05 | 36-38 | Fine Sand | Strong Odor | 550 | 1.25E+04 | 1.24E+03 J[f] | 2.94E+07 | 8.30E+07 | 1.40E+03 | 1.19E+02 J | 4.40E+03 | 1.08E+01 J | 8.36E+08 | 4.31E+05 | 6.08E+05 | 2.95E+09 | 1.58E+08 |
| PES-SB-7 | 23-Mar-05 | 46-48 | Fine Sand | Strong Odor | 300 J | 6.48E+04 | <1.59E+03 | 9.08E+07 | 3.25E+06 | 1.44E+02 J | 4.94E+02 J | <7.96E+02 | 1.55E+07 | 2.84E+09 | 5.21E+06 | 7.96E+05 | 3.77E+10 | 1.93E+08 |
| PES-SB-9 | 21-Mar-05 | 46 | Silty Fine Sand | Moderate Odor, Staining | 1,200 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 4.83E+08 |
| PES-SB-9 | 21-Mar-05 | 51 | Silty Fine Sand | Mild Odor | 210 J | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 4.21E+07 |
| PES-SB-9 | 21-Mar-05 | 56 | F-C Sand | Mild Odor | 350 J | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1.02E+07 |
| PES-SB-10 | 22-Mar-05 | 46 | Fine Sand | Strong Odor | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 2.60E+08 |
| PES-MW-10B | 31-Mar-05 | 49-50 | Fine Sand | Mild Odor | 370 J | <9.98E+02 | <2.00E+03 | 1.78E+03 J | 5.58E+06 | 7.11E+02 | <9.98E+02 | <9.98E+02 | 2.40E+08 | 1.13E+09 | 6.04E+08 | 3.99E+06 | 3.25E+08 | 2.45E+08 |
| PES-SB-3 | 14-Mar-05 | 32 | Sandy Silt | Very Mild Odor | NA | 2.45E+04 | <1.69E+03 | 6.41E+04 | <1.69E+03 | 1.26E+03 | 2.11E+02 J | <8.43E+02 | <1.69E+03 | 6.67E+06 | <1.69E+03 | <1.29E+03 | 1.39E+05 | 4.52E+05 |
| **Soil Samples Un-Impacted by Vegetable Oil** | | | | | | | | | | | | | | | | | | |
| PES-SB-4 | 24-Mar-05 | 42-44 | Fine Sand | None | 160 J | <4.0E+02 | <7.99E+02 | 4.99E+04 | 1.24E+05 | <6.00E+02 | <4.00E+02 | <4.00E+02 | <7.99E+02 | 7.43E+07 | 4.05E+04 | <6.00E+02 | 3.46E+05 | 1.98E+06 |
| PES-SB-5 | 25-Mar-05 | 42-44 | F-m Sand | None | 230 J | 4.17E+03 | <1.54E+03 | 1.04E+05 | <1.54E+03 | <1.15E+03 | 1.55E+01 J | <7.69E+02 | <1.54E+03 | 5.81E+07 | <1.54E+03 | <1.15E+03 | 3.42E+05 | 5.30E+05 |
| PES-SB-8 | 17-Mar-05 | 46 | Silty Fine Sand | None | 280 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 2.37E+05 |
| PES-SB-8 | 17-Mar-05 | 51 | Fine Sand and Silt | None | 280 J | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 6.26E+05 |
| PES-SB-8 | 17-Mar-05 | 56 | F-C Sand | None | 330 J | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 2.11E+05 |
| PES-SB-10 | 22-Mar-05 | 51 | Fine sand | None | 290 J | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1.49E+08 |
| PES-SB-10 | 22-Mar-05 | 56 | F-M Sand | None | 240 J | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 7.98E+06 |
| PES-MW-10B | 31-Mar-05 | 70-71 | F-M Sand | None | 220 J | 1.38E+03 | <1.97E+03 | 1.06E+05 | 5.14E+06 | <1.48E+03 | <9.84E+02 | <9.84E+02 | 6.61E+05 | 3.14E+08 | 6.89E+05 | <1.48E+03 | 1.03E+07 | 1.53E+06 |
| PES-MW-11A | 29-Mar-05 | 48-50 | Fine Sand | None | 310 J | 1.38E+03 | <8.71E+02 | 6.83E+05 | 4.03E+06 | 4.88E+00 J | <4.36E+02 | 5.46E+02 | 1.44E+01 J | 4.60E+08 | 6.74E+05 | <6.53E+02 | 3.66E+07 | 7.50E+05 |
| PES-MW-12B | 5-Apr-05 | 62-63 | Tight Clay | None | 5,900 | 6.24E+07 | <1.83E+03 | 5.90E+04 | 4.27E+05 | <1.38E+03 | <9.17E+02 | <9.17E+02 | 9.34E+02 | 2.43E+08 | 9.08E+04 | 1.94E+02 J | 3.38E+05 | 6.11E+05 |
| PES-MW-14B | 4-Apr-05 | 68-70 | Fine Sand | None | 370 J | 2.04E+06 | <1.90E+03 | 1.97E+04 | 1.41E+07 | <1.43E+03 | 6.57E+02 J | <9.51E+02 | 1.03E+04 | 3.55E+08 | 4.62E+06 | <1.43E+03 | 6.27E+06 | 7.54E+05 |
| PES-MW-13A | 28-Mar-05 | 42 | Fine Sand | None | 330 J | 5.54E+04 | <1.46E+03 | 1.84E+05 | <1.46E+03 | <1.09E+03 | 3.99E+01 J | <7.28E+02 | <1.46E+03 | 3.54E+05 | <1.46E+03 | <1.09E+03 | 3.85E+05 | 1.26E+05 |
| **Groundwater Samples Impacted by Vegetable Oil** | | | | | | | | | | | | | | | | | | |
| PES-INJ-02 | 19-Apr-05 | 40.0 - 50.0 | NA | NA | 2,400 | <2.5E-01 | <5.0E-01 | 9.82E+02 | 3.69E+04 | <3.75E-01 | <2.50E-01 | <2.50E-01 | 1.65E+02 | 2.54E+05 | 3.87E+03 | <3.75E-01 | 6.58E+03 | 7.14E+06 |
| PES-MW-10A | 15-Apr-05 | 45.0 - 55.0 | NA | NA | 190 | <2.5E-01 | <5.0E-01 | 2.87E+04 | 1.68E+05 | 5.85E+00 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 7.46E+07 | 2.23E+05 | 1.22E+04 | 1.36E+06 | 3.18E+06 |
| PES-MW-14A | 12-Apr-05 | 55.0 - 65.0 | NA | NA | 50 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 3.33E+05 |
| **Groundwater Samples Un-Impacted by Vegetable Oil** | | | | | | | | | | | | | | | | | | |
| 18S | 18-Apr-05 | 27.8 - 37.8 | NA | NA | 3.8 | <2.5E-01 | <5.0E-01 | 1.34E+04 | 1.20E+05 | <3.75E-01 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 3.34E+06 | 3.09E+03 | 1.09E+02 | 5.76E+05 | 2.47E+04 |
| 26S | 15-Apr-05 | 30.0 - 40.0 | NA | NA | 2.2 | <2.5E-01 | <5.0E-01 | 4.13E+02 | 6.23E+03 | <3.75E-01 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 1.16E+05 | 2.42E+03 | <3.75E-01 | 2.61E+03 | 1.28E+04 |
| GWMS-46S | 18-Apr-05 | 24.0 - 34.0 | NA | NA | 3.7 | <2.5E-01 | <5.0E-01 | 1.52E+03 | 1.85E+04 | 3.86E-02 J | <2.50E-01 | <2.50E-01 | <5.0E-01 | 2.75E+06 | 4.75E+03 | 3.29E+01 | 4.18E+04 | 3.64E+03 |
| PES-MW-1 | 15-Apr-05 | 35.0 - 45.0 | NA | NA | 3.0 | <2.5E-01 | <5.0E-01 | 3.11E+04 | 2.24E+05 | 8.61E-01 | <2.50E-01 | <2.50E-01 | 1.52E+04 | 1.05E+08 | 1.34E+05 | 3.19E+04 | 1.03E+06 | 1.13E+05 |
| PES-MW-6 | 15-Apr-05 | 35.0 - 45.0 | NA | NA | 2.6 | 3.23E+00 | <5.0E-01 | 3.16E+04 | 1.81E+05 | 8.61E-01 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 9.03E+07 | 1.02E+05 | 1.14E+04 | 1.16E+06 | 6.93E+04 |
| PES-MW-7 | 15-Apr-05 | 40.0 - 50.0 | NA | NA | 29 | 4.79E+00 | 1.84E+00 | 1.87E+04 | 2.09E+05 | 2.68E+00 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 9.77E+05 | 2.21E+05 | 1.85E+03 | 7.27E+05 | 4.03E+05 |
| PES-MW-9 | 13-Apr-05 | 30.0 - 40.0 | NA | NA | 3.6 | 4.19E+00 | <5.0E-01 | 1.49E+03 | 9.34E+04 | <3.75E-01 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 6.34E+07 | 7.08E+03 | 3.46E+01 | 1.78E+04 | 2.06E+04 |
| PES-MW-10B | 14-Apr-05 | 65.0 - 75.0 | NA | NA | 3.3 | 8.95E-01 | <5.0E-01 | 4.31E+02 | 9.99E+02 | <3.75E-01 | <2.50E-01 | <2.50E-01 | <5.0E-01 | 2.55E+05 | 6.60E+03 | <3.75E-01 | 2.33E+04 | 2.88E+04 |
| PES-MW-12A | 12-Apr-05 | 35.0 - 45.0 | NA | NA | 6.0 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1.12E+05 |

[a] feet bgs = feet below ground surface.

[b] mg/kg = micrograms per kilogram.

[c] DHC = Dehalococcoides; DSM = Desulfuromonas; DHB = Dehalobacter; DSB = Desulfitobacterium; BVC = BAV-1 VC R-Dase; TCER = TCE R-Dase; sMMO = Soluble Methane Monooxygenase

[d] cell/gram = live microbial cells per gram of soi

[e] <1.75E+03 indicates that the analyte was not detected above the indicated method detection limit

[f] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated valu

# TABLE 7
## SUMMARY OF AQUEOUS AND MINERALOGICAL INTRINSIC BIOREMEDIATION ASSESSMENT RESULTS
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Sample Date | Sample Depth (feet bgs)[a] | Stratigraphic Classification | Evidence of Organic Carbon Impact | Total Organic Carbon (mg/kg)[d] | $BAFe^{3+}$ [b] (mg/kg)[c] | WAEFe [b] (mg/kg) | SAEFe [b] (mg/kg) | O-$Fe^{total}$ [b] (mg/kg) | BAMn [b] (mg/kg) | WAEMn [b] (mg/kg) | SAEMn [b] (mg/kg) | AVS [b] (mg/kg) | CES [b] (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Samples Impacted by Vegetable Oil** | | | | | | | | | | | | | | |
| PES-SB-1 | 16-Mar-05 | 35 | Silt | Mild Odor | 410 | 423 | 550 | 540 | <5.9 | 15.6 | <100 | <200 | 1,600 | 6300 |
| PES-SB-2 | 15-Mar-05 | 38 | F-M Sand | Strong Odor | 6,200 | 1,430 | 250 | 4,400 | 100 | 41.5 | <100 | <200 | 1,300 | 2,200 |
| PES-SB-3 | 14-Mar-05 | 42 | Silty Fine Sand | Strong Odor, staining | 1,700 | 1,040 | 150 | 5,800 | <5.8 | 4.5 | <100 | <200 | <1200 | 1,500 |
| PES-SB-3 | 14-Mar-05 | 60 | Silty Fine Sand | Mild Odor | NA | <6.0 | 150 | 1,960 | <6.0 | 1,890 | <100 | <200 | 1,200 | 1,900 |
| PES-SB-9 | 21-Mar-05 | 36 | Silty Fine Sand | Moderate Odor | 350 J | 929 | 600 | 6,500 | <5.8 | 1.6 | <100 | <200 | <1200 | 1400 |
| PES-SB-10 | 22-Mar-05 | 46 | Fine Sand | Strong Odor | NA | 1,540 | 1,100 | 7,000 | 7.4 | 12.1 | <100 | <200 | <1200 | 3200 |
| | | | | | **Average Concentrations** | 1,072 [g] | 467 | 4,367 | 11.6 | 15 [g] | <100 | <200 | 983 | 2,750 |
| **Samples Un-Impacted by Vegetable Oil** | | | | | | | | | | | | | | |
| PES-SB-1 | 16-Mar-05 | 56 | Silty Fine Sand | None | NA | 1,100 | 150 | 7,900 | 282 | 114 | <100 | <200 | 2,200 | 11,000 |
| PES-SB-2 | 15-Mar-05 | 60 | Fine Sand | None | NA | 990 | 150 | 4,700 | <6.0 | 12.0 | <100 | <200 | 1,300 | 1,800 |
| PES-SB-4 | 24-Mar-05 | 44 | Fine Sand | None | 160 J | 544 | 200 | 5,000 | <6.0 | 20.3 | <100 | <200 | <1200 | 4,100 |
| PES-SB-4 | 24-Mar-05 | 54 | Fine Sand | None | NA | 1,020 | 150 | 1,800 | <6.1 | 29.7 | <100 | 7,000 | <1200 | 14,000 |
| PES-SB-8 | 17-Mar-05 | 50 | Silty Fine Sand | None | 230 J | 2,920 | 300 | 2,700 | 656 | 96.2 | <100 | <200 | <1200 | <1200 |
| | | | | | **Average Concentrations** | 1,315 | 190 | 4,420 | 124 | 54 | <100 | <200 [g] | 1,060 | 6300 |

[a] feet bgs = feet below ground surface.

[b] $BAFe^{3+}$ = bioavailable ferric iron; $WAEFe^{3+}$ = weak acid extractable ferric iron; $SAEFe^{3+}$ = strong acid extractable ferric iron; $WAEFe^{2+}$ = weak acid extractable ferrous iron; $SAEFe^{2+}$ = strong acid extractable ferrous iron; O-$Fe^{total}$ = total oxidized iron; BAMn = bioavailable manganese; WAEMn = weak acid manganese; SAEMn = strong acid extractable manganese; AVS = acid volatile sulfide; CES = chromium extractable sulfide.

[c] mg/kg = micrograms per kilogram.

[d] <25 indicates that the analyte was not detected above the indicated method detection limit.

[f] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated value.

[g] One value that is significantly different from the population was discluded from this calculation.

# TABLE 8
## SUMMARY OF GROUNDWATER ELEVATION DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Well/Borehole Identification | Date | Elevation Datum (Feet amsl)[a] | Depth to Water (Feet btoc)[b] | Depth to Oil (Feet btoc) | Groundwater Elevation[c] (Feet amsl) |
|---|---|---|---|---|---|
| **MONITORING WELLS** | | | | | |
| 18-S | 11-Apr-05 | 833.86 | 25.53 | N.E. [d] | 808.33 |
| | 4-Nov-05 | | 27.88 | N.E. | 805.98 |
| 26-S | 11-Apr-05 | 834.06 | 25.98 | N.E. | 808.08 |
| | 4-Nov-05 | | 28.30 | N.E. | 805.76 |
| GWMS-27S | 11-Apr-05 | 832.74 | 27.35 | N.E. | 805.39 |
| | 4-Nov-05 | | 29.72 | N.E. | 803.02 |
| GWMS-45S | 11-Apr-05 | 832.13 | 24.10 | N.E. | 808.03 |
| | 4-Nov-05 | | 26.37 | N.E. | 805.76 |
| GWMS-46S | 11-Apr-05 | 831.67 | 24.41 | N.E. | 807.26 |
| | 4-Nov-05 | | 26.14 | N.E. | 805.53 |
| GWMS-47S | 11-Apr-05 | 834.83 | 30.47 | N.E. | 804.36 |
| | 4-Nov-05 | | 32.62 | N.E. | 802.21 |
| GWMS-49S | 11-Apr-05 | 834.16 | N.M. [d] | N.E. | N.M. |
| | 4-Nov-05 | | 32.61 | N.E. | 801.55 |
| MWW-13 | 11-Apr-05 | 833.33 | 28.53 | N.E. | 804.80 |
| | 4-Nov-05 | | 30.31 | N.E. | 803.02 |
| PES-MW-1 | 11-Apr-05 | 832.49 | 24.66 | N.E. | 807.83 |
| | 4-Nov-05 | | 26.92 | N.E. | 805.57 |
| PES-MW-2 | 11-Apr-05 | 832.41 | 24.66 | N.E. | 807.75 |
| | 4-Nov-05 | | 26.93 | N.E. | 805.48 |
| PES-MW-3 | 11-Apr-05 | 832.80 | 25.72 | N.E. | 807.08 |
| | 4-Nov-05 | | N.M. | N.E. | N.M. |
| PES-MW-4 | 11-Apr-05 | 832.57 | 27.91 | N.E. | 804.66 |
| | 4-Nov-05 | | N.M. | N.E. | N.M. |
| PES-MW-5 | 11-Apr-05 | 832.60 | 27.94 | N.E. | 804.66 |
| | 4-Nov-05 | | 30.01 | N.E. | 802.59 |
| PES-MW-6 | 11-Apr-05 | 832.41 | 24.63 | N.E. | 807.78 |
| | 4-Nov-05 | | 26.90 | N.E. | 805.51 |
| PES-MW-7 | 11-Apr-05 | 832.58 | 24.81 | N.E. | 807.77 |
| | 4-Nov-05 | | 27.07 | N.E. | 805.51 |
| PES-MW-8 | 11-Apr-05 | 832.64 | 25.00 | N.E. | 807.64 |
| | 4-Nov-05 | | 27.26 | N.E. | 805.38 |
| PES-MW-9 | 11-Apr-05 | 832.85 | 25.18 | N.E. | 807.67 |
| | 4-Nov-05 | | 27.48 | N.E. | 805.37 |
| PES-MW-10A | 11-Apr-05 | 832.17 | 24.47 | N.E. | 807.70 |
| | 4-Nov-05 | | 26.74 | N.E. | 805.43 |
| PES-MW-10B | 11-Apr-05 | 832.11 | 24.33 | N.E. | 807.78 |
| | 4-Nov-05 | | 26.62 | N.E. | 805.49 |
| PES-MW-11A | 11-Apr-05 | 832.28 | 24.04 | N.E. | 808.24 |
| | 4-Nov-05 | | 26.93 | N.E. | 805.35 |
| PES-MW-12A | 11-Apr-05 | 833.89 | 29.53 | N.E. | 804.36 |
| | | | 31.71 | N.E. | 802.18 |
| PES-MW-12B | 11-Apr-05 | 833.80 | 29.48 | N.E. | 804.32 |
| | | | N.M. | N.E. | N.M. |

# TABLE 8
## SUMMARY OF GROUNDWATER ELEVATION DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Well/Borehole Identification | Date | Elevation Datum (Feet amsl)[a] | Depth to Water (Feet btoc)[b] | Depth to Oil (Feet btoc) | Groundwater Elevation[c] (Feet amsl) |
|---|---|---|---|---|---|
| PES-MW-13A | 11-Apr-05 | 832.15 | 24.17 | N.E. | 807.98 |
| | 4-Nov-05 | | 26.46 | N.E. | 805.69 |
| PES-MW-14A | 11-Apr-05 | 831.74 | 24.25 | N.E. | 807.49 |
| | 4-Nov-05 | | 26.53 | N.E. | 805.21 |
| PES-MW-14B | 11-Apr-05 | 831.84 | 24.28 | N.E. | 807.56 |
| | 4-Nov-05 | | 26.56 | N.E. | 805.28 |
| PES-CW-1 | 11-Apr-05 | 832.01 | 27.17 | N.E. | 804.84 |
| | 4-Nov-05 | | 29.36 | N.E. | 802.65 |
| PES-CW-2 | 11-Apr-05 | 833.02 | 28.25 | N.E. | 804.77 |
| | 4-Nov-05 | | 30.55 | N.E. | 802.47 |
| PES-CW-3 | 11-Apr-05 | 835.47 | 30.89 | N.E. | 804.58 |
| | 4-Nov-05 | | 33.09 | N.E. | 802.38 |
| PES-BG-1 | 11-Apr-05 | 832.75 | 24.87 | N.E. | 807.88 |
| | 4-Nov-05 | | 27.12 | N.E. | 805.63 |
| PES-BG-2 | 11-Apr-05 | 832.73 | 24.91 | N.E. | 807.82 |
| | 4-Nov-05 | | 27.18 | N.E. | 805.55 |
| PES-BG-3 | 11-Apr-05 | 832.56 | 24.72 | N.E. | 807.84 |
| | 4-Nov-05 | | 26.95 | N.E. | 805.61 |
| **INJECTION WELLS** | | | | | |
| PES-INJ-1 | 11-Apr-05 | 832.42 | 24.64 | N.E. | 807.78 |
| | 4-Nov-05 | | 26.84 | N.E. | 805.58 |
| PES-INJ-2 | 11-Apr-05 | 832.87 | 25.14 | N.E. | 807.73 |
| | 4-Nov-05 | | 27.38 | N.E. | 805.49 |
| PES-INJ-3 | 11-Apr-05 | 832.71 | 25.28 | 25.04 | 807.65 |

[a] Feet amsl indicates elevation in feet above mean sea level.

[b] Feet btoc indicates depth in feet below top of casing.

[c] Water elevations corrected for presence of oil using a specific gravity of 0.92.

[d] N.M. = not measured.

[e] N.E. = not encountered.

# TABLE 9
## PRE- AND POST-INJECTION HYDRAULIC CONDUCTIVITIES AND AVERAGE GROUNDWATER VELOCITIES
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Monitoring Well | Test Date | Rising or Falling Test | Screened Interval (ft bgs)[a] | Casing Inside Diameter (inches) | Static Water Level (feet btoc) | Hydraulic Conductivity (K) (ft/day)[b] | (cm/sec)[c] | (gpd/ft²)[d] | Estimated Effective Porosity | Hydraulic Gradient (ft/ft)[e] | Maximum Groundwater Velocity (ft/yr)[f] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pre-Injection Slug Tests in the Injection Area** | | | | | | | | | | | |
| PES-INJ-1 | 12/7/01 | Both | 35-45 | 3.0 | 28.37 | 210 | 7.43E-02 | 1,574 | 0.25 | 0.002 | 522 |
| PES-INJ-2 | 12/7/01 | Both | 30-40 | 3.0 | 28.84 | 221 | 7.79E-02 | 1,651 | 0.25 | 0.002 | 548 |
| PES-INJ-3 | 12/7/01 | Both | 40-50 | 3.0 | 28.73 | 254 | 8.96E-02 | 1,898 | 0.25 | 0.002 | 630 |
| PES-MW-1 | 12/7/01 | Both | 35-45 | 2.0 | 28.55 | 177 | 6.23E-02 | 1,321 | 0.25 | 0.002 | 438 |
| **GEOMETRIC MEAN** | | | | | | **214** | **7.54E-02** | **1,597** | **0.25** | **0.00** | **530** |
| **Pre-Injection Slug Tests Down Gradient From the Injection Area** | | | | | | | | | | | |
| PES-MW-3 | 12/6/01 | Both | 35-45 | 2.0 | 29.66 | 23 | 8.15E-03 | 173 | 0.25 | 0.059 | 1,988 |
| PES-MW-4 | 12/6/01 | Both | 30-40 | 2.0 | 31.20 | 14 | 5.03E-03 | 107 | 0.25 | 0.059 | 1,228 |
| PES-MW-8 | 12/7/01 | Both | 30-40 | 2.0 | 28.70 | 78 | 2.77E-02 | 587 | 0.25 | 0.059 | 6,754 |
| **GEOMETRIC MEAN** | | | | | | **30** | **1.04E-02** | **221** | **0.25** | **0.059** | **2,545** |
| PES-CW-1 | 12/6/01 | Both | 30-40 | 2.0 | 31.38 | **196** | **6.92E-02** | **1,467** | **0.25** | **0.002** | **572** |
| **December 2002 Post-Injection Slug Tests in the Injection Area** | | | | | | | | | | | |
| PES-INJ-1 | 12/14/02 | Both | 35-45 | 3.0 | 28.73 | 11 | 3.87E-03 | 82 | 0.25 | 0.002 | 27 |
| PES-INJ-2 | 12/14/02 | Rise | 30-40 | 3.0 | 28.82 | 7.9 | 2.79E-03 | 59 | 0.25 | 0.002 | 20 |
| PES-INJ-3 | 12/14/02 | Both | 40-50 | 3.0 | 28.73 | 13 | 4.59E-03 | 97 | 0.25 | 0.002 | 32 |
| **GEOMETRIC MEAN** | | | | | | **10** | **3.67E-03** | **78** | **0.25** | **0.002** | **26** |
| **December 2002 Post-Injection Slug Tests Down Gradient From the Injection Area** | | | | | | | | | | | |
| PES-MW-1 | 12/16/02 | Rise | 35-45 | 2.0 | 26.67 | 83 | 2.93E-02 | 622 | 0.25 | 0.041 | 4,974 |
| PES-MW-6 | 12/16/02 | Rise | 35-45 | 2.0 | 26.60 | 70 | 2.46E-02 | 522 | 0.25 | 0.041 | 4,179 |
| PES-MW-7 | 12/16/02 | Rise | 35-45 | 2.0 | 26.79 | 110 | 3.87E-02 | 820 | 0.25 | 0.041 | 6,560 |
| **GEOMETRIC MEAN** | | | | | | **86** | **3.04E-02** | **643** | **0.25** | **0.04** | **5,147** |
| **April 2003 Post-Injection Slug Tests in the Injection Area** | | | | | | | | | | | |
| PES-INJ-1 | 4/5/03 | Both | 35-45 | 3.0 | 27.73 | 1.0 | 3.39E-04 | 7.2 | 0.25 | 0.002 | 2.4 |
| PES-INJ-2 | 4/4/03 | Both | 40-50 | 3.0 | 28.23 | 8.4 | 2.96E-03 | 63 | 0.25 | 0.002 | 21 |
| **GEOMETRIC MEAN** | | | | | | **2.8** | **1.00E-03** | **21** | **0.25** | **0.00** | **7.0** |
| **April 2003 Post-Injection Slug Tests Down Gradient From the Injection Area** | | | | | | | | | | | |
| PES-MW-1 | 4/4/03 | Both | 35-45 | 2.0 | 27.77 | 124 | 4.36E-02 | 925 | 0.25 | 0.041 | 7,399 |
| PES-MW-6 | 4/4/03 | Both | 35-45 | 2.0 | 27.71 | 68 | 2.40E-02 | 509 | 0.25 | 0.041 | 4,071 |
| PES-MW-7 | 12/16/02 | Both | 35-45 | 2.0 | 26.79 | 85 | 2.99E-02 | 633 | 0.25 | 0.041 | 5,069 |
| **GEOMETRIC MEAN** | | | | | | **86** | **3.04E-02** | **644** | **0.25** | **0.041** | **5,156** |
| **August 2003 Post-Injection Slug Tests in the Injection Area** | | | | | | | | | | | |
| PES-INJ-1 | 8/28/03 | Both | 35-45 | 3.0 | 27.73 | 0.3 | 9.00E-05 | 1.9 | 0.25 | 0.002 | 0.6 |
| PES-INJ-2 | 8/27/03 | Both | 40-50 | 3.0 | 28.23 | 2.7 | 9.60E-04 | 20 | 0.25 | 0.002 | 6.8 |
| **GEOMETRIC MEAN FOR POST-INJECTION TESTS** | | | | | | **0.8** | **2.94E-04** | **6.2** | **0.25** | **0.00** | **2.1** |
| **August 2003 Post-Injection Slug Tests Down Gradient From the Injection Area** | | | | | | | | | | | |
| PES-MW-1 | 8/27/03 | Both | 35-45 | 2.0 | 27.77 | 94 | 3.31E-02 | 702 | 0.25 | 0.020 | 2,741 |
| PES-MW-6 | 8/27/03 | Both | 35-45 | 2.0 | 27.71 | 94 | 3.32E-02 | 704 | 0.25 | 0.023 | 3,159 |
| PES-MW-7 | 8/27/03 | Both | 35-45 | 2.0 | 26.79 | 66 | 2.34E-02 | 496 | 0.25 | 0.012 | 1,161 |
| **GEOMETRIC MEAN FOR POST-INJECTION TESTS** | | | | | | **81** | **2.87E-02** | **607** | **0.25** | **0.018** | **2,094** |

[a] ft bgs = feet below ground surface.
[b] ft/day = feet per day.
[c] cm/sec = centimeters per second.
[d] gpd/ft² = gallons per day per square foot.
[e] ft/ft = foot per foot.
[f] ft/yr = feet per year.
[g] Pre-injection mean calculations are for wells upgradient of PES-MW8 and PES-MW9.
[h] Pre-injection mean calculations are for wells PES-MW3, PES-MW8, and PES-MW9.
[i] Pre-injection calculations are for well PES-CW1.

# TABLE 10
## SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Date | PCE[a] (µg/L)[b] | TCE[a] (µg/L) | *cis-* 1,2-DCE[a] (µg/L) | *trans* 1,2-DCE[a] (µg/L) | 1,1-DCE[a] (µg/L) | Vinyl Chloride (µg/L) | 1,1,1-TCA[a] (µg/L) | 1,1-DCA[a] (µg/L) | 1,2-DCA[a] (µg/L) | Carbon Tetrachloride (µg/L) | Chloroform (µg/L) | Bromodichloro -methane (µg/L) | 2-Butanone (µg/L) | Acetone (µg/L) | Benzene (µg/L) | Toluene (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MONITORING WELLS** | | | | | | | | | | | | | | | | | |
| 18-S | 18-Apr-05 | 0.45 U | 400 | 96 | 27 | 0.87 J | 0.37 J | 0.90 U | 0.89 J | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 39 | 0.41 U | 0.67 U |
| MS-26S | 15-Apr-05 | 0.63 J | 230 | 48 | 2.7 | 0.61 J | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| GWMS-27S | 12-Nov-01 | 0.39 U[d] | 0.44 U | 0.99 U | 0.38 U | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 3.3 | 12 | 0.42 U |
| | 11-Feb-02 | 0.39 U | 0.76 J[d] | 2.4 | 0.38 U | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 21-May-02 | 0.39 U | 89 | 12 | 0.97 | 0.47 U | 0.17 U | 0.53 U | 1.2 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 26-Aug-02 | 0.39 U | 170 | 50 | 5.1 | 0.62 J | 0.17 U | 0.53 U | 0.62 J | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 9-Dec-02 | 0.25 U | 54 | 33 | 0.99 J | 0.58 J | 0.30 U | 0.23 U | 0.94 J | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.20 U | 0.22 U |
| | 7-Apr-03 | 0.24 U | 140 J | 10 | 1.5 | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 18-Aug-03 | 0.30 J | 290 | 45 | 6.4 | 0.22 U | 0.17 U | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 23 | 0.11 U | 0.11 U |
| MS-36S | 22-Apr-05 | 0.45 U | 21 | 270 | 51 | 0.57 U | 1.7 | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| MS-44S | 18-Apr-05 | 0.45 U | 77 | 19 | 2.3 | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 4.0 J | 0.41 U | 0.67 U |
| GWMS-45S | 18-Apr-05 | 0.45 U | 180 | 550 | 62 | 2.3 | 0.28 J | 0.90 U | 1.5 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 5.7 | 0.41 U | 0.67 U |
| GWMS-46S | 19-Nov-01 | 78 U | 20,000 | 200 U | 200 | 94 U | 34 U | 110 U | 94 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 210 U | 330 U | 88 U | 84 U |
| | 18-Feb-02 | 39 U | 14,000 | 120 | 140 | 47 U | 17 U | 53 U | 47 U | 52 U | 54 U | 47 U | 42 U | 100 U | 160 U | 44 U | 42 U |
| | 22-May-02 | 1.9 U | 5,600 | 55 | 61 | 4.6 | 0.85 U | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 28-Aug-02 | 0.78 U | 4,900 | 29 | 29 | 2.5 | 0.92 J | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.8 U | 2.1 U | 5.0 J | 0.88 U | 0.84 U |
| | 11-Dec-02 | 1.2 U | 7,200 | 65 | 73 | 6.4 | 1.5 U | 1.2 U | 1.0 U | 1.7 U | 1.4 U | 0.95 U | 1.6 U | 4.3 U | 10 U | 1.0 U | 1.1 U |
| | 9-Apr-03 | 0.24 U | 2,600 | 24 | 32 | 2.6 | 0.6 J | 0.23 U | 1.0 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 20-Aug-03 | 0.24 U | 4,500 | 57 | 85 | 3.5 | 1.3 J | 0.23 U | 1.8 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 18-Apr-05 | 0.45 U | 1,700 | 55 | 51 | 1.7 | 0.45 J | 0.90 U | 1.8 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| | 17-Nov-05 | 0.45 U | 1,300 | 35 | 36 | 2.0 | 0.43 J | 0.90 U | 1.7 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| GWMS-47S | 14-Nov-01 | 0.92 | 44 | 22 | 1.1 | 0.47 U | 0.17 U | 0.53 U | 0.89 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 12-Feb-02 | 1.1 J | 180 | 9.9 | 2.1 | 0.94 U | 0.34 U | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 21-May-02 | 0.60 | 220 | 9.3 | 3.3 | 0.50 | 0.17 U | 0.53 U | 1.1 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 26-Aug-02 | 0.39 U | 120 | 6.6 | 3.3 | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 10-Dec-02 | 0.64 J | 62 U | 25 | 1.4 | 0.26 U | 0.30 U | 0.23 U | 0.20 U | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.20 U | 0.22 U |
| | 8-Apr-03 | 1.5 | 66 U | 20 | 1.4 U | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 19-Aug-03 | 1.1 | 57 | 14 | 1.2 | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 11-Apr-05 | 0.87 J | 42 | 4.1 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| MS-53PC | 11-Apr-05 | 0.45 U | 0.83 J | 0.83 U | 0.19 U | 0.75 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.7 U | 0.41 U | 0.67 U |
| PES-MW-1 | 16-Nov-01 | 3.9 U | 1,100 | 14 | 15 | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.40 U | 4.7 U | 4.2 U | 10 U | 16 U | 4.4 U | 4.2 U |
| | 15-Feb-02 | 7.8 U | 1,100 | 20 U | 20 J | 9.4 U | 3.4 U | 11 U | 9.4 U | 10 U | 11 U | 9.4 U | 8.4 U | 21 U | 33 U | 8.8 U | 8.4 U |
| | 22-May-02 | 0.78 U | 3,200 | 450 | 75 | 4.5 | 0.34 U | 1.1 U | 1.6 | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 28-Aug-02 | 0.39 U | 2,600 | 630 | 39 | 3.8 | 1.3 J | 0.53 U | 1.5 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 12 U | 8.2 U | 0.44 U | 0.42 U |
| | 12-Dec-02 | 0.50 U | 1,700 | 230 | 26 | 2.5 | 0.6 U | 0.46 U | 1.4 J | 0.68 U | 0.58 U | 0.38 U | 0.64 U | 1.7 U | 1.0 U | 0.40 U | 4.1 |
| | 10-Apr-03 | 0.24 U | 1,300 | 370 | 30 | 2.0 | 0.17 U | 0.23 U | 1.2 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 21-Aug-03 | 0.24 U | 1,200 | 1100 | 79 | 3.2 | 1.4 J | 0.23 U | 2.3 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 15-Apr-05 | 0.45 U | 380 | 210 | 16 | 0.99 J | 0.18 U | 0.90 U | 1.0 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.30 U | 2.5 J | 0.41 U | 0.67 U |
| PES-MW-2 | 15-Nov-01 | 7.8 U | 2,100 | 22 | 27 | 9.4 U | 3.4 U | 11 U | 9.4 U | 10 U | 11 U | 9.4 U | 8.4 U | 21 U | 33 U | 8.8 U | 8.4 U |
| | 14-Feb-02 | 20 U | 3,600 | 50 U | 68 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 52 U | 82 U | 22 U | 21 U |
| | 22-May-02 | 0.78 U | 2,200 | 62 | 39 | 3.1 | 0.59 | 1.1 U | 1.7 | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 9.3 | 0.88 U | 0.84 U |
| | 28-Aug-02 | 0.78 U | 3,200 | 21 | 26 | 2.0 J | 0.34 U | 1.1 U | 1.3 J | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 11-Dec-02 | 0.50 U | 2,600 | 24 | 32 | 3.0 | 0.60 U | 0.5 U | 1.4 J | 0.68 U | 0.58 U | 0.38 U | 0.64 U | 1.7 U | 4.0 U | 0.40 U | 0.44 U |
| | 9-Apr-03 | 0.24 U | 2,900 | 46 | 55 | 2.7 | 0.53 J | 0.23 U | 1.6 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 20-Aug-03 | 0.24 U | 2,000 | 27 | 57 | 2.2 | 0.39 J | 0.23 U | 2.0 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 14-Apr-05 | 0.45 U | 930 | 45 | 18 | 1.5 | 0.18 U | 0.90 U | 0.93 J | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-3 | 14-Nov-01 | 20 U | 5,000 | 73 | 110 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 52 U | 82 U | 22 U | 21 U |
| | 13-Feb-02 | 20 U | 6,100 | 120 | 170 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 52 U | 82 U | 22 U | 21 U |
| | 21-May-02 | 1.9 U | 6,200 | 220 | 160 | 5.3 | 0.85 U | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 27-Aug-02 | 1.9 U | 5,900 | 390 | 95 | 4.7 J | 2.2 J | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 10-Dec-02 | 1.2 U | 5,000 | 260 | 120 | 5.7 | 1.5 U | 1.2 U | 1.0 U | 1.7 U | 1.4 U | 0.95 U | 1.6 U | 4.3 U | 10 U | 1.0 U | 1.1 U |
| | 8-Apr-03 | 0.24 U | 3,800 | 300 | 130 | 3.7 | 1.1 J | 0.2 U | 2.3 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 20-Aug-03 | 0.24 U | 2,400 | 320 | 110 | 3.0 | 0.90 J | 0.23 U | 2.8 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 14-Apr-05 | 0.45 U | 830 | 170 | 51 | 1.8 | 0.34 J | 0.90 U | 1.4 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-4 | 14-Nov-01 | 7.8 U | 3,300 | 83 | 120 | 9.4 U | 3.4 U | 11 U | 9.4 U | 10 U | 11 U | 9.4 U | 8.4 U | 21 U | 33 U | 8.8 U | 8.4 U |
| | 12-Feb-02 | 7.8 U | 3,300 | 88 | 110 | 9.4 U | 3.4 U | 11 U | 9.4 U | 10 U | 11 U | 9.4 U | 8.4 U | 21 U | 33 U | 8.8 U | 8.4 U |
| | 21-May-02 | 0.78 U | 4,200 | 140 | 190 | 4.1 | 0.34 U | 1.1 U | 3.5 | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 27-Aug-02 | 0.78 U | 3,100 | 56 | 67 | 2.2 | 0.34 U | 1.1 U | 1.7 J | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 10-Dec-02 | 0.50 U | 2,100 | 72 | 82 | 2.6 | 0.60 U | 0.46 U | 1.9 J | 0.68 U | 0.58 U | 0.38 U | 0.64 U | 1.7 U | 4.0 U | 0.40 U | 0.44 U |
| | 8-Apr-03 | 0.24 U | 2,300 | 80 | 100 | 2.1 | 0.17 U | 0.23 U | 0.17 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 19-Aug-03 | 0.73 J | 2,600 | 130 | 160 | 2.8 | 0.86 J | 0.23 U | 3.2 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 12-Apr-05 | 0.45 U | 820 | 200 | 86 | 1.5 | 0.33 J | 0.90 U | 2.2 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 180 | 0.41 U | 0.67 U |
| | 14-Nov-05 | 0.45 U | 1,000 | 140 | 76 | 1.9 | 0.18 U | 0.90 U | 2.0 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |

# TABLE 10
## SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Date | PCE[a] (µg/L)[b] | TCE[a] (µg/L) | *cis-* 1,2-DCE[a] (µg/L) | *trans* 1,2-DCE[a] (µg/L) | 1,1-DCE[a] (µg/L) | Vinyl Chloride (µg/L) | 1,1,1-TCA[a] (µg/L) | 1,1-DCA[a] (µg/L) | 1,2-DCA[a] (µg/L) | Carbon Tetrachloride (µg/L) | Chloroform (µg/L) | Bromodichloro -methane (µg/L) | 2-Butanone (µg/L) | Acetone (µg/L) | Benzene (µg/L) | Toluene (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PES-MW-5 | 14-Nov-01 | 0.39 U | 75 | 29 | 1.8 | 0.47 U | 0.17 U | 0.53 U | 0.76 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 12-Feb-02 | 0.39 U | 77 | 32 | 2.1 | 0.47 U | 0.17 U | 0.53 U | 0.74 J | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 21-May-02 | 0.39 U | 82 | 34 | 1.8 | 0.47 U | 0.17 U | 0.53 U | 0.67 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 27-Aug-02 | 0.39 U | 1,000 | 21 | 21 | 1.0 | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 10-Dec-02 | 0.25 U | 120 U | 94 | 4.4 | 0.26 U | 0.3 U | 0.23 U | 2.8 | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.20 U | 0.22 U |
| | 8-Apr-03 | 0.24 U | 780 | 53 | 17 | 0.22 U | 0.17 U | 0.23 U | 0.97 J | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 19-Aug-03 | 0.28 J | 880 | 28 | 30 | 1.7 | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 12-Apr-05 | 0.45 U | 38 | 8.7 | 0.92 J | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 9.1 | 0.41 U | 0.73 J |
| PES-MW-6 | 15-Nov-01 | 20 U | 6,200 | 88 | 140 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 52 U | 82 U | 22 U | 21 U |
| | 15-Feb-02 | 20 U | 5,800 | 100 | 150 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 52 U | 82 U | 22 U | 4.2 U |
| | 23-May-02 | 1.9 U | 5,100 | 84 | 130 | 3.2 | 1.7 | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 28-Aug-02 | 1.9 U | 6,600 | 87 | 83 | 3.2 J | 1.4 J | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 17 J | 2.2 U | 2.1 U |
| | 12-Dec-02 | 0.50 U | 3,800 | 240 | 71 | 3.9 | 0.60 U | 0.46 U | 1.6 J | 0.68 U | 0.58 U | 0.38 U | 0.64 U | 1.7 U | 4.0 U | 0.4 U | 0.44 U |
| | 10-Apr-03 | 0.24 U | 3,000 | 180 | 100 | 2.7 | 0.77 J | 0.23 U | 2.5 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.1 U | 0.11 U |
| | 21-Aug-03 | 0.24 U | 2,000 | 97 | 61 | 2.8 | 0.59 J | 0.23 U | 2.1 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 15-Apr-05 | 0.45 U | 700 | 170 | 27 | 1.7 | 0.27 J | 0.90 U | 0.87 J | 0.36 U | 0.49 U | 0.37 U | 0.91 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-7 | 16-Nov-01 | 0.78 U | 300 | 5.2 | 0.78 U | 0.94 U | 0.34 U | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 14-Feb-02 | 1.9 U | 540 | 7.9 | 7.4 | 2.3 U | 0.85 U | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 74 | 8.2 U | 2.2 U | 2.1 U |
| | 22-May-02 | 0.39 U | 980 | 14 | 18 | 2.2 | 0.36 | 0.53 U | 1.6 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 130 | 340 | 0.44 U | 0.42 U |
| | 28-Aug-02 | 0.48 J | 1,300 | 65 | 11 | 2.1 | 0.42 J | 0.53 U | 0.98 J | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 66 | 55 | 0.44 U | 0.42 U |
| | 12-Dec-02 | 0.25 U | 350 J | 180 | 8.3 | 2.0 | 0.53 U | 0.23 U | 1.0 | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 320 | 2.0 U | 0.20 U | 4.5 |
| | 10-Apr-03 | 0.24 U | 12 U | 270 | 5.5 | 0.99 J | 0.69 J | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 1,800 | 65 | 0.11 U | 0.11 U |
| | 21-Aug-03 | 0.24 U | 2.1 | 410 | 7.2 | 0.22 U | 0.90 J | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 89 | 14 | 0.11 U | 0.11 U |
| | 15-Apr-05 | 0.45 U | 4.1 | 130 | 4.7 | 0.57 U | 0.29 J | 0.90 U | 0.89 J | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 4.9 J | 0.41 U | 0.67 U |
| | 17-Nov-05 | 0.45 U | 1.0 | 150 | 2.7 | 0.57 U | 0.80 J | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.88 J |
| PES-MW-8 | 15-Nov-01 | 20 U | 6,700 | 160 | 220 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 10 U | 82 U | 22 U | 21 U |
| | 14-Feb-02 | 20 U | 4,700 | 150 | 200 | 23 U | 8.5 U | 26 U | 23 U | 26 U | 27 U | 23 U | 21 U | 10 U | 82 U | 22 U | 21 U |
| | 22-May-02 | 1.9 U | 5,400 | 180 | 210 | 4.8 | 2.2 | 2.6 U | 4.0 | 2.6 U | 2.7 U | 23 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 27-Aug-02 | 1.9 U | 5,700 | 130 | 130 | 4.0 J | 1.8 J | 2.6 U | 3.8 J | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 19 J | 2.2 U | 2.1 U |
| | 12-Dec-02 | 1.2 U | 5,500 | 70 | 73 | 1.3 U | 1.5 U | 1.2 U | 1.0 U | 1.7 U | 1.4 U | 0.95 U | 1.6 U | 4.3 U | 10 U | 1.0 U | 1.1 U |
| | 9-Apr-03 | 0.2 U | 3,000 | 120 | 130 | 3.0 | 0.81 J | 0.23 U | 2.8 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 21-Aug-03 | 0.32 J | 2,200 | 76 | 96 | 3.3 | 0.17 U | 0.23 U | 1.9 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 14-Apr-05 | 0.45 U | 1,100 | 90 | 57 | 1.6 | 0.34 J | 0.90 U | 1.5 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-9 | 15-Nov-01 | 3.9 U | 1,400 | 15 | 20 | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 52 U | 16 U | 4.4 U | 0.42 U |
| | 13-Feb-02 | 3.9 U | 1,300 | 17 | 20 | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 52 U | 16 U | 4.4 U | 4.2 U |
| | 22-May-02 | 0.78 U | 410 | 1,800 | 63 | 8.2 | 1.2 | 1.1 U | 1.5 | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 91 | 150 | 0.88 U | 0.84 U |
| | 27-Aug-02 | 1.9 U | 120 | 3,000 | 67 | 9.6 | 12 | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.30 U | 2.1 U | 290 | 180 | 2.2 U | 2.1 U |
| | 11-Dec-02 | 0.50 U | 20 U | 1,500 | 33 | 6.8 | 5.7 | 0.46 U | 0.4 U | 0.68 U | 0.58 U | 0.38 U | 0.64 U | 180 | 68 | 0.4 U | 0.44 U |
| | 9-Apr-03 | 0.24 U | 2,300 | 180 | 42 | 2.7 | 0.17 U | 0.23 U | 1.3 | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 20-Aug-03 | 0.24 U | 2,200 | 370 | 110 | 3.2 | 0.71 J | 0.23 U | 2.8 | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 13-Apr-05 | 2.2 U | 490 | 270 | 30 | 1.0 | 0.90 U | 4.5 U | 0.77 J | 1.8 U | 2.40 U | 1.8 U | 2.8 U | 22 U | 12 U | 2.0 U | 3.4 U |
| | 16-Nov-05 | 0.45 U | 28 | 500 | 18 | 3.2 | 0.18 U | 0.90 U | 1.0 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-CW-1 | 13-Nov-01 | 1.9 U | 630 | 12 | 7.5 | 2.3 U | 0.85 U | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 11-Feb-02 | 0.78 U | 170 | 9.5 | 2.4 | 0.94 U | 0.34 U | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 20-May-02 | 0.39 U | 170 | 8.2 | 2.3 | 0.47 U | 0.17 U | 0.53 U | 0.86 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 26-Aug-02 | 0.89 J | 61 | 39 | 3.8 | 0.47 U | 0.17 U | 0.53 U | 0.65 J | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 9-Dec-02 | 0.53 J | 250 J | 9.6 | 2.9 | 0.67 J | 0.30 U | 0.23 U | 0.99 J | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.20 U | 0.22 U |
| | 7-Apr-03 | 1.5 | 54 | 9.6 | 0.93 J | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 18-Aug-03 | 2.0 | 67 | 8.9 | 0.97 J | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| PES-CW-2 | 13-Nov-01 | 1.9 U | 290 | 7.3 | 1.9 U | 2.3 U | 0.85 U | 2.6 U | 2.3 U | 2.3 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 11-Feb-02 | 0.78 U | 350 | 9.0 | 4.8 | 0.94 U | 0.34 U | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 20-May-02 | 0.39 U | 210 | 7.0 | 2.1 | 0.71 | 0.17 U | 0.53 U | 1.4 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 26-Aug-02 | 0.39 U | 200 | 14 | 3.7 | 0.47 J | 0.17 U | 0.53 U | 0.73 J | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 9-Dec-02 | 0.25 U | 230 J | 6.4 | 1.5 | 0.26 U | 0.30 U | 0.23 U | 1.0 U | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.20 U | 0.22 U |
| | 7-Apr-03 | 0.75 J | 100 | 11 | 1.1 | 0.22 U | 0.17 U | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.75 J |
| | 19-Aug-03 | 1.3 | 87 | 14 | 1.5 | 0.22 U | 0.17 U | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 11-Apr-05 | 0.45 U | 110 | 4.9 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 12 | 0.41 U | 0.67 U |
| | 14-Nov-05 | 0.66 J | 63 | 6.4 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |

# TABLE 10
## SUMMARY OF VOLATILE ORGANIC COMPOUNDS DETECTED IN GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Date | PCE[a] (µg/L)[b] | TCE[a] (µg/L) | *cis-* 1,2-DCE[a] (µg/L) | *trans* 1,2-DCE[a] (µg/L) | 1,1-DCE[a] (µg/L) | Vinyl Chloride (µg/L) | 1,1,1-TCA[a] (µg/L) | 1,1-DCA[a] (µg/L) | 1,2-DCA[a] (µg/L) | Carbon Tetrachloride (µg/L) | Chloroform (µg/L) | Bromodichloro -methane (µg/L) | 2-Butanone (µg/L) | Acetone (µg/L) | Benzene (µg/L) | Toluene (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PES-CW-3 | 13-Nov-01 | 0.78 U | 240 | 5.7 | 0.76 U | 0.94 U | 0.34 U | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 12-Feb-02 | 0.78 U | 330 | 6.5 | 2.3 | 0.94 U | 0.34 U | 1.1 U | 0.94 U | 1.0 U | 1.1 U | 0.94 U | 0.84 U | 2.1 U | 3.3 U | 0.88 U | 0.84 U |
| | 20-May-02 | 0.39 U | 200 | 7.0 | 1.3 | 0.77 | 0.17 U | 0.53 U | 1.4 | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 26-Aug-02 | 0.39 U | 230 | 5.8 | 2.9 | 0.47 U | 0.17 U | 0.53 U | 0.88 J | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 1.0 U | 1.6 U | 0.44 U | 0.42 U |
| | 10-Dec-02 | 0.25 U | 220 J | 6.0 | 0.98 J | 0.58 J | 0.30 U | 0.23 U | 1.0 | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.20 U | 0.22 U |
| | 8-Apr-03 | 0.24 U | 190 U | 4.7 U | 0.25 U | 0.22 U | 0.17 U | 0.23 U | 0.72 J | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 19-Aug-03 | 0.24 U | 160 | 8.6 | 1.2 | 0.22 U | 0.17 U | 0.23 U | 0.76 J | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 0.86 U | 2.0 U | 0.11 U | 0.11 U |
| | 11-Apr-05 | 0.45 U | 120 | 4.5 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| | 14-Nov-05 | 0.45 U | 140 | 6.0 | 1.1 | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-10A | 15-Apr-05 | 0.45 U | 6.8 | 180 | 4.8 | 0.57 U | 0.67 J | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 870 | 66 | 0.41 U | 0.67 U |
| | 16-Nov-05 | 0.45 U | 1.2 | 81 | 1.4 | 0.57 U | 0.56 J | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 250 | 9.7 | 0.41 U | 0.67 U |
| PES-MW-10B | 14-Apr-05 | 3.5 | 48 | 3.7 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 0.83 J | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.4 J | 0.41 U | 0.67 U |
| | 15-Nov-05 | 3.9 | 49 | 4.1 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 0.77 J | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-11A | 13-Apr-05 | 0.45 U | 100 | 110 | 6.5 | 0.57 U | 0.18 U | 0.90 U | 1.1 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 3.7 J | 0.41 U | 0.67 U |
| | 15-Nov-05 | 0.45 U | 48 | 28 | 0.89 U | 0.57 U | 0.18 U | 0.90 U | 1.1 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| PES-MW-12A | 12-Apr-05 | 0.45 U | 80 | 20 | 3.0 | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 1.3 | 0.56 U | 11 | 24 | 0.41 U | 0.79 J |
| | 15-Nov-05 | 0.90 U | 350 | 13 | 5.0 | 1.1 U | 0.36 U | 1.8 U | 1.5 U | 0.72 U | 0.98 U | 0.74 U | 1.1 U | 8.6 U | 4.6 U | 0.82 U | 1.3 U |
| PES-MW-12B | 20-Apr-05 | 1.1 U | 330 | 22 | 8.7 | 1.4 U | 0.45 U | 2.2 U | 1.9 U | 1.9 U | 1.2 U | 0.92 U | 1.4 U | 11 U | 5.8 U | 1.0 U | 1.7 U |
| | 15-Nov-05 | 0.90 U | 290 | 12 | 6.3 | 1.1 U | 0.36 U | 1.8 U | 1.5 U | 0.72 U | 0.98 U | 0.74 U | 1.1 U | 8.6 U | 4.6 U | 0.82 U | 1.3 U |
| PES-MW-13A | 22-Apr-05 | 0.45 U | 380 | 8.1 | 6.2 | 0.57 U | 0.18 U | 0.90 U | 1.2 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| | 16-Nov-05 | 1.1 U | 230 | 5.8 | 5.0 | 1.4 U | 0.45 U | 2.2 U | 1.9 U | 1.9 U | 1.2 U | 0.92 U | 1.4 U | 11 U | 5.8 U | 1.0 U | 1.7 U |
| PES-MW-14A | 12-Apr-05 | 0.45 U | 87 | 490 | 25 | 1.0 | 0.85 J | 0.90 U | 0.81 J | 0.36 U | 0.49 U | 1.8 | 0.56 U | 4.3 U | 190 | 0.41 U | 0.74 J |
| | 15-Nov-05 | 2.2 U | 87 | 510 | 12 | 2.8 U | 1.3 J | 4.5 U | 3.8 U | 1.8 U | 2.4 U | 1.8 U | 2.8 U | 22 U | 12 U | 2.0 U | 3.4 U |
| PES-MW-14B | 20-Apr-05 | 0.45 U | 110 | 1.3 | 5.6 | 0.57 U | 0.18 U | 0.90 U | 1.4 | 0.36 U | 0.49 U | 0.38 J | 0.56 U | 4.3 U | 3.1 J | 0.41 U | 0.67 U |
| | 16-Nov-05 | 0.45 U | 110 | 5.5 | 1.2 | 0.57 U | 0.18 U | 0.90 U | 1.4 | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 4.3 U | 2.3 U | 0.41 U | 0.67 U |
| **INJECTION WELLS** | | | | | | | | | | | | | | | | | |
| PES-INJ-1 | 19-Nov-01 | 3.9 U | 1,400 | 16 | 20 | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 10 U | 16 U | 4.4 U | 4.2 U |
| | 18-Feb-02 | 3.9 U | 70 | 15 | 3.8 U | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 340 | 16 U | 4.4 U | 4.2 U |
| | 23-May-02 | 0.39 U | 47 | 13 | 2.7 | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 420 | 360 | 0.44 U | 1.1 |
| | 29-Aug-02 | 0.39 U | 29 | 9.6 | 2.3 | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 370 | 270 | 0.44 U | 0.42 U |
| | 13-Dec-02 | 0.25 U | 37 J | 19 | 2.6 | 0.64 | 0.83 | 0.23 U | 0.20 U | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 360 | 130 | 0.20 U | 0.7 U |
| | 10-Apr-03 | 0.24 U | 66 | 16 | 2.0 | 0.22 U | 0.63 J | 0.23 U | 0.22 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 320 | 66 | 0.11 U | 0.11 U |
| | 22-Aug-03 | 0.24 U | 20 | 17 | 1.8 | 0.22 U | 0.7 J | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 450 | 170 | 0.11 U | 0.9 J |
| | 19-Apr-05 | 1.80 U | 10 | 11 | 3.6 U | 2.30 U | 0.72 U | 3.60 U | 3.0 U | 1.40 U | 2.00 U | 1.50 U | 2.20 U | 1,900 | 640 | 1.60 U | 2.7 U |
| PES-INJ-2 | 19-Nov-01 | 1.90 U | 630 | 8.6 | 7.9 | 2.3 U | 0.85 U | 2.6 U | 2.3 U | 2.6 U | 2.7 U | 2.3 U | 2.1 U | 5.2 U | 8.2 U | 2.2 U | 2.1 U |
| | 15-Feb-02 | 3.9 U | 45 | 9.90 U | 3.8 U | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 390 | 16 U | 4.4 U | 4.2 U |
| Veg. Oil | 12-Feb-02 | 1,100 U | 6,200 | 680 U | 850 U | 800 U | 1,000 U | 480 U | 620 U | 800 U | 610 U | 670 U | 660 U | 940 U | 650 U | 590 U | 2,000 J |
| | 23-May-02 | 0.39 U | 25 | 3.8 | 2.9 | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 670 | 150 | 0.44 U | 0.45 |
| | 29-Aug-02 | 0.39 U | 16 | 3.4 | 2.4 | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 590 | 160 | 0.44 U | 0.42 U |
| | 13-Dec-02 | 0.25 U | 18 J | 3.4 | 2.7 | 0.34 U | 0.30 U | 0.23 U | 0.20 U | 0.34 U | 0.34 U | 0.19 U | 0.32 U | 1,200 | 320 | 0.20 U | 9.4 |
| | 11-Apr-03 | 0.24 U | 16 | 3.1 | 2.2 | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 870 | 92 | 0.11 U | 3.8 |
| | 22-Aug-03 | 0.24 U | 13 | 3.0 | 2.1 | 0.22 U | 0.17 U | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 1,100 | 170 | 0.11 U | 2.4 |
| | 19-Apr-05 | 0.45 U | 14 | 2.9 | 1.9 | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 820 | 150 | 0.41 U | 1.1 |
| PES-INJ-3 | 16-Nov-01 | 3.9 U | 760 | 9.9 U | 9.1 | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 10 U | 16 U | 4.4 U | 4.2 U |
| | 18-Feb-02 | 3.9 U | 29 | 9.9 U | 3.8 U | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 490 | 240 | 4.4 U | 4.2 U |
| Veg. Oil | 12-Feb-02 | 1,100 U | 7,800 | 680 U | 850 U | 800 U | 1,000 U | 480 U | 620 U | 720 U | 610 U | 670 U | 660 U | 940 U | 650 U | 590 U | 770 U |
| | 23-May-02 | 0.39 U | 21 | 3.7 | 0.39 U | 0.47 U | 0.17 U | 0.53 U | 0.47 U | 0.52 U | 0.54 U | 0.47 U | 0.42 U | 770 | 610 | 0.44 U | 0.42 U |
| | 29-Aug-02 | 3.90 U | 10 | 9.9 U | 3.8 U | 4.7 U | 1.7 U | 5.3 U | 4.7 U | 5.2 U | 5.4 U | 4.7 U | 4.2 U | 440 | 710 | 4.4 U | 4.2 U |
| Veg. Oil | 29-Aug-02 | 570 U | 4,900 | 550 U | 560 U | 620 U | 940 U | 520 U | 530 U | 610 U | 610 U | 540 U | 470 U | 3,300 | 2,800 | 470 U | 640 U |
| | 13-Dec-02 | 0.25 U | 12 J | 3.8 | 2.8 | 0.26 U | 0.30 U | 0.23 U | 0.20 U | 0.34 U | 0.29 U | 0.19 U | 0.32 U | 560 | 680 | 0.20 U | 0.22 U |
| Veg. Oil | 9-Dec-02 | 1,100 U | 3,500 | 680 U | 850 U | 800 U | 1,000 U | 480 U | 620 U | 720 U | 610 U | 670 U | 660 U | 4,000 | 1,600 J | 590 U | 4,800 |
| | 11-Apr-03 | 0.24 U | 9.8 | 3.1 | 2.2 | 0.22 U | 0.17 U | 0.23 U | 0.20 U | 0.17 U | 0.25 U | 0.19 U | 0.32 U | 900 | 400 | 0.11 U | 0.11 U |
| | 22-Aug-03 | 0.24 U | 10 | 3.5 | 2.4 | 0.22 U | 0.17 U | 0.23 U | 0.2 U | 0.17 U | 0.25 U | 0.19 U | 0.11 U | 1,200 | 470 | 0.11 U | 0.11 U |
| | 19-Apr-05 | 0.45 U | 8.7 | 3.3 | 1.9 | 0.57 U | 0.18 U | 0.90 U | 0.75 U | 0.36 U | 0.49 U | 0.37 U | 0.56 U | 960 | 480 | 0.41 U | 0.67 U |
| | 17-Nov-05 | 9.0 U | 15.0 J | 17 U | 18 U | 11 U | 3.6 U | 18 U | 15 U | 7.2 U | 9.8 U | 7.4 U | 11 U | 1,500 | 2,600 | 8.2 U | 24 |
| **PRE-INJECTION OIL SAMPLES** | | | | | | | | | | | | | | | | | |
| PES-INJ-2A-OIL | 11-Dec-02 | 1,000 U | 920 U | 670 U | 840 U | 790 U | 1,000 U | 470 U | 610 U | 710 U | 600 U | 650 U | 650 U | 880 U | 640 U | 580 U | 750 U |
| PES-INJ-2-OIL | 11-Dec-02 | 1,000 U | 950 U | 670 U | 840 U | 790 U | 1,000 U | 470 U | 610 U | 710 U | 600 U | 650 U | 650 U | 900 U | 640 U | 580 U | 750 U |

[a] PCE = tetrachloroethene; TCE = trichloroethene; DCE = dichloroethene; TCA = trichloroethane; DCA = dichloroethane.

[b] µg/L = micrograms per liter.

[c] U = Analyte was not detected at a concentration above the method detection limit.

[d] J = Analyte was detected at a concentration above the method detection limit and below the reporting limit.

# TABLE 11
## SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Sample Date | Methane (µg/L)[a] | Ethane (µg/L) | Ethene (µg/L) | TOC[b] (mg/L)[c] | Dissolved Oxygen (mg/L) | Dissolved Hydrogen (nM)[d] | Nitrate (mg/L) | Nitrite (mg/L) | Ferrous Iron (mg/L) | Manganese (mg/L) | Sulfate (mg/L) | Sulfide (mg/L) | Ammonia (mg/L) | Total Alkalinity (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) | Redox Potential (mV)[e] | pH (SU)[f] | Temperature (°C)[g] | Specific Conductivity (µs/cm)[h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MONITORING WELLS** | | | | | | | | | | | | | | | | | | | | | |
| 18-S | 4/18/2005 | NM[j] | NM | NM | 3.8 | R[l] | NM | NM | NM | 1.44 | 2.0 | 180 | 0.01 | NM | NM | 35 | NM | -87 | 7.49 | 11.9 | 1,238 |
| MS-26S | 4/15/2005 | NM | NM | NM | 2.2 | R | NM | NM | NM | 0.19 | 0.9 | 160 | 0.06 | NM | NM | 25 | NM | -96 | 7.52 | 12.8 | 1,309 |
| MS-27S | 12-Nov-01 | 46 J[j] | 1.6 U | 1.4 U | 3.7 | 0.34 | Na[j] | <0.2[k] | <0.2 | 0.05 | 0.1 | 19 | <0.01 | 0.12 | 119 | 1.25 | 20 | -123 | 9.81 | 12.5 | 1,136 |
| | 11-Feb-02 | 36 | 1.6 U | 1.4 U | 1.4 | 0.02 | Na | <0.13 | <0.077 | 0.22 | <0.6 | 43 | 0.02 | 0.06 | 163 | 18 | 75 | -371 | 8.06 | 11.4 | 575 |
| | 21-May-02 | 2.0 U | 1.6 U | 1.4 U | <1.7 | 0.33 | 3.3 | <0.13 | <0.077 | 0.90 | <0.6 | 170 | 0.02 | 0.02 | 340 | 35 | 55 | -315 | 7.00 | 10.8 | 1,068 |
| | 26-Aug-02 | 2.7 J | 1.6 U | 1.4 U | 9.9 | 0.06 | 2.2 | <0.13 | <0.077 | 0.83 | <0.6 | 170 | <0.01 | 0.01 | 425 | 60 | 70 | -85 | 6.36 | 12.8 | 1,052 |
| | 9-Dec-02 | 4.3 | 0.064 | 0.036 | 16 | 0.26 | 3.0 | <0.057 | <0.018 | 0.73 | <0.6 | 170 | <0.01 | 0.05 | 357 | 45 | 60 | 60 | 7.17 | 9.8 | 645 |
| | 7-Apr-03 | 2.6 | 0.022 | 0.023 | 2.8 | 0.23 | 5.2 | <0.058 | <0.018 | 0.82 | <0.6 | 150 | 0.03 | 0.01 | 272 | 30 | 60 | -77 | 7.24 | 10.4 | 1,011 |
| | 18-Aug-03 | 4.5 | 0.033 | 0.056 | 1.2 J | 1.34 | 2.4 | <0.058 | <0.018 | 0.86 | 1.1 | 140 | 0.01 | 0.02 | 340 | 55 | 75 | -47 | NM | 15.4 | 142 |
| MS-36S | 22-Apr-05 | NM | NM | NM | 3.4 | R | NM | NM | NM | 0.05 | 0.1 | 60 | 0.51 | NM | NM | 15 | NM | -184 | 8.18 | 15.1 | 1,538 |
| MS-44S | 18-Apr-05 | NM | NM | NM | 0.4 | R | NM | NM | NM | 0.17 | 2.2 | 170 | <0.01 | NM | NM | 25 | NM | -50 | 7.07 | 11.5 | 1,380 |
| GWMS-45S | 18-Apr-05 | 20 | 0.095 | 0.071 | 7.0 | R | NM | NM | NM | 1.08 | 1.4 | 160 | 0.06 | NM | NM | 25 | NM | -94 | 7.59 | 11.2 | 1,130 |
| GWMS-46S | 19-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.8 | 0.57 | Na | <0.2 | <0.2 | 2.2 | 1.9 | 210 | 0.01 | 0.07 | 391 | 50 | 15 | -82 | 7.04 | 10.1 | 1,134 |
| | 18-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 3.6 | 0.96 | Na | <0.13 | <0.077 | 1.9 | 1.0 | 340 | 0.01 | 0.09 | 85 | 10 | 25 | -276 | 6.95 | 10.7 | 1,048 |
| | 22-May-02 | 2.0 U | 1.6 U | 1.4 U | 2.3 | <0.01 | 1.1 | <0.13 | <0.077 | 1.4 | 1.4 | 180 | <0.01 | 0.08 | 323 | 30 | 55 | -276 | 7.30 | 13.1 | 1,132 |
| | 28-Aug-02 | 6.0 | 1.6 U | 1.4 U | 10 | <0.01 | 2.0 | <0.13 | <0.077 | 1.2 | 1.3 | 170 | 0.01 | 0.06 | 340 | 40 | 50 | -229 | 7.13 | 12.9 | 1,045 |
| | 11-Dec-02 | 2.0 U | 0.014 | 0.069 | 18 | 0.12 | 1.2 | <0.057 | <0.018 | 1.7 | 1.1 | 210 | <0.01 | 0.09 | 357 | 35 | 40 | R | 7.37 | 10.0 | 564 |
| | 9-Apr-03 | 4.2 | 0.007 | 0.030 | 1.0 J | 1.52 | 1.6 | <0.058 | <0.018 | 1.7 | 1.8 | 190 | 0.01 | 0.09 | 323 | 35 | 45 | -58 | 7.31 | 10.6 | 1,137 |
| | 20-Aug-03 | 18 | 0.010 | 0.046 | <1.0 | 3.9 | 1.8 | <0.058 | <0.018 | 2.4 | 1.9 | 190 | 0.01 | 0.07 | 306 | 35 | 45 | -95 | 7.18 | 16.3 | 1,094 |
| | 18-Apr-05 | 30 | 0.071 | 0.080 | 3.7 | R | NM | NM | NM | 1.1 | 2.0 | 210 | <0.01 | NM | NM | 25 | NM | -115 | 7.45 | 12.0 | 1,132 |
| | 17-Nov-05 | NM | NM | NM | 3.7J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NA | 7.40 | 9.3 | 979 |
| GWMS-47S | 14-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.7 | 1.7 | Na | 1.3 | <0.2 | <0.01 | 1.8 | 70 | 0.13 | <0.01 | 459 | 134 | 50 | 115 | 6.82 | 12.9 | 1,102 |
| | 12-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 1.6 | 8.8 | Na | <0.13 | <0.077 | <0.01 | <0.6 | 160 | <0.01 | <0.01 | 442 | 50 | 65 | -14 | 7.21 | 10.7 | 1,092 |
| | 21-May-02 | 2.0 U | 1.6 U | 1.4 U | <1.1 | 6.1 | 2.6 | 0.59 | <0.077 | 0.01 | <0.6 | 140 | <0.01 | 0.01 | 340 | 35 | 50 | -31 | 7.10 | 12.0 | 1,078 |
| | 26-Aug-02 | 2.0 U | 1.6 U | 1.4 U | 11 | 3.7 | 3.0 | 0.45 | <0.077 | 0.04 | <0.6 | 100 | 0.03 | 0.03 | 340 | 45 | 55 | 149 | 6.94 | 13.9 | 1,054 |
| | 10-Dec-02 | 2.0 U | 0.007 | 0.013 | 38 | 2.4 | 3.1 | 2.5 | <0.018 | <0.01 | <0.6 | 111 | <0.01 | <0.01 | 476 | 65 | 95 | 265 | 7.09 | 10.4 | 818 |
| | 8-Apr-03 | 0.32 | 0.005 U | 0.010 | 1.1 | 1.0 | 1.8 | 1.1 | <0.018 | 0.02 | <0.6 | 170 | <0.01 | 0.02 | 442 | 40 | 75 | 112 | 7.02 | 9.9 | 1,283 |
| | 19-Aug-03 | 0.46 | 0.006 U | 0.001 U | 1 J | 2.3 | 3.2 | 1.1 | <0.018 | 0.00 | 0.6 | 100 | <0.01 | <0.01 | 408 | 65 | 95 | 208 | 6.88 | 20.9 | 1,227 |
| | 11-Apr-05 | NM | NM | NM | 3.8 | R | NM | NM | NM | 0.04 | <0.6 | 170 | 0.01 | NM | NM | 65 | NM | 16 | 7.11 | 11.6 | 1,405 |
| MS-53PC | 11-Apr-05 | NM | NM | NM | 110 | NA | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NA | NA | NA | NA |
| PES-MW-1 | 16-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.0 | 1.3 | Na | <0.2 | <0.2 | 0.02 | 0.6 | 100 | <0.01 | 0.03 | 255 | 15 | 55 | -50 | 8.29 | 11.0 | 873 |
| | 15-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 30 | 1.1 | Na | <0.13 | <0.077 | 0.91 | 1.2 | 290 | 0.18 | 0.04 | 408 | 40 | 50 | -324 | 7.25 | 10.5 | 1,032 |
| | 22-May-02 | 2.9 | 1.6 U | 1.4 U | 3 | <0.01 | 2.3 | <0.13 | <0.077 | 0.37 | 0.6 | 200 | 0.02 | 0.05 | 374 | 40 | 45 | -245 | 7.40 | 11.9 | 1,217 |
| | 28-Aug-02 | 170 | 1.6 U | 1.4 U | 14 | <0.01 | 2.1 | <0.13 | <0.077 | 1.3 | 1.1 | 140 | 0.18 | 0.06 | 357 | 50 | 55 | -299 | 7.06 | 12.8 | 1,084 |
| | 12-Dec-02 | 380 | 0.014 | 0.079 | 12 | R | 3.9 | <0.057 | <0.018 | 1.2 | 0.6 | 200 | 0.16 | 0.05 | 425 | 45 | 45 | R | 7.42 | 10.6 | R |
| | 10-Apr-03 | 2,000 | 0.002 J | 0.050 | < 1.0 | 1.23 | 1.7 | <0.058 | <0.018 | 3.0 | 1.6 | 180 | <0.01 | 0.07 | 374 | 45 | 50 | -241 | 7.30 | 11.7 | 1,154 |
| | 21-Aug-03 | 0.16 | 0.004 J | 0.013 | 1.4 J | 0.49 | 1.5 | <0.058 | <0.018 | 2.4 | 1.9 | 160 | 0.52 | 0.05 | 374 | 45 | 50 | -164 | 7.28 | 14.3 | 1,098 |
| | 15-Apr-05 | 4,600 | 0.095 | 0.120 | 3.0 | R | NM | NM | NM | 3.1 | 7.6 | 220 | 0.09 | NM | NM | 35 | NM | -132 | 7.23 | 11.6 | 1,158 |
| PES-MW-2 | 15-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.7 | 0.39 | Na | 0.2 | <0.2 | 0.17 | <0.6 | 190 | <0.01 | 0.09 | 1,700 | 50 | 60 | -185 | 11.66 | 11.5 | 1,181 |
| | 14-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 3.2 | 0.74 | Na | <0.13 | <0.077 | 0.04 | <0.6 | 340 | <0.01 | 0.05 | 340 | 25 | 50 | -188 | 7.82 | 10.3 | 1,005 |
| | 22-May-02 | 2.0 U | 1.6 U | 1.4 U | 2.5 | 0.07 | 1.8 | <0.13 | <0.077 | 0.03 | <0.6 | 230 | 0.02 | 0.06 | 323 | 30 | 45 | -160 | 7.40 | 13.8 | 1,139 |
| | 28-Aug-02 | 2.5 J | 1.6 U | 1.4 U | 12 | 0.19 | 2.9 | <0.13 | <0.077 | 0.11 | 1.2 | 220 | 0.08 | 0.06 | 340 | 45 | 45 | -176 | 6.98 | 12.7 | 1,091 |
| | 11-Dec-02 | 150 | 0.008 | 0.054 | 6.5 | 0.03 | 1.4 | <0.057 | <0.018 | 0.02 | 0.6 | 200 | 0.01 | 0.07 | 374 | 30 | 40 | R | 7.45 | 10.3 | 589 |
| | 9-Apr-03 | 1,700 | 0.001 U | 0.025 | < 1.0 | 1.60 | 1.3 | <0.058 | <0.018 | 0.04 | 1.5 | 230 | 0.01 | 0.07 | 347 | 30 | 45 | -26 | 7.37 | 10.8 | 1,180 |
| | 20-Aug-03 | 0.3 | 0.007 | 0.023 | 1.0 J | 0.48 | 1.8 | <0.058 | <0.018 | 0.02 | 1.5 | 210 | <0.01 | 0.03 | 340 | 30 | 55 | -1 | 7.27 | 15.6 | 1,095 |
| | 14-Apr-05 | 11 | 0.022 | 0.070 | 1.9 | R | NM | NM | NM | 0.03 | 1.1 | 200 | 0.01 | NM | NM | 35 | NM | -57 | 7.29 | 11.5 | 1,071 |
| PES-MW-3 | 14-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.6 | 0.35 | Na | <0.2 | <0.2 | 0.48 | 0.9 | 150 | <0.01 | 0.02 | 340 | 40 | 45 | -76 | 7.05 | 12.1 | 1,078 |
| | 13-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 0.2 | 0.46 | Na | <0.13 | <0.077 | 1.3 | 1.4 | 200 | <0.01 | 0.05 | 391 | 40 | 45 | -288 | 7.09 | 10.3 | 1,092 |
| | 21-May-02 | 2.0 U | 1.6 U | 1.4 U | 2.9 | 0.12 | 1.4 | <0.13 | <0.077 | 1.8 | 0.8 | 200 | 0.03 | 0.06 | 391 | 45 | 55 | -311 | 7.30 | 12.8 | 1,151 |
| | 27-Aug-02 | 4.4 | 1.6 U | 1.4 U | 13 | <0.01 | 2.0 | <0.13 | <0.077 | 2.1 | 1.5 | 150 | 0.04 | 0.08 | 374 | 65 | 55 | -136 | 6.81 | 12.5 | 1,106 |
| | 10-Dec-02 | 210 | 0.020 | 0.081 | 24 | R | 1.5 | <0.057 | <0.018 | 2.1 | 0.8 | 220 | 0.14 | 0.09 | 425 | 35 | 50 | -60 | 7.35 | 10.6 | 727 |
| | 8-Apr-03 | 1,700 | 0.005 U | 0.007 | 2.0 J | 4.91 | 1.9 | <0.058 | <0.018 | 2.7 | 0.8 | 190 | 0.04 | 0.09 | 408 | 35 | 55 | -100 | 7.29 | 10.8 | 1,178 |
| | 20-Aug-03 | 1.3 | 0.012 | 0.026 | 2.6 J | 1.2 | 3.4 | <0.058 | <0.018 | 2.0 | 1.9 | 200 | 0.12 | 0.04 | 357 | 50 | 55 | -93 | 7.07 | 17.8 | 1,134 |
| | 14-Apr-05 | 88 | 0.038 | 0.065 | 1.6 | R | NM | NM | NM | 2.4 | 1.4 | 180 | 0.02 | NM | NM | 40 | NM | -86 | 7.09 | 11.4 | 1,106 |

# TABLE 11
## SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Sample Date | Methane (µg/L)[a] | Ethane (µg/L) | Ethene (µg/L) | TOC[b] (mg/L)[c] | Dissolved Oxygen (mg/L) | Dissolved Hydrogen (nM)[d] | Nitrate (mg/L) | Nitrite (mg/L) | Ferrous Iron (mg/L) | Manganese (mg/L) | Sulfate (mg/L) | Sulfide (mg/L) | Ammonia (mg/L) | Total Alkalinity (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) | Redox Potential (mV)[e] | pH (SU)[f] | Temperature (°C)[g] | Specific Conductivity (µs/cm)[h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PES-MW-4 | 14-Nov-01 | 2.0 U | 1.6 U | 1.4 U | Na | 1.3 | Na | <0.2 | <0.2 | <0.01 | 0.9 | 230 | <0.01 | 0.02 | 374 | 55 | 70 | -48 | 7.12 | 12.1 | 1,115 |
| | 12-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 1.3 | 3.0 | Na | <0.13 | <0.077 | 0.11 | 0.7 | 120 | <0.01 | 0.03 | 408 | 35 | 65 | -133 | 7.38 | 9.0 | 1,045 |
| | 21-May-02 | 2.0 U | 1.6 U | 1.4 U | 2.0 | 1.2 | 2.9 | 0.18 | <0.077 | 0.13 | <0.6 | 180 | <0.01 | 0.03 | 357 | 40 | 65 | -129 | 7.10 | 13.1 | 1,123 |
| | 27-Aug-02 | 2.0 U | 1.3 U | 1.4 U | 10 | 0.12 | 3.8 | <0.13 | <0.077 | 0.04 | <0.6 | 200 | 0.08 | 0.05 | 340 | 60 | 70 | 6 | 6.62 | 12.2 | 1,083 |
| | 10-Dec-02 | 2.0 U | 0.018 | 0.068 | 15 | R | 1.6 | 0.56 | <0.018 | 0.31 | <0.6 | 180 | <0.01 | 0.07 | 408 | 35 | 65 | 20 | 7.30 | 10.7 | 740 |
| | 8-Apr-03 | 0.42 | 0.008 | 0.025 | 1.7 J | 3.16 | 1.6 | <0.058 | <0.018 | 0.39 | 0.6 | 190 | <0.01 | 0.05 | 340 | 30 | 60 | 4 | 7.28 | 10.6 | 1,133 |
| | 19-Aug-03 | 2.6 | 0.019 | 0.082 | 1.2 J | 0.87 | 1.4 | <0.058 | <0.018 | 0.26 | 1.9 | 90 | 0.01 | 0.11 | 340 | 35 | 60 | -47 | 7.07 | 20.5 | 1,087 |
| | 12-Apr-05 | 5.8 | 0.056 | 0.085 | 51 | R | NM | NM | NM | 0.46 | 1.4 | 180 | 0.20 | NM | NM | 50 | NM | 15 | 7.20 | 10.2 | 941 |
| | 14-Nov-05 | NM | NM | NM | 4.1J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 47 | 7.10 | 10.3 | 1,028 |
| PES-MW-5 | 14-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.6 | 1.4 | Na | 0.58 | <0.2 | 0.02 | <0.6 | 120 | <0.01 | <0.01 | 422 | 85 | 105 | 104 | 6.80 | 11.7 | 1,279 |
| | 12-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 1.7 | 3.8 | Na | <0.13 | <0.077 | 0.04 | <0.6 | 90 | 0.02 | 0.01 | 561 | 70 | 120 | -64 | 7.04 | 10.1 | 1,241 |
| | 21-May-02 | 2.0 U | 1.6 U | 1.4 U | 1.8 | 0.7 | 2.3 | 0.28 | <0.077 | 0.01 | <0.6 | 130 | <0.01 | <0.01 | 459 | 70 | 100 | -65 | 6.90 | 13.1 | 1,266 |
| | 27-Aug-02 | 2.0 U | 1.6 U | 1.4 U | 12 | 5.5 | 2.1 | 0.26 | <0.077 | <0.01 | <0.6 | 120 | <0.01 | <0.01 | 202 | 50 | 80 | 197 | 6.17 | 11.9 | 1,011 |
| | 10-Dec-02 | 2.0 U | 0.008 | 0.009 | 23 | 2.5 | 1.4 | <0.057 | <0.018 | 0.02 | <0.6 | 111 | <0.01 | 0.02 | 442 | 60 | 95 | 240 | 7.08 | 10.5 | 828 |
| | 8-Apr-03 | 0.04 | 0.005 U | 0.009 | < 1.0 | 3.3 | 1.9 | 0.87 | < 0.018 | 0.06 | <0.6 | 150 | <0.01 | <0.01 | 408 | 60 | 105 | 131 | 7.08 | 10.6 | 1,367 |
| | 19-Aug-03 | 0.1 | 0.015 | 0.026 | <1.0 | 1.4 | 2.2 | <0.058 | <0.018 | 0.02 | 0.7 | 180 | <0.01 | 0.01 | 306 | 40 | 85 | 218 | 7.10 | 21.9 | 1,081 |
| | 12-Apr-05 | 4.5 | 0.050 | 0.062 | 6.9 | R | NM | NM | NM | 0.02 | <0.6 | 170 | 0.01 | NM | NM | 35 | NM | 13 | 6.99 | 9.4 | 1,403 |
| PES-MW-6 | 15-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.4 | 0.22 | Na | <0.2 | <0.2 | 0.01 | <0.6 | 160 | 0.20 | 0.04 | 306 | 40 | 55 | -158 | 7.79 | 11.5 | 1,030 |
| | 15-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 12 | 0.35 | Na | <0.13 | <0.077 | 0.47 | 1.1 | 290 | 1.2 | 0.04 | 408 | 50 | 55 | -408 | 7.29 | 11.0 | 1,107 |
| | 23-May-02 | 2.0 U | 1.6 U | 1.4 U | <0.83 | 0.03 | 1.9 | <0.13 | <0.077 | 0.28 | <0.6 | 190 | 1.8 | 0.07 | 391 | 30 | 45 | -160 | 7.30 | 11.1 | 1,256 |
| | 28-Aug-02 | 3.8 | 1.6 U | 1.4 U | 7 | <0.01 | 2.6 | <0.13 | <0.077 | 0.52 | 1.0 | 170 | 0.80 | 0.07 | 357 | 70 | 55 | -296 | 7.09 | 12.7 | 1,109 |
| | 12-Dec-02 | 70 | 0.019 | 0.082 | 16 | 0.90 | 3.5 | <0.057 | <0.018 | 0.55 | <0.6 | 220 | 0.59 | 0.08 | 391 | 35 | 50 | R | 7.31 | 10.5 | R |
| | 10-Apr-03 | 12 | 0.012 | 0.051 | <1.0 | 0.88 | 2.9 | <0.058 | <0.018 | 0.51 | 1.1 | 180 | 0.61 | 0.09 | 340 | 25 | 50 | -292 | 7.30 | 11.0 | 1,163 |
| | 21-Aug-03 | 8.0 | 0.010 | 0.066 | 1.7 J | 3.6 | 1.9 | <0.058 | <0.018 | 0.56 | 2.2 | 200 | 0.31 | 0.06 | 306 | 40 | 60 | -98 | 7.19 | 14.3 | 1,075 |
| | 15-Apr-05 | 210 | 0.051 | 0.110 | 2.6 | R | NM | NM | NM | 0.38 | 1.5 | 200 | 0.02 | NM | NM | 30 | NM | -89 | 7.37 | 12.3 | 1,104 |
| PES-MW-7 | 16-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.4 | 2.3 | Na | <0.2 | <0.2 | <0.01 | <0.6 | 110 | <0.01 | 0.03 | 238 | 50 | 60 | -26 | 8.96 | 11.6 | 854 |
| | 14-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 26,000 | 0.50 | Na | <0.13 | <0.077 | 1.9 | 3.0 | 160 | 0.51 | 0.04 | 765 | 85 | 55 | -314 | 6.93 | 10.9 | 1,552 |
| | 22-May-02 | 3.4 | 1.6 U | 1.4 U | 150 | 0.01 | 5.8 | <0.65 | 2.2 | 7.8 | 18 | 80 | 0.35 | 0.23 | 663 | 200 | 60 | -188 | 6.70 | 12.3 | 1,531 |
| | 28-Aug-02 | 7,400 | 1.6 U | 1.4 U | 150 | 0.06 | 3.2 | <0.13 | 1.0 | 3.9 | 9.8 | 60 | 1.5 | 2.5 | 561 | 180 | 60 | -395 | 6.58 | 12.5 | 1,351 |
| | 12-Dec-02 | 18,000 | 0.005 U | 0.95 | 200 | 0.78 | 4.3 | <0.057 | 0.69 | 6.3 | 29 | 100 | 0.36 | 0.70 | 629 | 190 | 60 | R | 6.74 | 10.6 | R |
| | 10-Apr-03 | 9,800 | 0.170 | 0.076 | 210 | R | 3.1 | <0.058 | <0.018 | 3.2 | 28 | <7.0 | 0.25 | 0.50 | 629 | 200 | 60 | -173 | 6.60 | 11.9 | 1,523 |
| | 21-Aug-03 | 8,500 | 0.006 U | 0.001 U | 53 | 0.29 | 2.5 | <0.058 | <0.018 | 4.7 | 33 | <7.0 | 2.50 | 1.15 | 544 | 165 | 60 | -161 | 6.71 | 13.0 | 1,285 |
| | 15-Apr-05 | 16,000 | 0.100 | 0.092 | 29 | R | NM | NM | NM | 5.2 | 33 | 140 | 0.07 | NM | NM | 70 | NM | -110 | 6.80 | 11.4 | 1,123 |
| | 17-Nov-05 | NM | NM | NM | 110 | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | -43 | 6.88 | 9.9 | 1,827 |
| PES-MW-8 | 15-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 2.4 | 0.43 | Na | <0.2 | <0.2 | 0.70 | 0.9 | 110 | <0.01 | 0.04 | 408 | 55 | 65 | -54 | 7.02 | 11.6 | 1,120 |
| | 14-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 6.8 | 0.55 | Na | <0.13 | <0.077 | 1.3 | 0.8 | 310 | <0.01 | 0.05 | 442 | 40 | 50 | -200 | 7.29 | 9.8 | 1,129 |
| | 22-May-02 | 2.0 U | 1.6 U | 1.4 U | 1.9 | 0.07 | 1.2 | <0.13 | <0.077 | 1.1 | 0.7 | 220 | <0.01 | <0.01 | 408 | 40 | 60 | -85 | 7.20 | 12.1 | 1,318 |
| | 28-Aug-02 | 2.6 J | 1.6 U | 1.4 U | 14 | <0.01 | 2.1 | <0.13 | <0.077 | 1.2 | 1.3 | 220 | 0.01 | 0.04 | 374 | 75 | 60 | -69 | 6.83 | 12.7 | 1,160 |
| | 12-Dec-02 | 35 | 0.016 | 0.062 | 4.6 | 0.12 | 1.2 | <0.057 | <0.018 | 1.2 | 1.0 | 180 | 0.05 | 0.06 | 357 | 35 | 50 | -80 | 7.15 | 10.2 | R |
| | 9-Apr-03 | 3.7 | 0.002 J | 0.011 | <1.0 | 2.55 | 1.7 | <0.058 | <0.018 | 1.2 | 1.4 | 160 | <0.01 | 0.04 | 374 | 30 | 55 | -128 | 7.25 | 11.2 | 1,201 |
| | 21-Aug-03 | 12 | 0.015 | 0.066 | 3.7 | 0.29 | 1.6 | <0.058 | <0.018 | 1.1 | 2.3 | 150 | 0.01 | 0.04 | 306 | 50 | 70 | -82 | 7.08 | 13.3 | 1,087 |
| | 14-Apr-05 | 11 | 0.035 | 0.049 | 1.7 | R | NM | NM | NM | 1.0 | 1.5 | 180 | 0.03 | NM | NM | 50 | NM | -87 | 7.22 | 11.9 | 1,097 |
| PES-MW-9 | 15-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.4 | 1.1 | Na | <0.2 | <0.2 | 0.40 | 1.1 | 140 | 0.01 | 0.03 | 391 | 45 | 60 | -123 | 7.09 | 10.9 | 1,051 |
| | 13-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 1.8 | 0.79 | Na | <0.13 | <0.077 | 0.55 | 0.9 | 220 | 0.01 | 0.05 | 340 | 25 | 50 | -183 | 7.30 | 10.7 | 1,018 |
| | 22-May-02 | 2.0 U | 1.6 U | 1.4 U | 58 | 0.15 | 1.5 | <0.65 | <0.39 | 4.7 | 2.1 | 30 | 0.04 | <0.01 | 510 | 80 | 50 | -460 | 7.10 | 11.2 | 1,346 |
| | 27-Aug-02 | 28 | 5.4 J | 13 | 180 | <0.01 | 8.2 | <0.13 | 0.66 | 3.3 | 8.5 | 7.0 | 0.22 | 0.60 | 646 | 250 | 80 | -180 | 6.58 | 12.5 | 1,445 |
| | 11-Dec-02 | 3,200 | 0.012 | 0.210 | 240 | 0.15 | 3.3 | <0.057 | 0.37 | NA | 13 | <7.0 | 0.06 | 1.1 | 646 | 600 | 60 | R | 7.03 | 10.4 | 1,650 |
| | 9-Apr-03 | 5,500 | 0.001 U | 0.035 | 2.6 | 1.88 | 1.8 | <0.058 | <0.018 | 4.1 | 10 | 110 | 0.12 | 0.68 | 347 | 65 | 45 | -192 | 7.52 | 11.1 | 1,182 |
| | 21-Aug-03 | 5,000 | 0.006 U | 0.001 U | 1.5 J | 0.42 | 1.9 | <0.058 | <0.018 | 4.7 | 2.7 | 135 | 0.10 | 0.25 | 340 | 55 | 60 | -180 | 7.30 | 15.9 | 1,141 |
| | 16-Apr-05 | 300 | 0.012 | 0.030 | 3.6 | R | NM | NM | NM | 2.5 | 1.6 | 190 | 0.02 | NM | NM | 35 | NM | -93 | 7.41 | 10.7 | 991 |
| | 16-Nov-05 | NM | NM | NM | 2.8J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | -207 | 6.27 | 10.5 | 1,023 |
| PES-CW-1 | 13-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.0 | 0.25 | Na | <0.2 | <0.2 | 0.04 | 0.6 | 80 | <0.01 | <0.01 | 333 | 60 | 60 | -25 | 7.08 | 11.9 | 1,064 |
| | 11-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 1.3 | 0.92 | Na | 0.49 | <0.077 | 0.05 | <0.6 | 130 | <0.01 | 0.03 | 387 | 116 | 65 | -195 | 7.23 | 11.3 | 1,079 |
| | 20-May-02 | 2.0 U | 1.6 U | 1.4 U | <1.3 | 2.3 | 2.3 | 0.20 | <0.077 | 0.01 | <0.6 | 160 | <0.01 | 0.01 | 347 | 60 | 65 | -28 | 7.04 | 11.2 | 1,079 |
| | 26-Aug-02 | 2.0 U | 1.6 U | 1.4 U | 11 | 1.8 | 3.3 | 0.19 | <0.077 | 0.04 | <0.6 | 110 | <0.01 | 0.04 | 408 | 70 | 110 | 45 | 6.47 | 13.1 | 1,258 |
| | 9-Dec-02 | 2.6 J | 0.017 | 0.014 | 1.6 | 0.25 | 2.5 | <0.057 | <0.018 | 0.03 | <0.6 | 120 | <0.01 | 0.04 | 391 | 35 | 60 | 120 | 7.27 | 10.4 | 770 |
| | 7-Apr-03 | 0.23 | 0.005 U | 0.013 | < 1.0 | 0.65 | 3.1 | 0.73 | <0.018 | <0.01 | <0.6 | 140 | <0.01 | 0.02 | 408 | 50 | 125 | 72 | 6.89 | 10.4 | 1,354 |
| | 18-Aug-03 | 0.16 | 0.004 J | 0.013 | 1.6 J | 0.71 | 1.5 | 0.65 | <0.018 | 0.03 | 2.0 | 160 | <0.01 | 0.02 | 357 | 70 | 130 | 103 | 7.00 | 15.7 | 215 |

# TABLE 11
## SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Sample Date | Methane (µg/L)[a] | Ethane (µg/L) | Ethene (µg/L) | TOC[b] (mg/L)[a] | Dissolved Oxygen (mg/L) | Dissolved Hydrogen (nM)[d] | Nitrate (mg/L) | Nitrite (mg/L) | Ferrous Iron (mg/L) | Manganese (mg/L) | Sulfate (mg/L) | Sulfide (mg/L) | Ammonia (mg/L) | Total Alkalinity (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) | Redox Potential (mV)[a] | pH (SU)[e] | Temperature (°C)[a] | Specific Conductivity (µs/cm)[b] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PES-CW-2 | 13-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 0.97 | 0.28 | Na | <0.2 | <0.2 | 0.30 | 1.1 | 50 | <0.01 | 0.05 | 323 | 74 | 65 | -32 | 7.05 | 12.0 | 1,064 |
| | 11-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 0.97 | 2.3 | Na | <0.13 | <0.077 | <0.01 | <0.6 | 190 | <0.01 | 0.01 | 340 | 45 | 55 | -78 | 7.21 | 10.6 | 1,011 |
| | 20-May-02 | 2.0 U | 1.6 U | 1.4 U | <1.0 | 1.1 | 2.9 | <0.13 | <0.077 | 0.06 | <0.6 | 140 | <0.01 | 0.06 | 357 | 45 | 60 | -44 | 7.10 | 11.9 | 1,020 |
| | 26-Aug-02 | 2.0 U | 1.6 U | 1.4 U | 12 | 1.1 | 3.3 | 0.15 | <0.077 | 0.02 | <0.6 | 130 | 0.01 | <0.01 | 357 | 55 | 80 | 82 | 6.59 | 13.2 | 1,134 |
| | 9-Dec-02 | 4.0 | 0.017 | 0.006 | 5.4 | 0.33 | 1.8 | <0.057 | <0.018 | 0.01 | <0.6 | 170 | <0.01 | 0.09 | 357 | 30 | 55 | 210 | 7.35 | 10.6 | 819 |
| | 7-Apr-03 | 0.12 | 0.005 U | 0.011 | < 1.0 | 0.85 | 3.8 | 0.84 | <0.018 | <0.01 | 0.6 | 140 | <0.01 | 0.02 | 425 | 45 | 100 | 128 | 6.94 | 10.6 | 1,292 |
| | 19-Aug-03 | 0.3 | 0.007 | 0.023 | 1.7 J | 1.79 | 1.8 | 1.10 | <0.018 | 0.02 | 0.4 | 120 | <0.01 | 0.01 | 391 | 50 | 125 | 87 | 6.50 | 15.8 | 140 |
| | 11-Apr-05 | NM | NM | NM | 3.6 | R | NM | NM | NM | 0.03 | 0.3 | 160 | <0.01 | NM | NM | 60 | NM | -3 | 7.14 | 11.9 | 1,164 |
| | 14-Nov-05 | NM | NM | NM | 30 | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | -9 | 7.22 | 11.2 | 1,273 |
| PES-CW-3 | 13-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 0.75 | 0.60 | Na | <0.2 | <0.2 | 0.02 | 1.0 | 110 | <0.01 | 0.04 | 357 | 70 | 63 | 32 | 7.07 | 12.8 | 1,014 |
| | 12-Feb-02 | 2.0 U | 1.6 U | 1.4 U | 2.1 | 1.0 | Na | <0.13 | <0.077 | <0.01 | <0.6 | 150 | <0.01 | 0.03 | 323 | 25 | 50 | 71 | 7.03 | 10.4 | 988 |
| | 20-May-02 | 2.0 U | 1.6 U | 1.4 U | <1.6 | 1.5 | 2.6 | <0.13 | <0.077 | 0.04 | <0.6 | 130 | <0.01 | 0.03 | 340 | 40 | 60 | -60 | 7.10 | 14.0 | 920 |
| | 26-Aug-02 | 2.8 | 1.6 U | 1.4 U | 11 | 1.3 | 6.7 | <0.13 | <0.077 | 0.04 | <0.6 | 150 | 0.01 | 0.08 | 238 | 35 | 50 | 81 | 6.74 | 13.4 | 962 |
| | 10-Dec-02 | 2.0 U | 0.016 | 0.013 | 14 | 0.20 | 2.6 | <0.057 | <0.018 | 0.02 | <0.6 | 140 | <0.01 | 0.05 | 306 | 30 | 55 | 200 | 7.02 | 10.2 | 458 |
| | 7-Apr-03 | 1.2 | 0.007 | 0.011 | < 1.0 | 0.80 | 3.0 | <0.058 | <0.018 | 0.03 | <0.6 | 180 | <0.01 | 0.01 | 289 | 30 | 55 | 103 | 7.29 | 7.4 | 1,056 |
| | 19-Aug-03 | 1.3 | 0.012 | 0.026 | <1.0 | 0.98 | 3.4 | 0.360 | <0.018 | 0.01 | 1.0 | 140 | <0.01 | <0.01 | 340 | 50 | 80 | 215 | 6.92 | 20.0 | 1,142 |
| | 11-Apr-05 | NM | NM | NM | 3.7 | R | NM | NM | NM | 0.03 | 0.4 | 170 | <0.01 | NM | NM | 45 | NM | 29 | 7.50 | 11.5 | 1,153 |
| | 14-Nov-05 | NM | NM | NM | 3.5J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 38 | 7.11 | 10.7 | 1,029 |
| PES-MW-10A | 15-Apr-05 | 21,000 | 0.360 | 0.110 | 190 | R | NM | NM | NM | 5.1 | 17 | 87 | 0.10 | NM | NM | 120 | NM | -111 | 6.61 | 11.4 | 1,365 |
| | 16-Nov-05 | NM | NM | NM | 51 | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | -202 | 5.54 | 10.0 | 1,037 |
| PES-MW-10B | 14-Apr-05 | 4.5 | 0.034 | 0.045 | 3.3 | R | NM | NM | NM | 0.04 | 0.8 | 180 | 0.04 | NM | NM | 40 | NM | -52 | 7.15 | 13.0 | 1,064 |
| | 15-Nov-05 | NM | NM | NM | <5.0 | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 19 | 7.32 | 10.5 | 901 |
| PES-MW-11A | 13-Apr-05 | 3,900 | 0.090 | 0.066 | 8.9 | R | NM | NM | NM | 3.1 | 2.4 | 150 | 0.01 | NM | NM | 35 | NM | -21 | 6.91 | 10.8 | 1,047 |
| | 15-Nov-05 | NM | NM | NM | 3.6J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 4 | 7.40 | 10.6 | 807 |
| PES-MW-12A | 12-Apr-05 | 2.1 | 0.042 | 0.080 | 6.0 | R | NM | NM | NM | 0.08 | <0.6 | 150 | 0.03 | NM | NM | 35 | NM | 60 | 7.31 | 11.7 | 1,291 |
| | 15-Nov-05 | NM | NM | NM | 2.9J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 32 | 7.26 | 10.5 | 1,270 |
| PES-MW-12B | 20-Apr-05 | 7.8 | 0.140 | 0.180 | 5.5 | R | NM | NM | NM | 0.03 | 1.6 | 150 | 0.01 | NM | NM | 25 | NM | 18 | 7.08 | 10.6 | 1,348 |
| | 15-Nov-05 | NM | NM | NM | 3.5J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | -6 | 7.39 | 10.7 | 827 |
| PES-MW-13A | 22-Apr-05 | 4.8 | 0.032 | 0.042 | 5.1 | R | NM | NM | NM | 0.19 | 1.3 | 190 | 0.01 | NM | NM | 25 | NM | -34 | 7.57 | 13.5 | 1,102 |
| | 16-Nov-05 | NM | NM | NM | 3.0J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 210 | 6.00 | 10.3 | 942 |
| PES-MW-14A | 12-Apr-05 | 6,900 | 0.150 | 0.180 | 50 | R | NM | NM | NM | 3.19 | 2.3 | 130 | 0.12 | NM | NM | 65 | NM | -44 | 6.88 | 12.0 | 901 |
| | 15-Nov-05 | NM | NM | NM | 7.1 | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | -12 | 7.05 | 10.3 | 1,044 |
| PES-MW-14B | 20-Apr-05 | 7.7 | 0.120 | 0.140 | 4.2J | R | NM | NM | NM | 0.01 | 0.7 | 220 | 0.01 | NM | NM | 20 | NM | 57 | 7.28 | 12.1 | 1,082 |
| | 16-Nov-05 | NM | NM | NM | 2.8J | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 195 | 6.03 | 10.7 | 984 |
| **INJECTION WELLS** | | | | | | | | | | | | | | | | | | | | | |
| PES-INJ-1 | 19-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.1 | 0.14 | Na | <0.2 | <0.2 | 0.01 | 0.6 | 140 | <0.01 | 0.03 | 323 | 25 | 55 | -1 | 7.62 | 10.7 | 1,015 |
| | 18-Feb-02 | 200 U | 160 U | 140 U | 11,000 | 0.15 | Na | 19 | <13 | NA | NA | NA | 36 | 6.3 | 8,500 | 8,500 | 85 | -325 | 5.67 | 10.9 | 4,660 |
| | 23-May-02 | 140 U | 280 U | 250 U | 2,500 | 0.10 | 4.4 | 0.9 | 9.7 | 280 | 3.3 | <7.0 | 1.0 | 0.6 | 21,250 | 5,500 | 2,500 | -89 | 5.50 | 11.3 | 1,702 |
| | 29-Aug-02 | 190 | 70 | 41 | 2,900 | <0.01 | 16 | <2.6 | 21 | 17 | 6.6 | <7.0 | 0.11 | 0.1 | 2,975 | 2,500 | 125 | -98 | 5.23 | 12.0 | 4,520 |
| | 13-Dec-02 | 630 | 35 | 24 | 2,600 | R | 5.2 | <2.5 | 7.9 | 13 | 6.9 | <7.0 | 0.14 | 1.3 | 4,675 | 2,800 | 125 | -40 | 5.25 | 8.2 | R |
| | 10-Apr-03 | 73 | 3.1 | 7.6 | 2,300 | 1.58 | 4.4 | <0.58 | 13 | 3.9 | 16 | <7.0 | 0.04 | 0.7 | 4,250 | 2,500 | 250 | -91 | 5.24 | 12.6 | 3,310 |
| | 22-Aug-03 | 660 | 21 | 25 | 2,100 | 0.65 | 32 | <0.58 | 9.8 J | 4.8 | 9.3 | <7.0 | 0.03 | 0.5 | 2,040 | 2,000 | 100 | -33 | 5.21 | 12.1 | 2,950 |
| | 19-Apr-05 | 14,000 | 6.3 | 4.6 | 2,500 | R | NM | NM | NM | 3.6 | 14 | <7.0 | 6.9 | NM | NM | 2,500 | NM | 0 R | 5.60 | 11.6 | 3,081 |
| PES-INJ-2 | 19-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 0.8 | <0.01 | Na | <0.2 | <0.2 | 0.01 | <0.6 | 130 | <0.01 | 0.04 | 289 | 25 | 55 | 74 | 7.77 | 10.5 | 971 |
| | 15-Feb-02 | 50 U | 40 U | 35 U | 9,500 | 0.01 | Na | 34 | 110 | NA | NA | NA | 9 | 7.0 | 8,500 | 3,000 | 2,500 | -323 | 5.44 | 10.6 | 4,200 |
| | 23-May-02 | 28 U | 56 U | 50 U | 4,100 | 0.05 | 93 | 2.7 | 19 | 2.6 | 14 | <7.0 | 1.9 | 3.1 | 29,750 | 7,500 | 2,500 | -93 | 5.10 | 12.3 | 1,872 |
| | 29-Aug-02 | 13 | 5 | 2.8 | 4,130 | <0.01 | 4.9 | <2.6 | 28 | NA | 17 | 23 | 2.9 | 0.72 | 2,550 | 2,250 | 100 | -55 | 5.10 | 12.4 | 4,870 |
| | 13-Dec-02 | 11 | 0.34 | 1.4 | 4,400 | R | 12 | 20 | 13 | NA | 5.4 | 61 | 0.8 | 0.68 | 4,250 | 2,900 | 100 | -30 | 5.10 | 10.5 | R |
| | 11-Apr-03 | 99 | 0.35 | 1.4 | 2,300 | 0.63 | 39 | <0.58 | 11 J | NA | 78 | <7.0 | 0.8 | 0.40 | 5,100 | 2,750 | 100 | -33 | 5.09 | 11.1 | 3,160 |
| | 22-Aug-03 | 1,500 | 1.1 | 4.5 | 2,000 | 1.05 | 300 | <0.58 | 6.7 J | 2.4 | 69 | <7.0 | 0.3 | 0.56 | 1,700 | 1,300 | 150 | 1 | 5.11 | 12.8 | 2,650 |
| | 19-Apr-05 | 5,800 | 1.1 | 3.8 | 2,400 | R | NM | NM | NM | 1.6 | 50 | 5 | 12 | NM | NM | 3,500 | NM | 5 R | 5.35 | 11.0 | 2,434 |

# TABLE 11
## SUMMARY OF GROUNDWATER GEOCHEMICAL DATA
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Sample Date | Methane (µg/L)[a] | Ethane (µg/L) | Ethene (µg/L) | TOC[b] (mg/L)[c] | Dissolved Oxygen (mg/L) | Dissolved Hydrogen (nM)[d] | Nitrate (mg/L) | Nitrite (mg/L) | Ferrous Iron (mg/L) | Manganese (mg/L) | Sulfate (mg/L) | Sulfide (mg/L) | Ammonia (mg/L) | Total Alkalinity (mg/L) | Carbon Dioxide (mg/L) | Chloride (mg/L) | Redox Potential (mV)[e] | pH (SU)[f] | Temperature (°C)[g] | Specific Conductivity (µs/cm)[h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PES-INJ-3 | 16-Nov-01 | 2.0 U | 1.6 U | 1.4 U | 1.0 | 0.92 | Na | <0.2 | <0.2 | 0.01 | 0.6 | 110 | <0.01 | 0.06 | 255 | 10 | 60 | -79 | 8.47 | 12.1 | 881 |
| | 18-Feb-02 | 200 U | 160 U | 140 U | 6,900 | 0.67 | Na | 15 | <7.7 | NA | NA | NA | 23 | 3.3 | 11,900 | 4,500 | 60 | -317 | 5.65 | 10.8 | 6,310 |
| | 23-May-02 | 140 U | 280 U | 250 U | 4,100 | 0.12 | 30 | 1.9 | 23 | NA | NA | 66 | 1.8 | 2.2 | 25,500 | 7,500 | 2,500 | -76 | 5.30 | 12.9 | 1,843 |
| | 29-Aug-02 | 7.5 | 5.6 J | 1.4 U | 3,650 | <0.01 | 15 | <2.6 | 32 | 5.6 | 31 | <7.0 | 1.6 | 1.5 | 2,975 | 2,875 | 100 | -98 | 5.23 | 12.0 | 4,520 |
| | 13-Dec-02 | 3.3 | 0.630 | 1.2 | 4,900 | 0.47 | 57 | <2.5 | 13 | NA | 30 | <7.0 | 2.8 | 2.0 | 5,525 | 3,875 | 100 | -35 | 5.26 | 10.3 | R |
| | 11-Apr-03 | 58 | 0.35 | 1.4 | 4,600 | 0.04 | 39 | <0.58 | 17 J | NA | 20 | <7.0 | 4.6 | 2.7 | 5,950 | 5,000 | 100 | -88 | 5.14 | 11.3 | 4,010 |
| | 22-Aug-03 | 290 | 1.4 | 3.7 | 2,600 | 2.34 | 150 | <0.58 | 15 J | 5.7 | 22 | <7.0 | 0.2 | 0.7 | 2,380 | 2,100 | 100 | -54 | 5.19 | 15.0 | 3,710 |
| | 19-Apr-05 | 2,800 | 3.6 | 3.4 | 4,700 | R | NM | NM | NM | 4.5 | 74 | <7.0 | 14 | NM | NM | 2,000 | NM | 9 R | 5.33 | 11.6 | 3,328 |
| | 17-Nov-05 | NM | NM | NM | 13,000 | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | NM | 3 | 5.86 | 10.5 | 5,081 |

[a] µg/L = micrograms per liter.
[b] TOC = total organic carbon.
[c] mg/L = milligrams per liter.
d/ nM = nano-Mol
[e] mV = millivolts.
[f] SU = pH standard units.
[g] °C = degrees Centigrade.
[h] µs/cm = microsiemens per centimeter.
[i] J indicates that the analyte was detected at a concentration above the method detection limit but below the reporting limit resulting in an estimated value.
[j] NM = Not measured.
[k] <20 indicates that the analyte was not detected above the referenced method detection limit.
[l] R = This data point is of suspect quality or was collected in the incorrect units (as percent saturation instead of mg/L). Therefore it is rejected and was not considered during data interpretation.

# TABLE 12
## BIOMASS AND VOLATILE FATTY ACIDS IN GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Distance Downgradient From Injection Wells (feet) | Sample Date | Total Organic Carbon (mg/L)[a] | Bacterial Biomass (pmol/mL)[b] | Starvation Ratio (unitless) | Total Volatile Fatty Acids (mg/L) | Metabolic Acids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pyruvic (mg/L) | Lactic (mg/L) | Formic (mg/L) | Acetic (mg/L) | Proprionic (mg/L) | Butyric (mg/L) |
| **MONITORING WELLS** | | | | | | | | | | | | |
| 18S | | 4/18/2005 | 3.8 | NM | 0.00 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| 26-S | | 4/15/2005 | 2.2 | NM | 0.09 | NM | NM | NM | NM | NM | NM | NM |
| GWMS-27S | 220 | 21-May-02 | <1.7 [c] | NM [d] | NM | < 4 [b] | < 80 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 26-Aug-02 | 9.9 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 9-Dec-02 | 16 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 7-Apr-03 | 2.8 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 18-Aug-03 | 1.2 J | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| GWMS-46S [e] | -22 | 22-May-02 | 2.3 | NM | NM | 5.6 | < 40 | < 1 | 4.0 | 1.6 | < 1 | < 1 |
| | | 28-Aug-02 | 10 | NM | NM | 6.2 | < 4 | 0.8 J [g] | 1.9 | 2.6 | 0.9 J | < 1 |
| | | 11-Dec-02 | 18 | 13.4 | 0.56 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 8-Apr-03 | 1.0 J | 3 | 0.12 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 20-Aug-03 | 1.0 UJ | 11 | 0.32 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 18-Apr-05 | 4 | NM | 1.22 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| GWMS-47S | 224 | 21-May-02 | <1.1 | NM | NM | < 4 | < 80 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 26-Aug-02 | 11 | NM | NM | 3.8 | < 4 | < 1 | 1.8 | 2.0 | < 1 | < 1 |
| | | 10-Dec-02 | 38 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 8-Apr-03 | 1.1 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 19-Aug-03 | 1.0 J | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-1 | 16 | 22-May-02 | 3.0 | NM | NM | 6.5 | < 40 | < 1 | 3.7 | 1.8 | 0.97 | < 1 |
| | | 28-Aug-02 | 14 | NM | NM | 10.4 | < 4 | < 1 | 1.7 | 6.8 | 1.9 | < 1 |
| | | 12-Dec-02 | 12 | 31.3 | 1.13 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 10-Apr-03 | <1.0 | 54 | 0.07 | 3.0 | < 4 | 1.0 | < 1 | 1.0 | 1.0 | < 1 |
| | | 21-Aug-03 | 1.4 J | 14 | 0.25 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 15-Apr-05 | 3 | NM | 0.26 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-2 | 28 | 22-May-02 | 2.5 | NM | NM | 8.0 | < 40 | < 1 | 3.9 | 1.9 | 2.2 | < 1 |
| | | 28-Aug-02 | 12 | NM | NM | 3.6 | < 4 | < 1 | 1.7 | 1.9 | < 1 | < 1 |
| | | 9-Dec-02 | 6.5 | 0.2 | 1.54 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 9-Apr-03 | <1.0 | 7 | 0.11 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 20-Aug-03 | 1 J | 19 | 0.07 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 14-Apr-05 | 1.9 | NM | 0.16 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-3 | 48 | 21-May-02 | 2.9 | NM | NM | 8.1 | < 40 | < 1 | 4.0 | 2.4 | 1.7 | < 1 |
| | | 27-Aug-02 | 13 | NM | NM | 6.7 | < 4 | < 1 | 1.7 | 3.8 | 1.2 | < 1 |
| | | 10-Dec-02 | 24 | 0.0 | 0.00 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 8-Apr-03 | 2.0 J | 194 | 0.92 | 3.6 | < 4 | < 1 | < 1 | 1.9 | 1.7 | < 1 |
| | | 20-Aug-03 | 2.6 J | 44 | 0.27 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 14-Apr-05 | 2 | NM | 0.76 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-4 | 76 | 21-May-02 | 2.0 | NM | NM | 1.5 | < 80 | < 1 | 1.5 | < 1 | < 1 | < 1 |
| | | 27-Aug-02 | 10 | NM | NM | 3.7 | < 4 | < 1 | 1.8 | 1.9 | < 1 | < 1 |
| | | 10-Dec-02 | 15 | 1.0 | 0.09 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 8-Apr-03 | 1.7 J | 6.0 | 0.36 | 2.0 | < 4 | < 1 | < 1 | 1.0 | 1.0 | < 1 |
| | | 19-Aug-03 | 1.2 J | 119 | 0.62 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 12-Apr-05 | 51 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |

# TABLE 12
## BIOMASS AND VOLATILE FATTY ACIDS IN GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Distance Downgradient From Injection Wells (feet) | Sample Date | Total Organic Carbon (mg/L)[a] | Bacterial Biomass (pmol/mL)[b] | Starvation Ratio (unitless) | Total Volatile Fatty Acids (mg/L) | Metabolic Acids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pyruvic (mg/L) | Lactic (mg/L) | Formic (mg/L) | Acetic (mg/L) | Proprionic (mg/L) | Butyric (mg/L) |
| PES-MW-5 | 142 | 21-May-02 | 1.8 | NM | NM | 1.4 | < 80 | < 0 | 1.4 | < 1 | < 1 | < 1 |
| | | 27-Aug-02 | 12 | NM | NM | 4.3 | < 4 | < 0.9 | 1.8 | 2.5 | < 1 | < 1 |
| | | 10-Dec-02 | 23 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 8-Apr-03 | <1.0 | NM | NM | 2.0 | < 4 | < 1 | < 1 | 1.0 | 1.0 | < 1 |
| | | 19-Aug-03 | <1.0 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-6 | 16 | 23-May-02 | <0.83 | NM | NM | 19.1 | < 40 | < 1 | 4.1 | 12.3 | 2.7 | < 1 |
| | | 28-Aug-02 | 7 | NM | NM | 6.3 | < 4 | < 1 | 2.1 | 4.2 | < 1 | < 1 |
| | | 12-Dec-02 | 16 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 10-Apr-03 | <1.0 | 57 | 0.07 | 8.0 | 4.0 | 1.0 | < 1 | 1.0 | 1.0 | 1.0 |
| | | 21-Aug-03 | 1.7 J | 18 | 0.02 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 15-Apr-05 | 3 | NM | 0.07 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-7 | 16 | 22-May-02 | 150 | NM | NM | 347 | < 20 | < 1 | 3.9 | 133 | 182 | 28 |
| | | 28-Aug-02 | 150 | NM | NM | 212 | < 4 | < 1 | 1.9 | 57.8 | 122 | 30 |
| | | 12-Dec-02 | 200 | NM | NM | 149 | < 4 | < 1 | < 1 | 28.3 | 98 | 23 |
| | | 10-Apr-03 | 210 | 87 | 0.50 | 202.2 | < 4 | < 1 | < 1 | 43.4 | 153.5 | 5.3 |
| | | 21-Aug-03 | 53 | 558 | 0.21 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 15-Apr-05 | 29 | NM | 0.10 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-8 | 40 | 22-May-02 | 1.9 | NM | NM | 5.6 | < 40 | < 1 | 4.0 | 1.6 | < 1 | < 1 |
| | | 28-Aug-02 | 14 | NM | NM | 3.9 | < 4 | < 1 | 1.9 | 2.0 | < 1 | < 1 |
| | | 12-Dec-02 | 4.6 | NM | NM | < 1 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 9-Apr-03 | <1.0 | 62 | 2.35 | 8.0 | 4.0 | 1.0 | < 1 | 1.0 | 1.0 | 1.0 |
| | | 21-Aug-03 | 3.7 | 29 | 1.45 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 14-Apr-05 | 1.7 | NM | 0.67 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-9 | 36 | 22-May-02 | 58 J | NM | NM | 140 | < 40 | < 1 | 4.2 | 53.8 | 82.4 | < 1 |
| | | 27-Aug-02 | 180 | NM | NM | 308 | < 4 | < 0.5 | 1.9 | 199 | 99.1 | 7.6 |
| | | 11-Dec-02 | 240 | NM | NM | 295 | < 4 | < 1 | 0.6 J | 229 | 47.5 | 18.1 |
| | | 9-Apr-03 | 2.6 | 45 | 0.42 | 4.0 | < 4 | 1.0 | < 1 | 1.0 | 1.0 | 1.0 |
| | | 20-Aug-03 | 1.5 J | 121 | 0.19 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 16-Apr-05 | 4 | NM | 0.58 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-10A | 16 | 15-Apr-05 | 190 | NM | 0.20 | 50.5 | < 4 | < 1 | < 1 | 26.8 | 11.6 | 12.1 |
| PES-MW-10B | 13 | 14-Apr-05 | 3 | NM | 0.07 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-11A | 38 | 13-Apr-05 | 9 | NM | 0.17 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-12A | 155 | 12-Apr-05 | 6 | NM | 0.08 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-12B | 155 | 20-Apr-05 | 6 | NM | 0.00 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-13A | NA | 20-Apr-05 | 5 | NM | 0.08 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-14A | 75 | 12-Apr-05 | 50 | NM | 0.37 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-MW-14B | 75 | 20-Apr-05 | 4.2J | NM | 0.05 | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-CW-1 | 220 | 20-May-02 | <1.3 | NM | NM | <1 | < 80 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 26-Aug-02 | 11 | NM | NM | 3.4 | < 4 | < 1 | 1.6 | 1.8 | < 1 | < 1 |
| | | 9-Dec-02 | 1.5 | NM | NM | < 1 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 7-Apr-03 | <1.0 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 18-Aug-03 | 1.6 J | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |

# TABLE 12
## BIOMASS AND VOLATILE FATTY ACIDS IN GROUNDWATER
### NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT FRIDLEY
### ANOKA COUNTY PARK
### FRIDLEY, MINNESOTA

| Sample Location | Distance Downgradient From Injection Wells (feet) | Sample Date | Total Organic Carbon (mg/L)[a] | Bacterial Biomass (pmol/mL)[b] | Starvation Ratio (unitless) | Total Volatile Fatty Acids (mg/L) | Metabolic Acids | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pyruvic (mg/L) | Lactic (mg/L) | Formic (mg/L) | Acetic (mg/L) | Proprionic (mg/L) | Butyric (mg/L) |
| PES-CW-2 | 212 | 20-May-02 | <1.0 | NM | NM | <1 | < 80 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 26-Aug-02 | 12 | NM | NM | 3.4 | < 4 | < 1 | 1.7 | 1.7 | < 1 | < 1 |
| | | 9-Dec-02 | 5.4 | NM | NM | < 1 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 7-Apr-03 | <1.0 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 19-Aug-03 | 1.7 J | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| PES-CW-3 | 220 | 20-May-02 | <1.6 | NM | NM | <1 | < 80 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 26-Aug-02 | 11 | NM | NM | 4.0 | < 4 | 0.4 J | 1.8 | 1.8 | < 1 | < 1 |
| | | 10-Dec-02 | 14 | NM | NM | < 1 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| | | 8-Jul-03 | <1.0 | NM | NM | 3.0 | < 4 | < 1 | < 1 | 1.0 | 1.0 | 1.0 J |
| | | 19-Aug-03 | <1.0 | NM | NM | < 4 | < 4 | < 1 | < 1 | < 1 | < 1 | < 1 |
| **INJECTION WELLS** | | | | | | | | | | | | |
| PES-INJ-1 | NA [d] | 23-May-02 | 2,500 | NM | NM | 3,279 | < 80 | 1.2 | 4.9 | 1,500 | 843 | 930 |
| | | 29-Aug-02 | 2,900 | NM | NM | 2,910 | < 4 | 1.2 | 3.0 | 1,468 | 458 | 980 |
| | | 13-Dec-02 | 2,600 | NM | NM | 2,509 | < 4 | < 1 | 3.8 | 1,294 | 255 | 956 |
| | | 10-Apr-03 | 2,300 | 3.0 | 2.47 | 2,321 | < 4 | < 1 | 1.5 | 1,276 | 179 | 865 |
| | | 22-Aug-03 | 2,100 | 4.0 | 1.73 | 1,973 | < 4 | < 1 | < 1 | 963 | 311 | 699 |
| | | 19-Apr-05 | 2,500 | NM | NM | 1,954 | < 4 | < 1 | < 1 | 1,222 | 167 | 565 |
| PES-INJ-2 | NA | 23-May-02 | 4,100 | NM | NM | 5,777 | < 80 | < 20 | 32.7 | 1,471 | 2,835 | 1,438 |
| | | 29-Aug-02 | 4,130 | NM | NM | 4,371 | 333 | < 20 | < 20 | 1,059 | 1,753 | 1,226 |
| | | 13-Dec-02 | 4,400 | 7,698 | 0.05 | 3,176 | 177 | < 10 | < 10 | 917 | 1,047 | 1,035 |
| | | 11-Apr-03 | 2,300 | 98 | 0.18 | 2,139 | 40 | 10 | 10 | 905 | 466 | 708 |
| | | 22-Aug-03 | 2,000 | 350 | 0.00 | 1,879 | < 4 | < 1 | < 1 | 893 | 379 | 607 |
| | | 19-Apr-05 | 2,400 | NM | 0.25 | 1,334 | < 4 | < 1 | < 1 | 794 | 174 | 366 |
| PES-INJ-3 | NA | 23-May-02 | 4,100 | NM | NM | 5,410 | < 80 | < 20 | 33.4 | 1,303 | 2,355 | 1,719 |
| | | 29-Aug-02 | 3,650 | NM | NM | 2,965 | < 80 | < 20 | < 20 | 889 | 806 | 1,270 |
| | | 13-Dec-02 | 4,900 | NM | NM | 3,202 | < 4 | < 10 | < 10 | 1,265 | 652 | 1,285 |
| | | 11-Apr-03 | 4,600 | 27 | 0.00 | 2,668 | < 4 | < 1 | 2.2 | 1,039 | 255 | 1,372 |
| | | 22-Aug-03 | 3,600 | 59 | 0.79 | 2,787 | 243 | < 1 | 20 | 963 | 231 | 1,330 |
| | | 19-Apr-05 | 4,700 | NM | NM | 1,822 | < 4 | 2.3 | 84 | 646 | 127 | 963 |
| **OTHER WELLS** | | | | | | | | | | | | |
| MS-53PC | NA | 11-Apr-05 | 110 | NM | NM | 792 | < 4 | 1.0 | 106 | 469 | 210 | 6 |

[a] mg/L = milligrams per liter.

[b] pmol/mL = picomoles per milliliter.

[c] "<" indicates that anayte was below the limit of quantitation.

[d] NM = not measured.

[e] This well is located upgradient of the injection area.

f/ J indicates that the analyte was detectedat a concentration greater than the method detection limit and less than the reporting limit. Thus, the concentration is estimated.

# FIGURES

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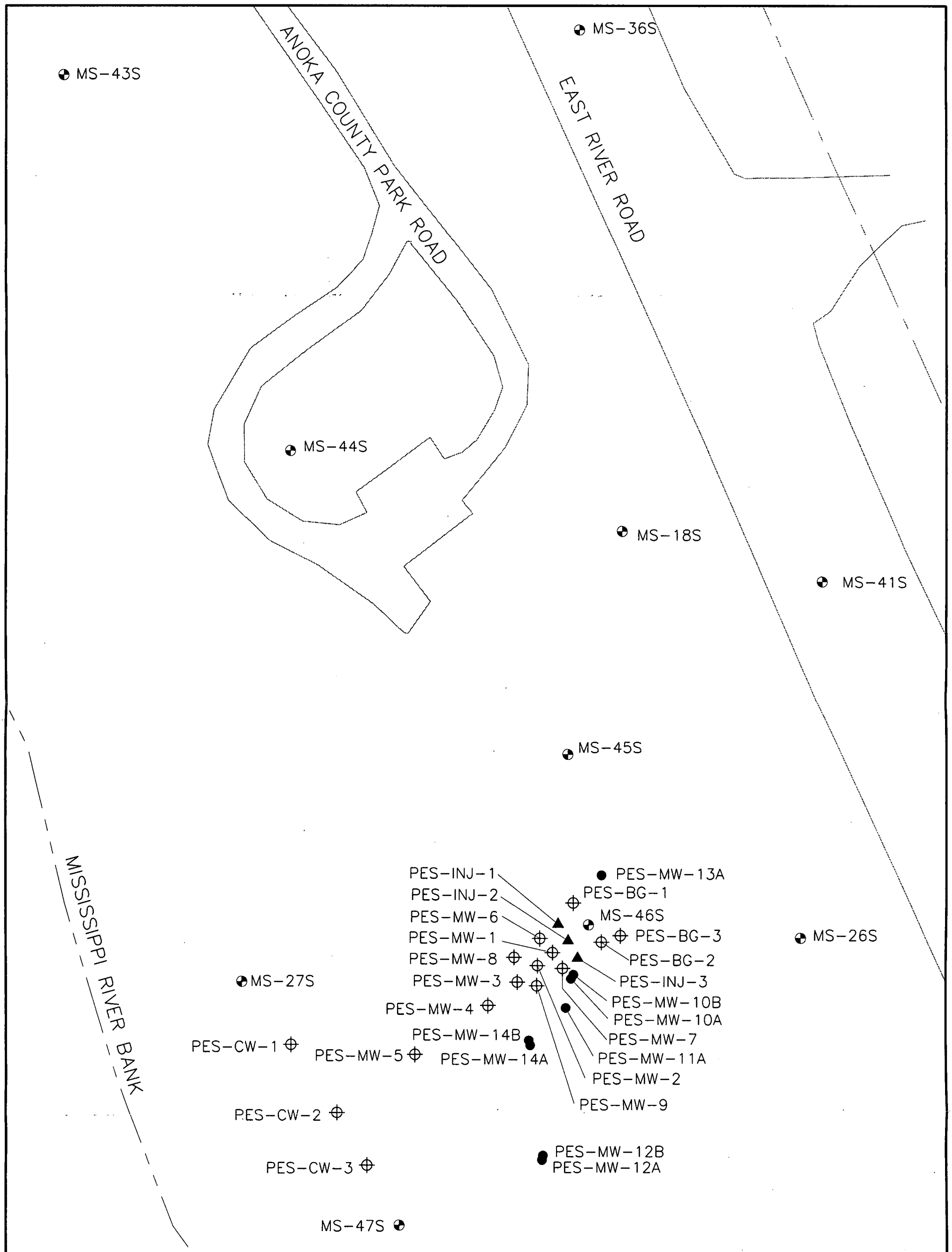


LEGEND

- ● NEWLY INSTALLED PILOT TEST MONITORING WELL
- ◕ EXISTING MONITORING WELL
- ⊕ EXISTING PILOT TEST INSTALLED MONITORING WELL
- ▲ VEGETABLE OIL INJECTION WELL

N

0' 35' 70'

SCALE: 1"=70'

**FIGURE 1**

**REGIONAL MAP OF THE PILOT TEST AREA**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado (303) 831-8100

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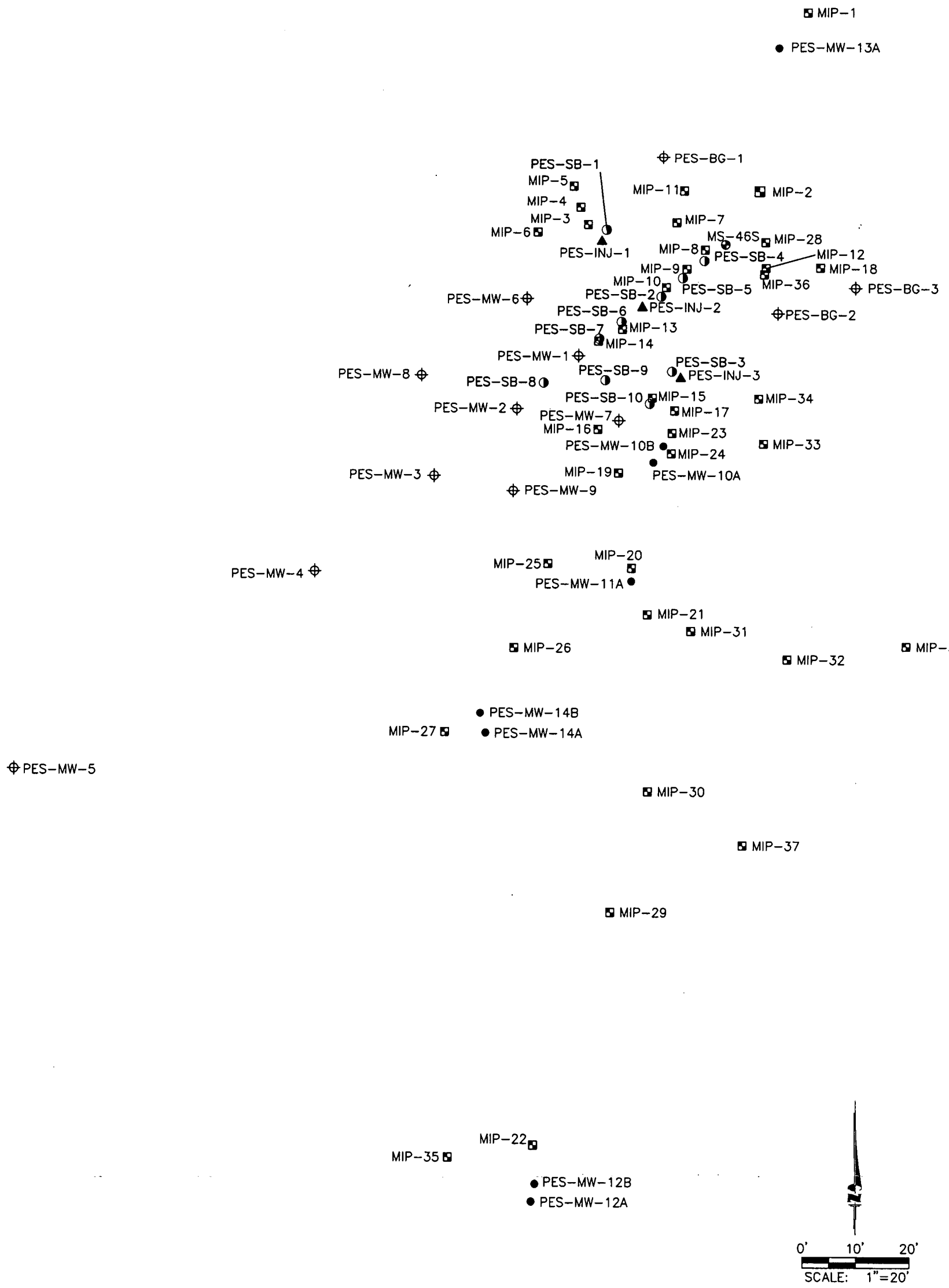


LEGEND

- EXISTING MONITORING WELL
- NEWLY INSTALLED MONITORING WELL
- VEGETABLE OIL INJECTION WELL
- MIP WELL LOCATION
- NEWLY INSTALLED SOIL BORING

**FIGURE 2**

**LOCAL MAP OF THE PILOT TEST AREA**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado (303) 831-8100

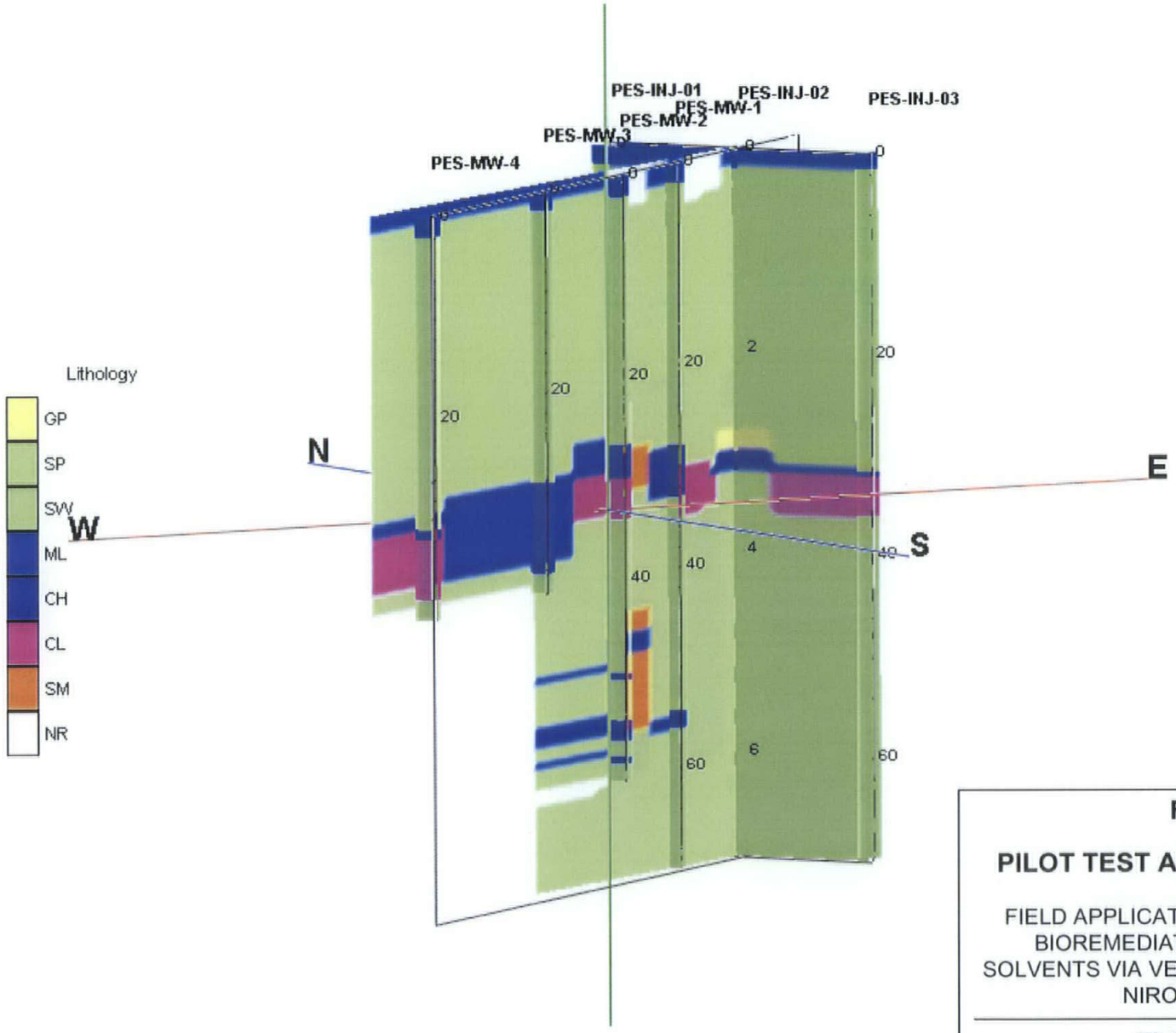


**FIGURE 3**

**PILOT TEST AREA FENCE DIAGRAM**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado (303) 831-8100

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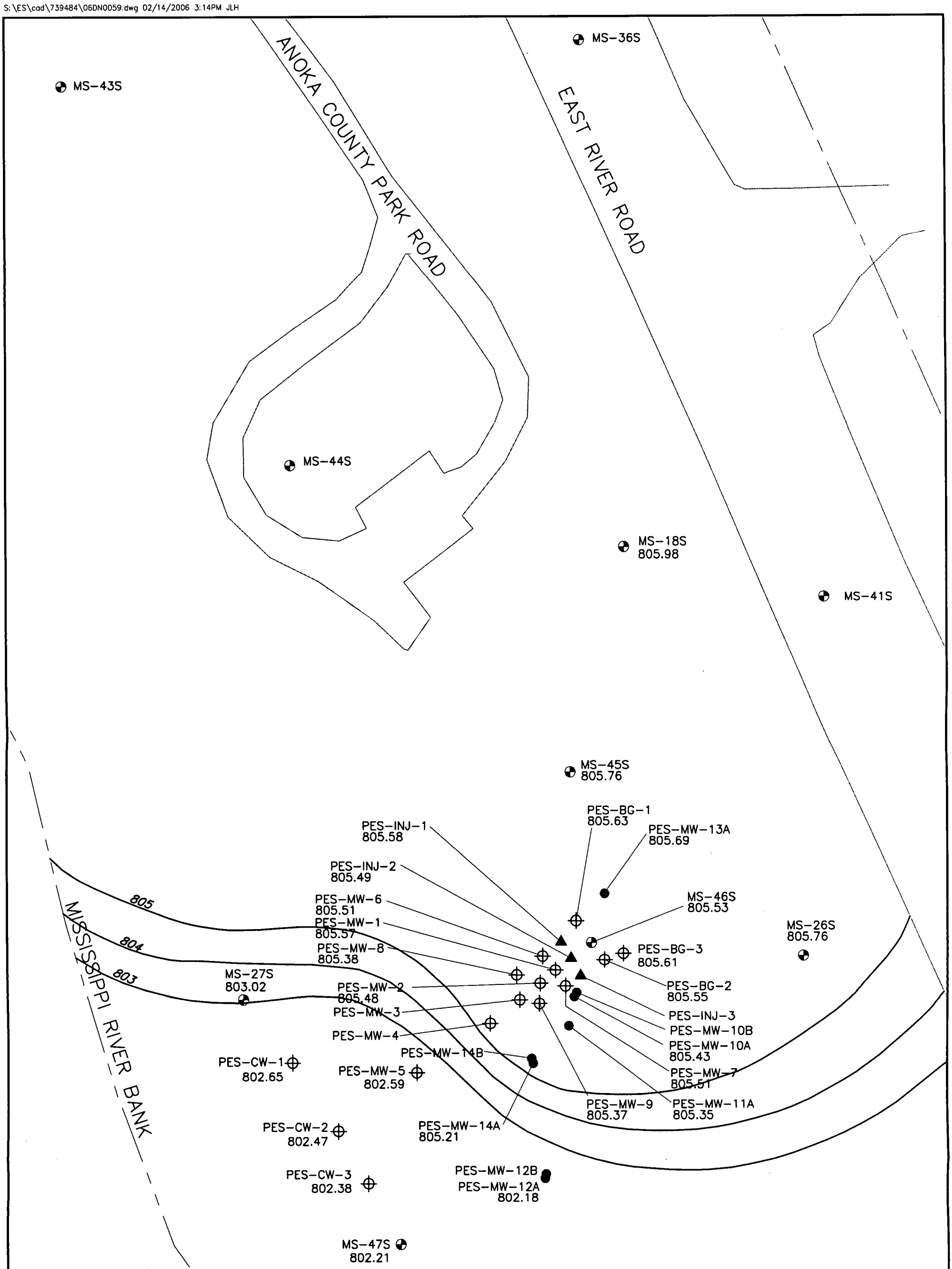


**FIGURE 4**

**GROUNDWATER POTENTIOMETRIC SURFACE, NOVEMBER 2005**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado (303) 831-8100

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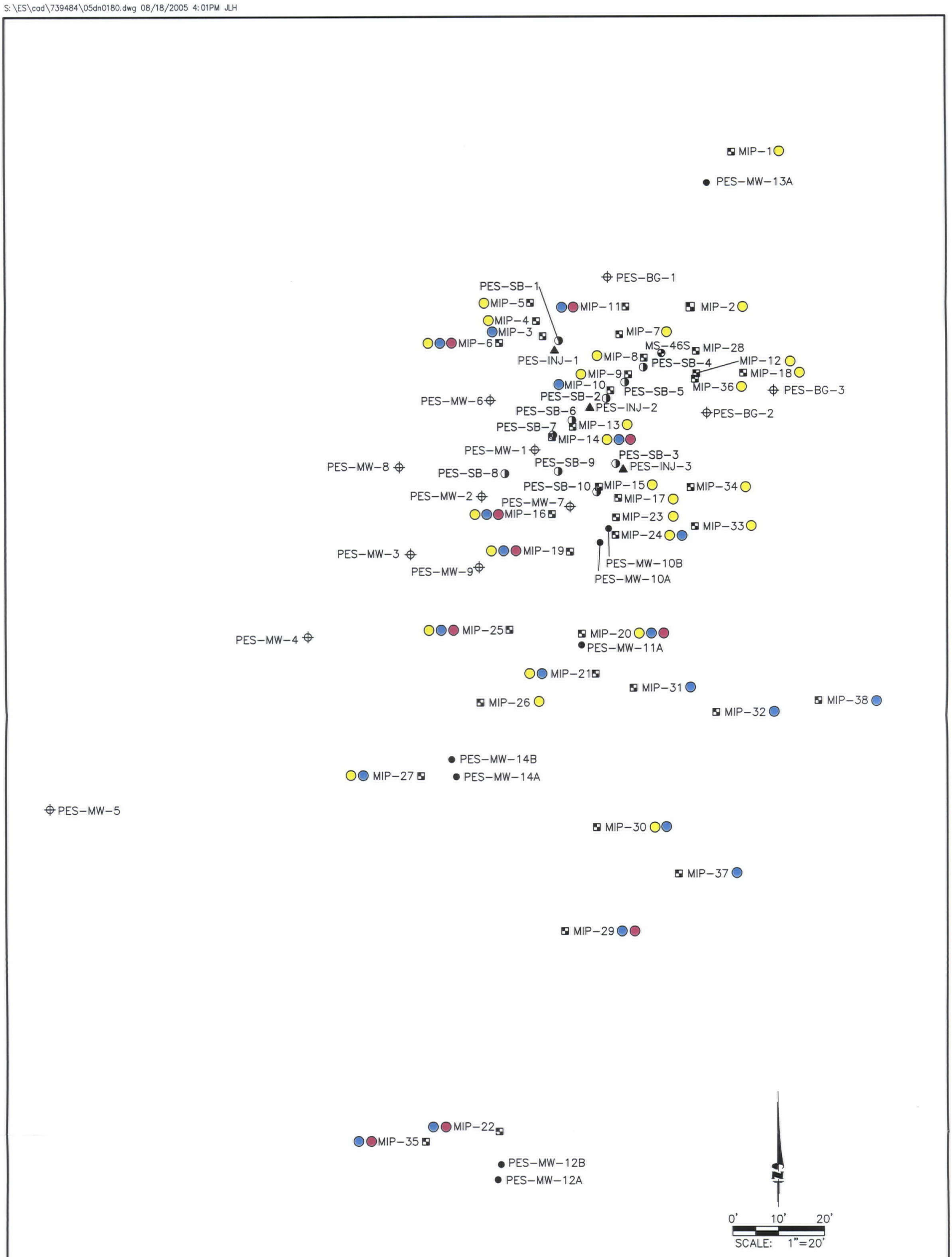


LEGEND

- EXISTING MONITORING WELL
- NEWLY INSTALLED MONITORING WELL
- VEGETABLE OIL INJECTION WELL
- MIP WELL LOCATION
- NEWLY INSTALLED SOIL BORING

PRESENCE AND DEPTH OF ELEVATED ECD RESPONSE

- 30 – 40 FEET BGS
- 40 – 50 FEET BGS
- 50 – 60 FEET BGS

**FIGURE 5**

**SUMMARY OF ECD RESPONSE**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado (303) 831-8100

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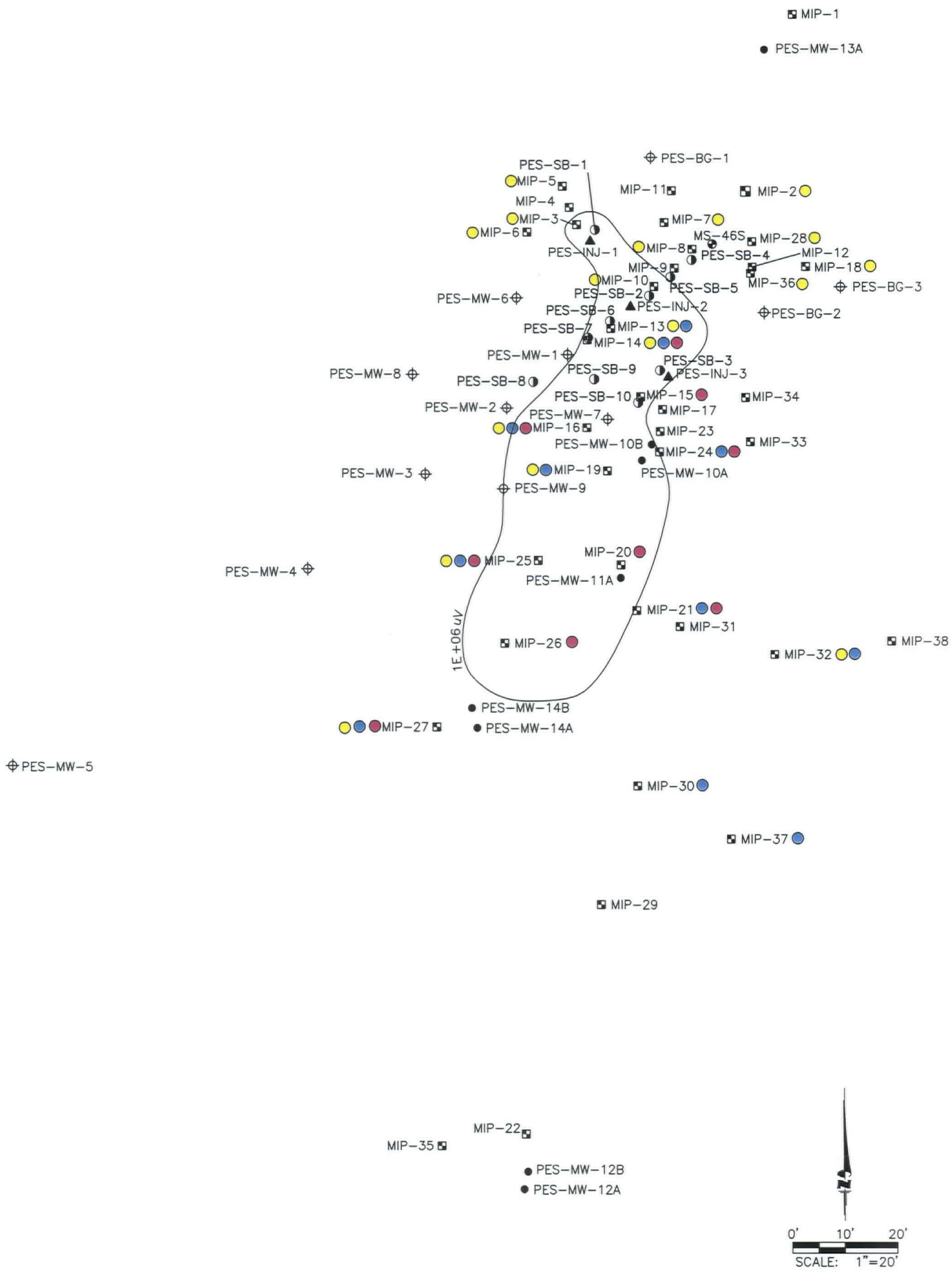


LEGEND

- EXISTING MONITORING WELL
- NEWLY INSTALLED MONITORING WELL
- VEGETABLE OIL INJECTION WELL
- MIP WELL LOCATION
- NEWLY INSTALLED SOIL BORING

PRESENCE AND DEPTH OF FID RESPONSE

- < 40 FEET BGS
- < 40 – 50 FEET BGS
- < 50 – 60 FEET BGS

**FIGURE 6**

**SUMMARY OF FID RESPONSE**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado (303) 831-8100

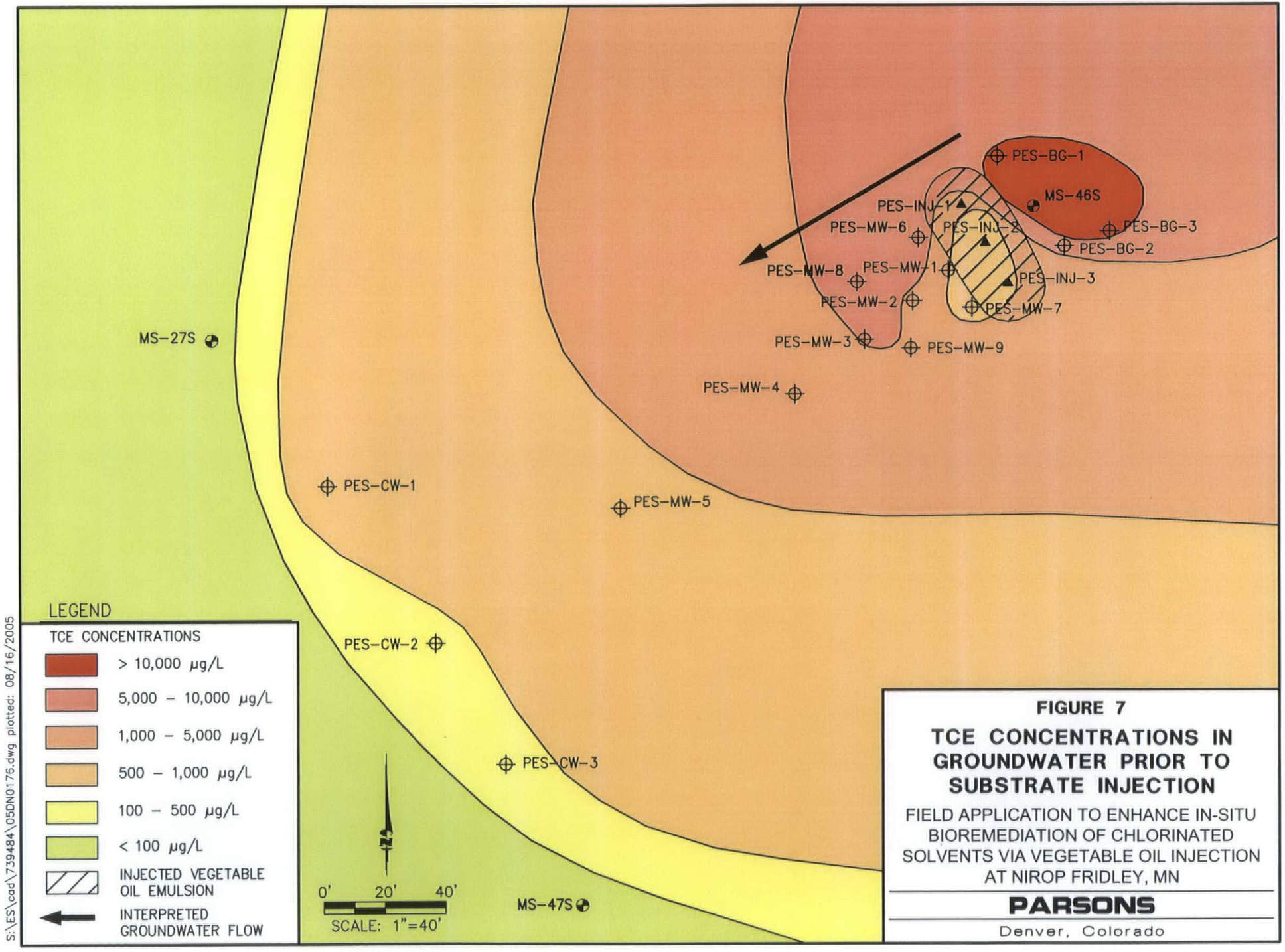


**FIGURE 7**

**TCE CONCENTRATIONS IN GROUNDWATER PRIOR TO SUBSTRATE INJECTION**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado

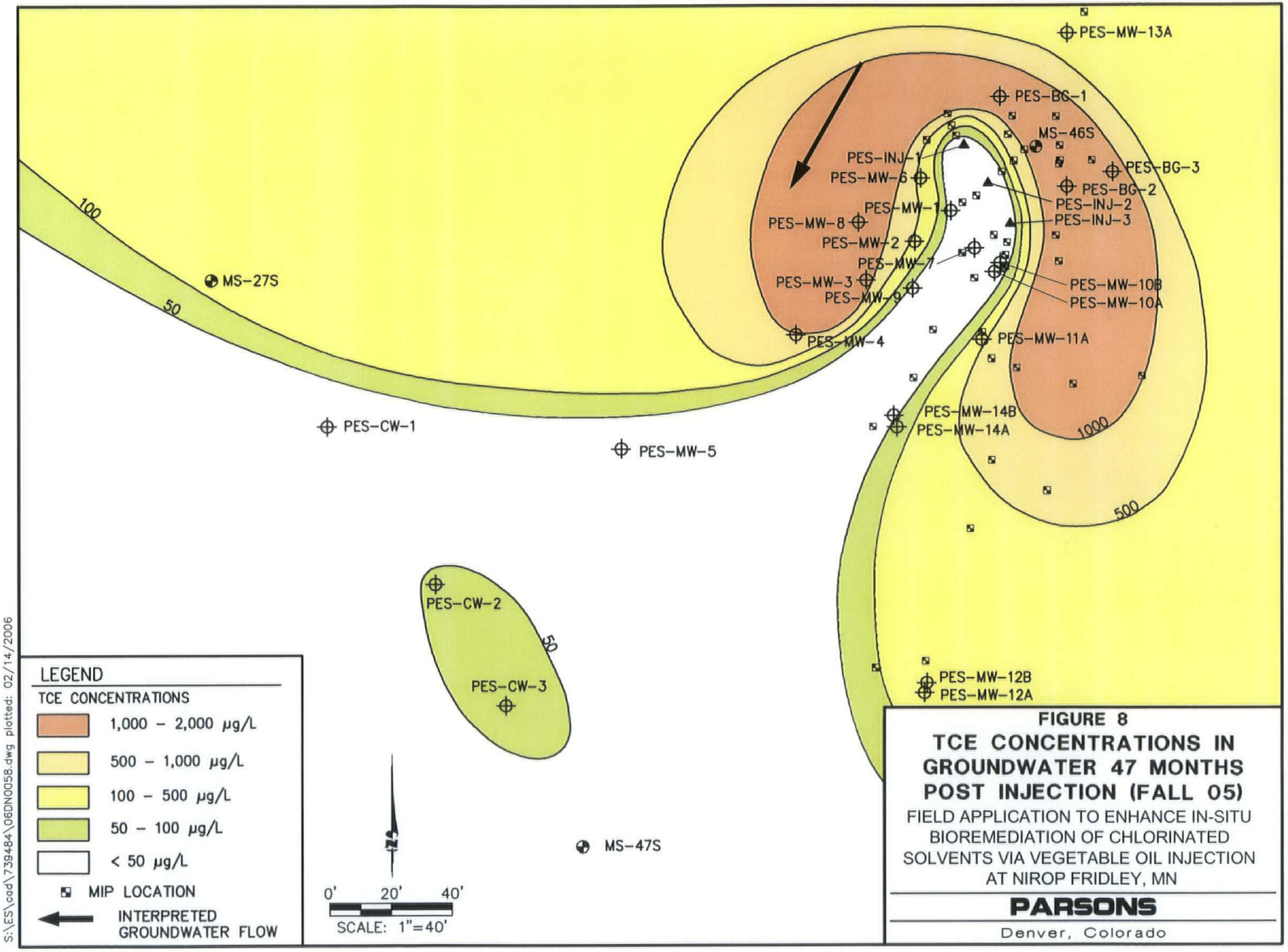


**FIGURE 8**

**TCE CONCENTRATIONS IN GROUNDWATER 47 MONTHS POST INJECTION (FALL 05)**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado

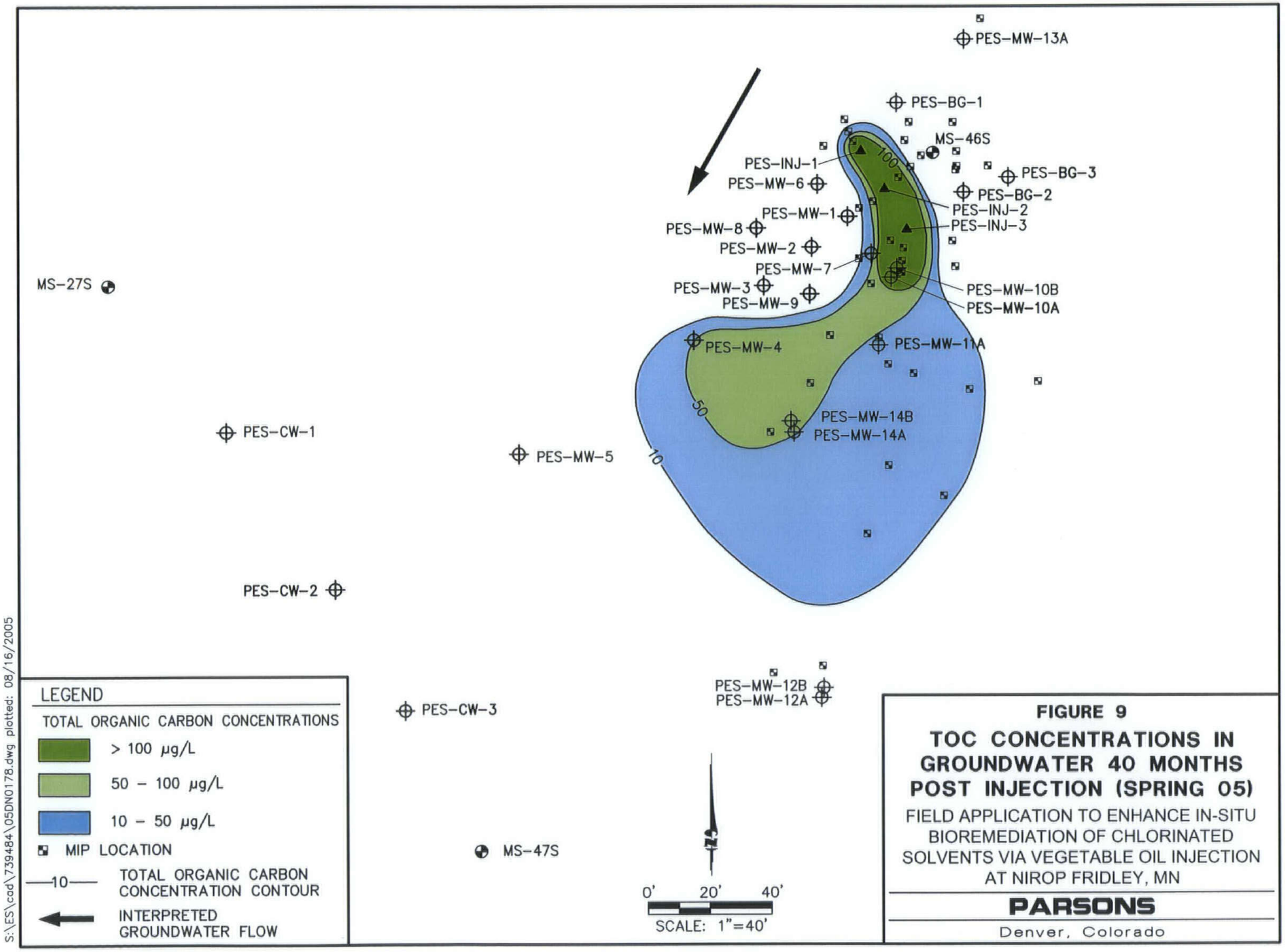


**FIGURE 9**

**TOC CONCENTRATIONS IN GROUNDWATER 40 MONTHS POST INJECTION (SPRING 05)**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado

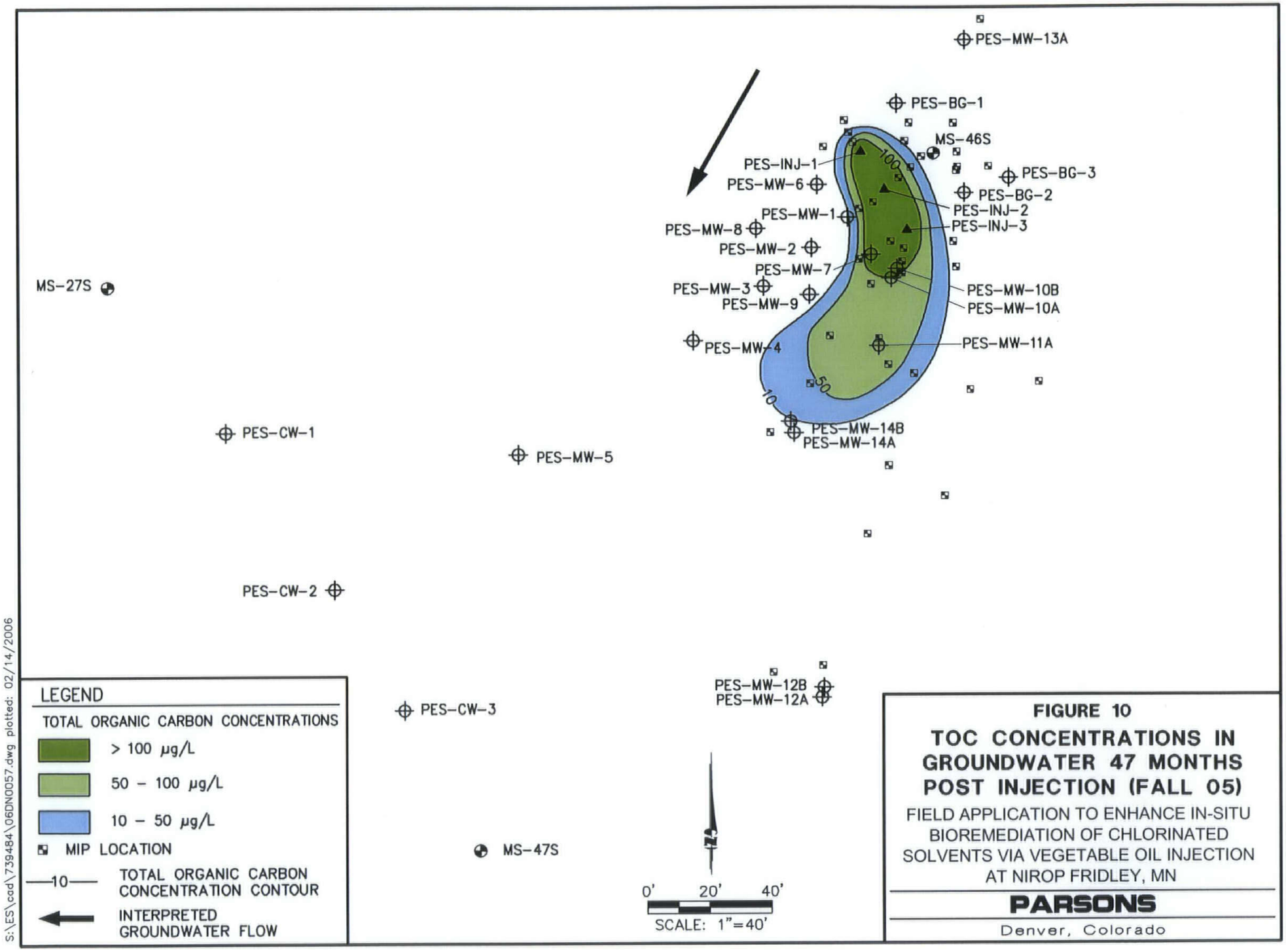


**FIGURE 10**

**TOC CONCENTRATIONS IN GROUNDWATER 47 MONTHS POST INJECTION (FALL 05)**

FIELD APPLICATION TO ENHANCE IN-SITU BIOREMEDIATION OF CHLORINATED SOLVENTS VIA VEGETABLE OIL INJECTION AT NIROP FRIDLEY, MN

**PARSONS**

Denver, Colorado

# APPENDIX A

# MEMBRANE INTERFACE PROBE LOGS

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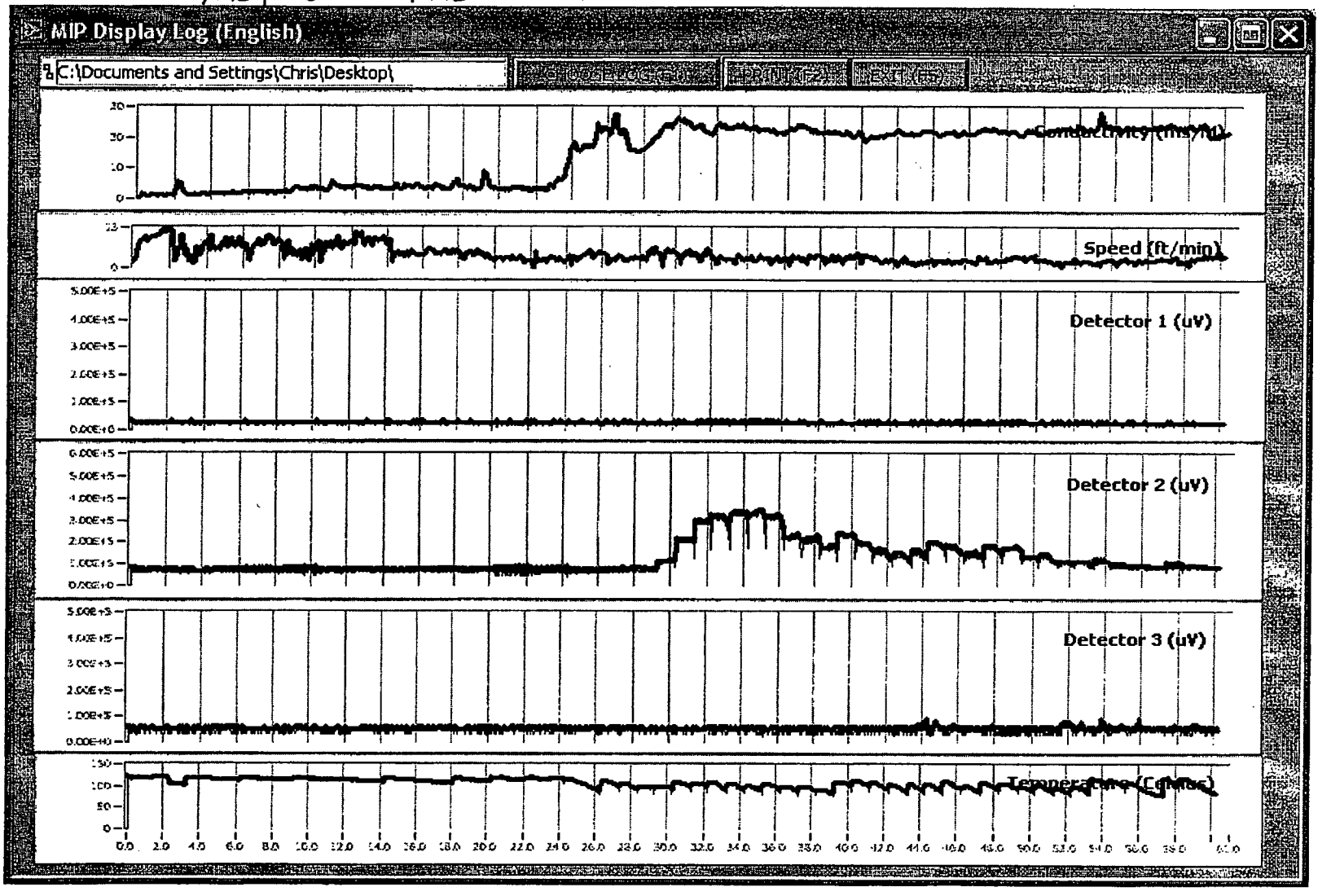


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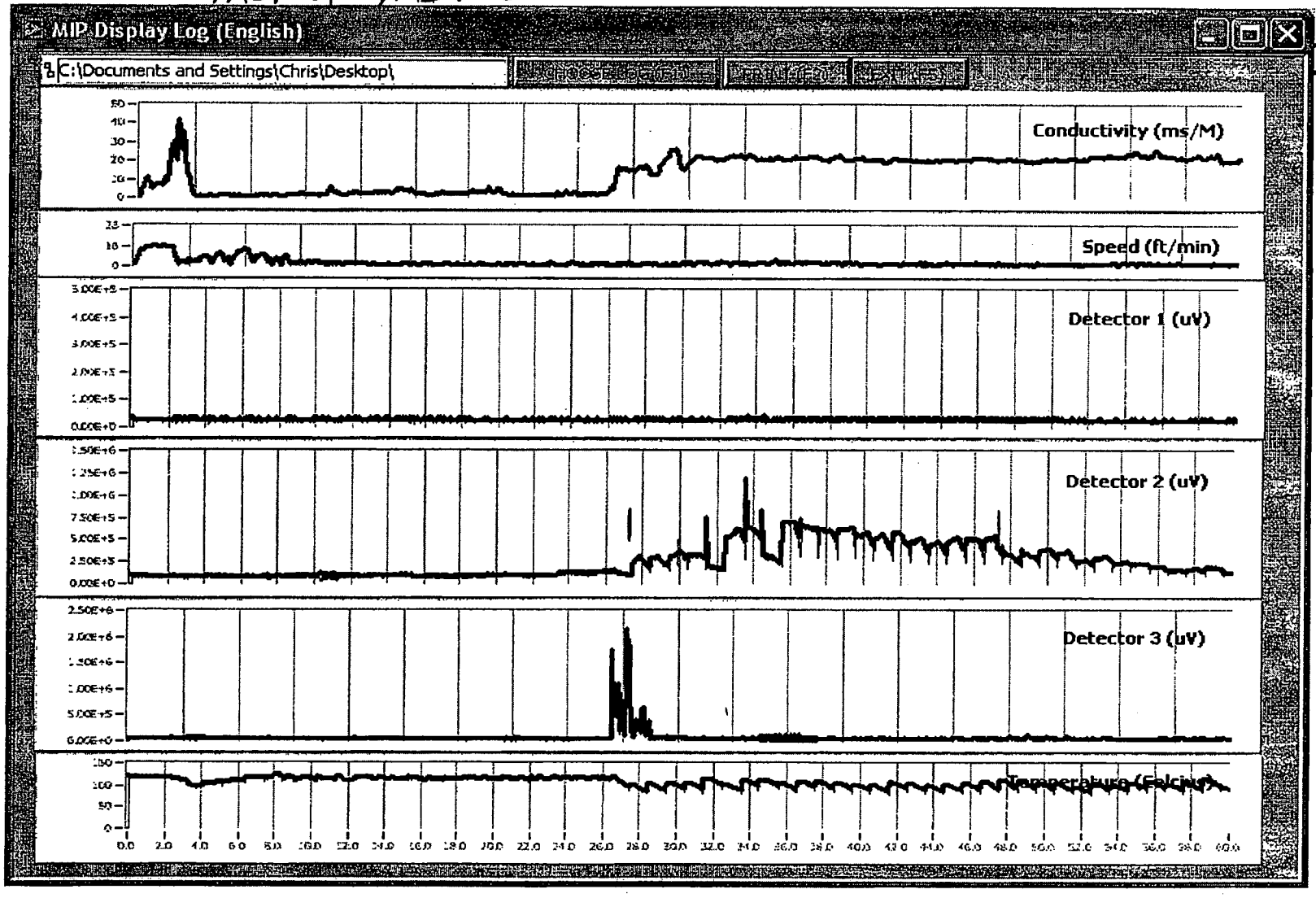


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MIP-03

MIP Display Log (English)

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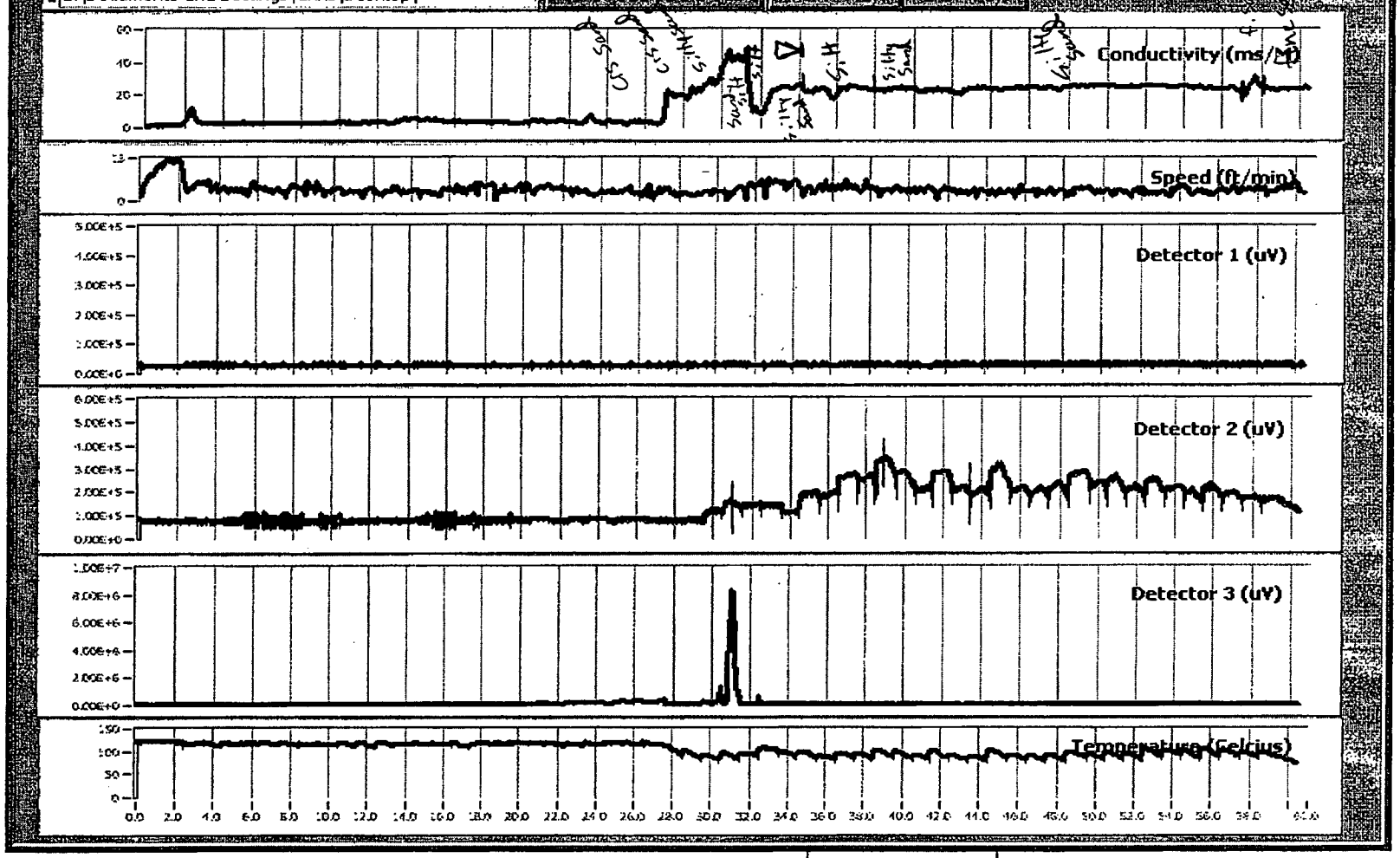


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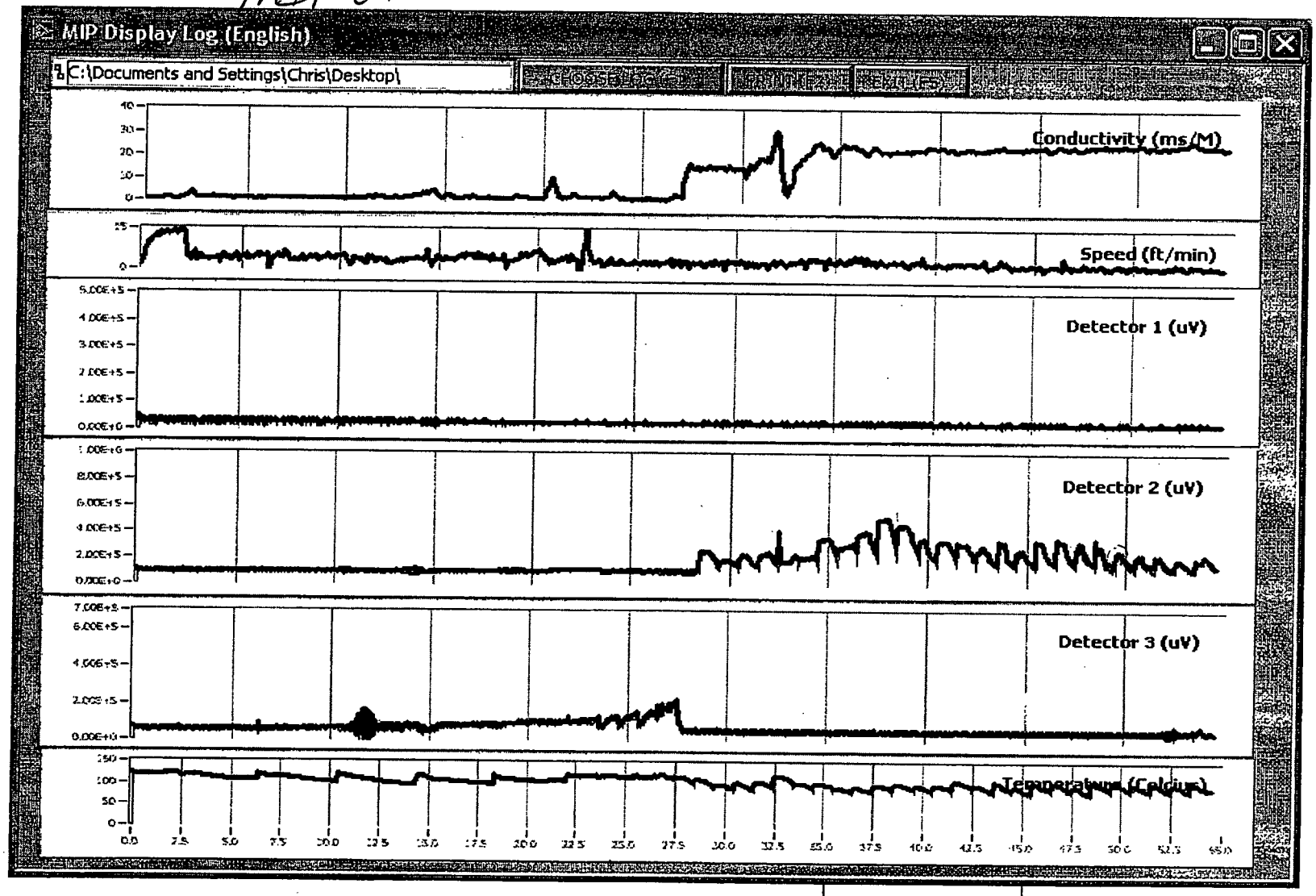


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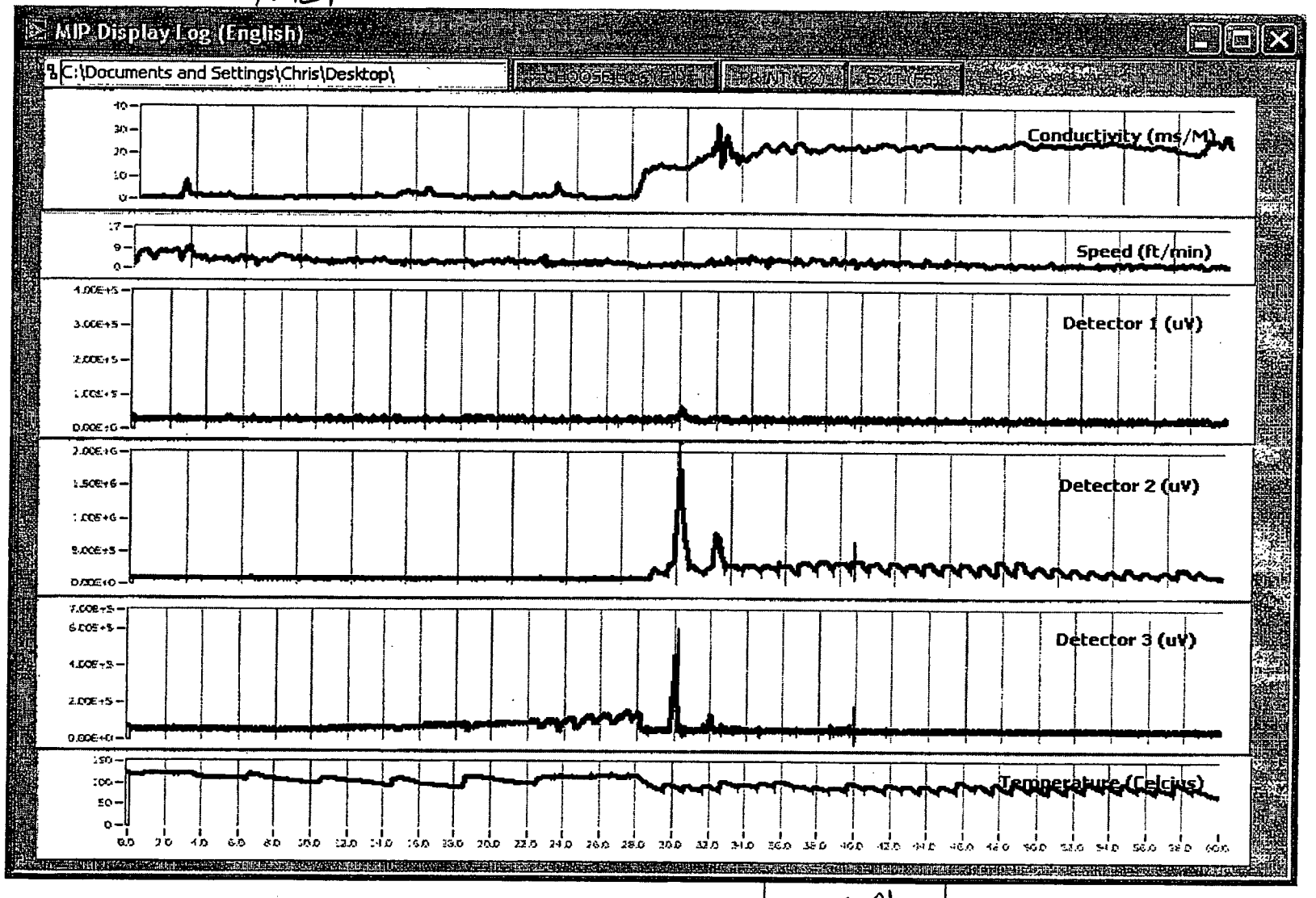


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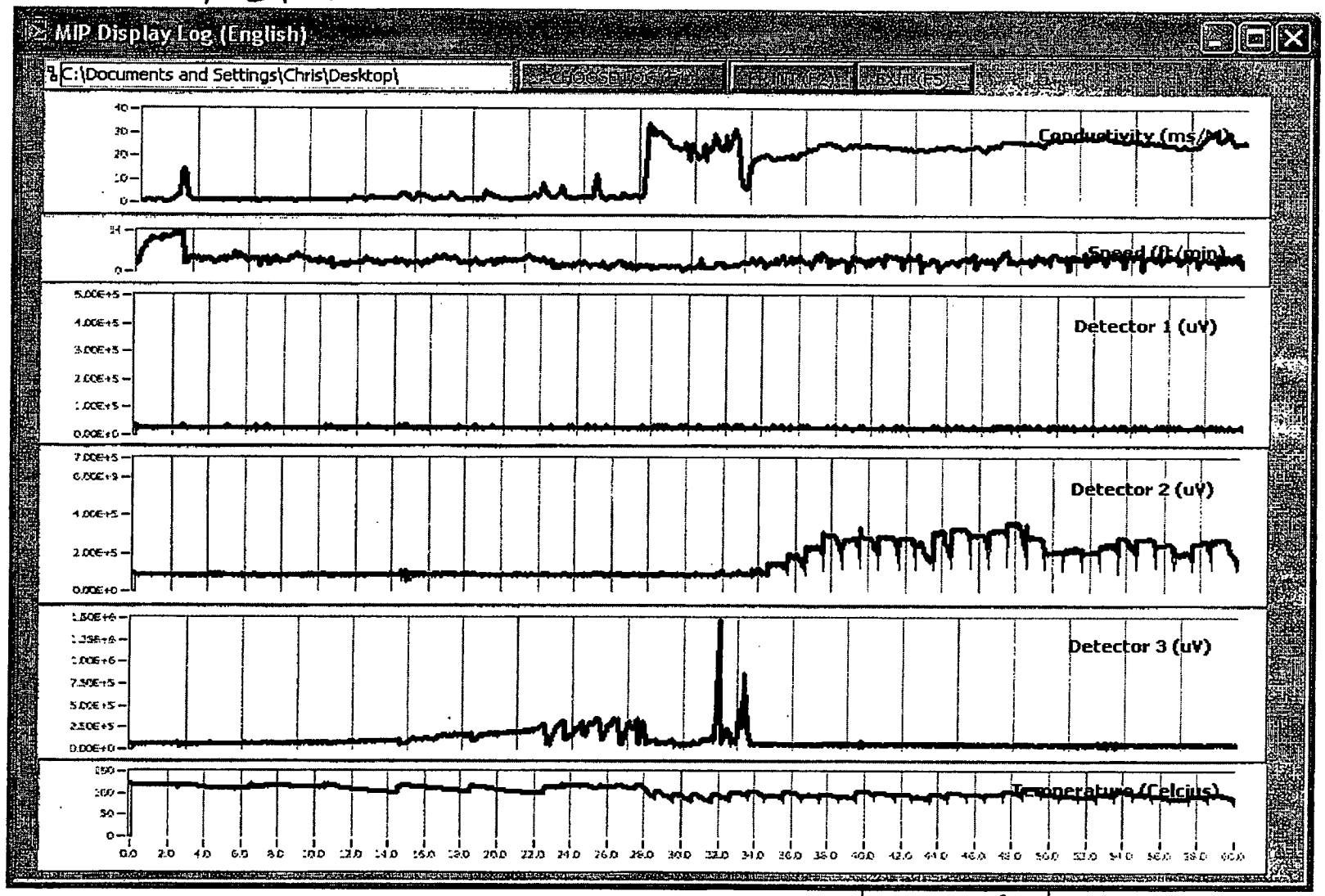


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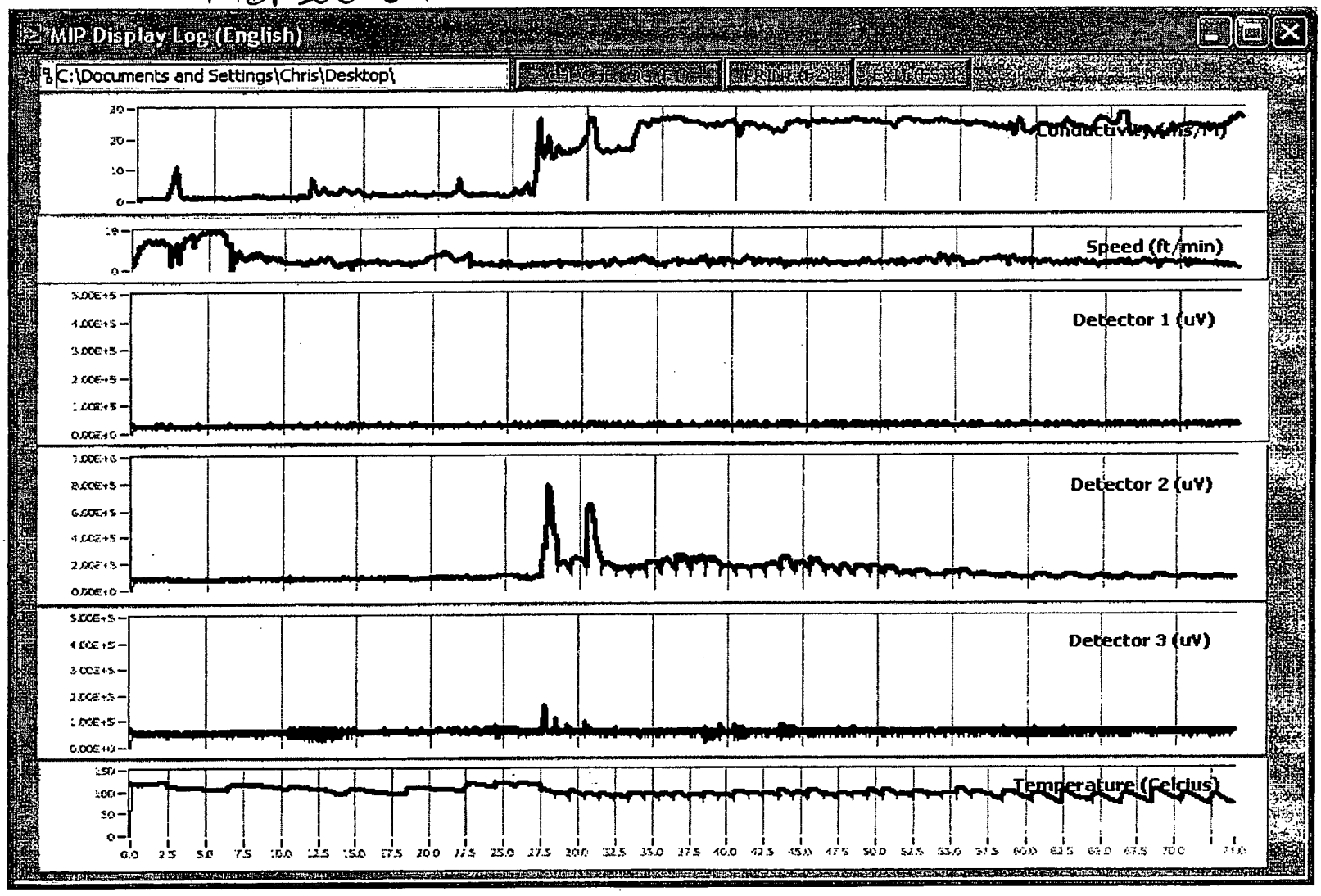
INJ-01

MIP-~~06~~ 07

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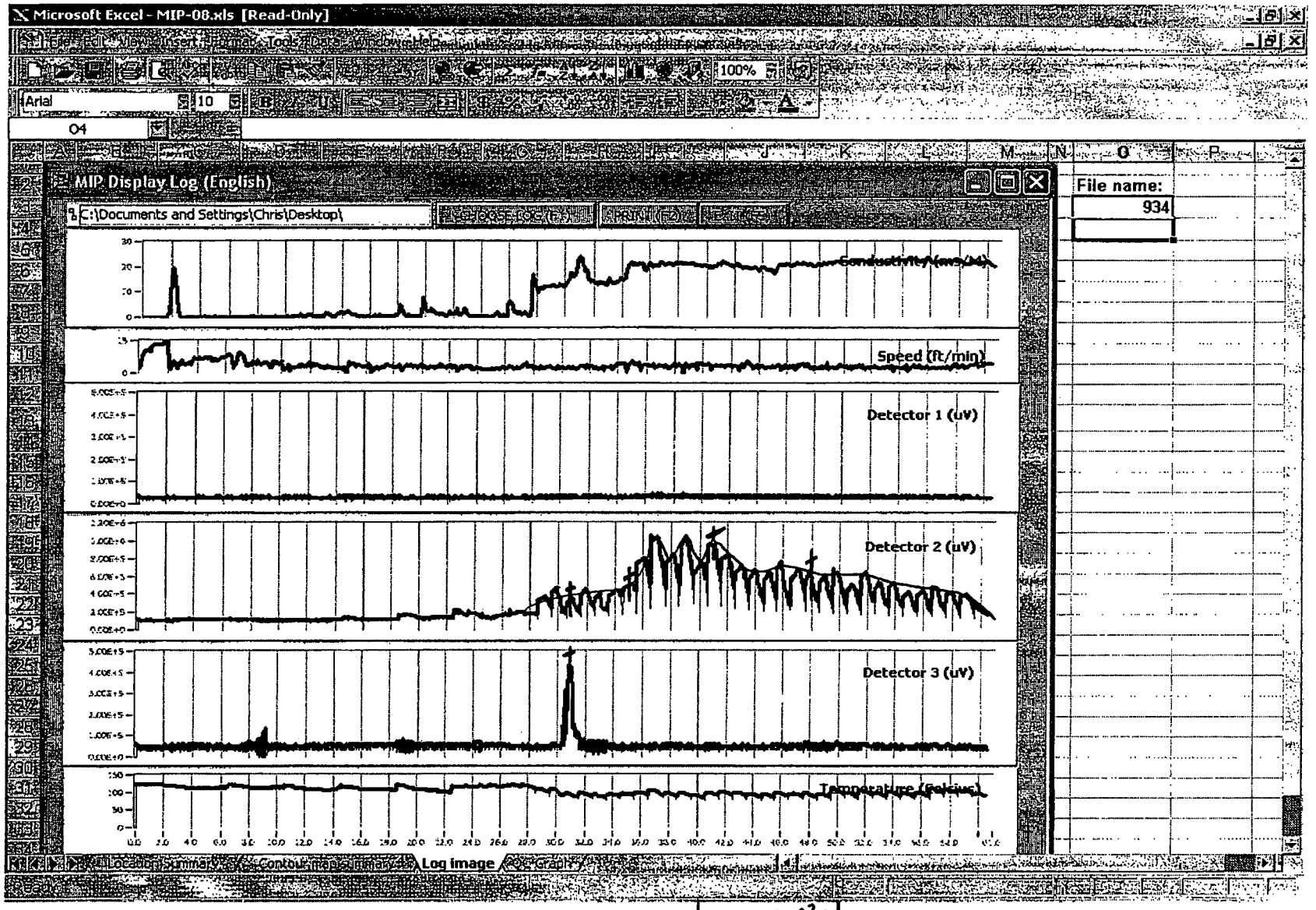
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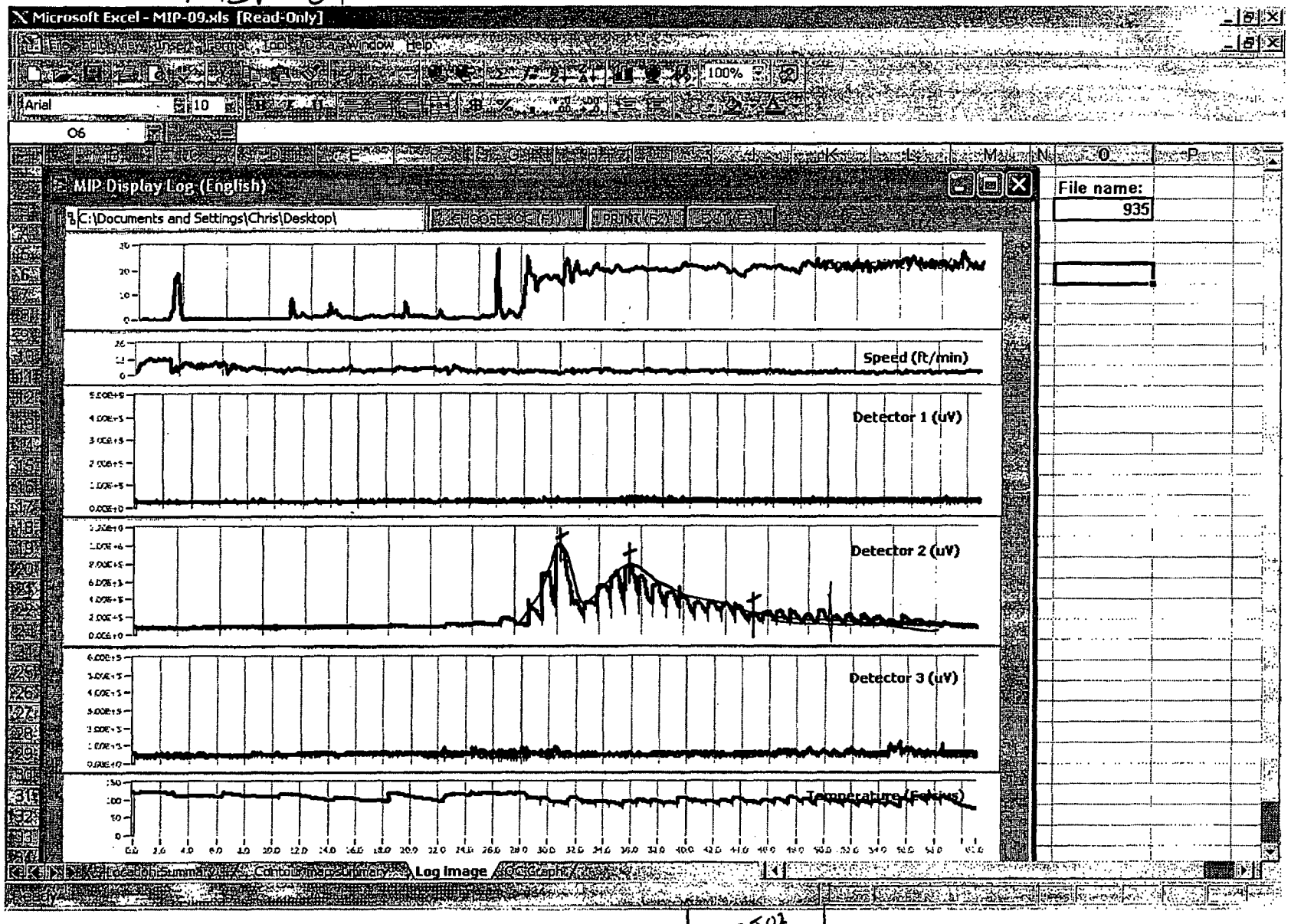
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Log image

INJ-02

MIP -09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Detector 2 (uV)
Detector 3 (uV)
Temperature (Fahrenheit)
Log Image

INS02

Microsoft Excel - MIP-10.xls [Read-Only]

MIP Display Log (English)

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File name: 936

Conductivity (ms/M)

Speed (ft/min)

Detector 1 (uV)

"Rock" NR

Detector 2 (uV)

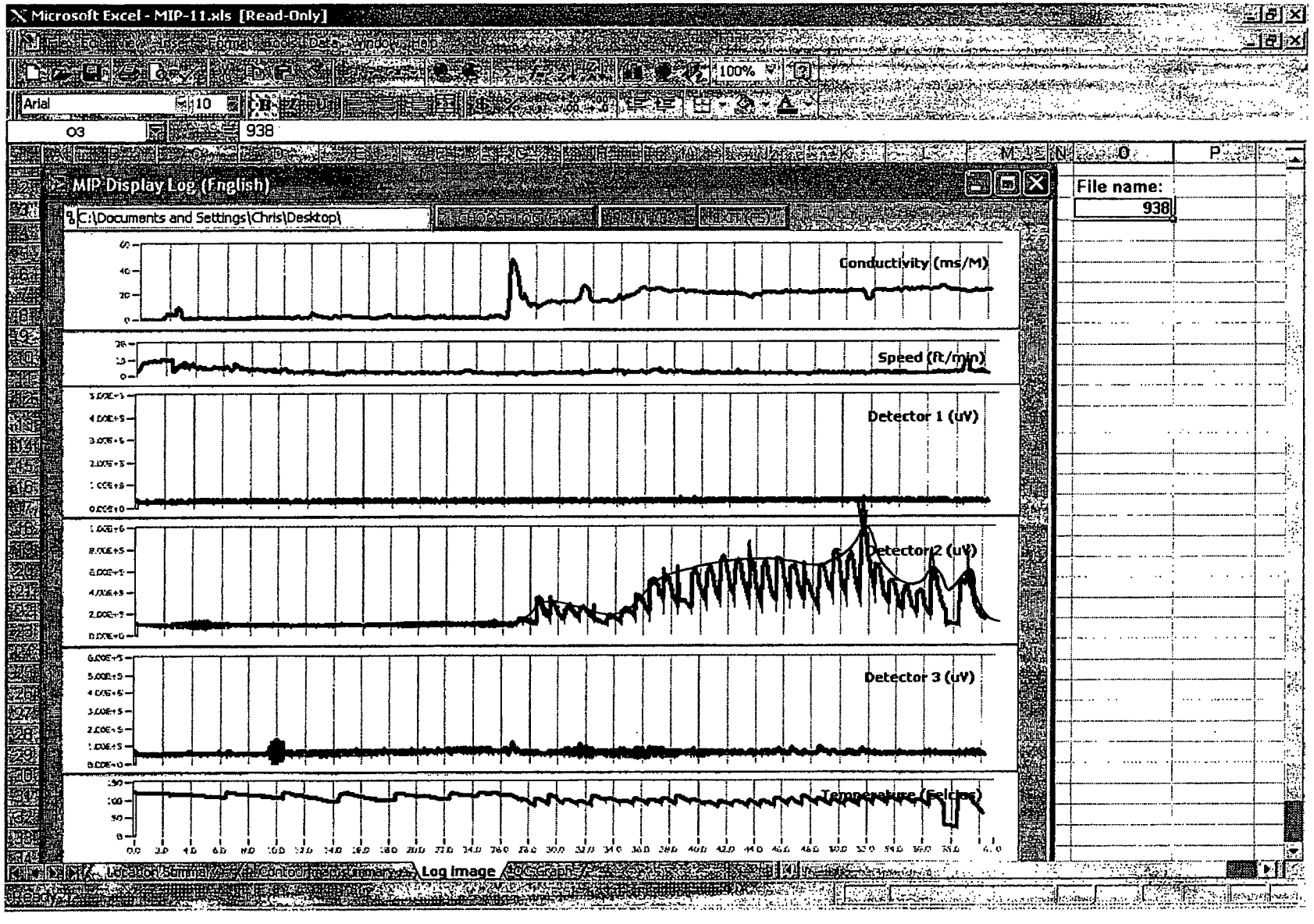
Detector 3 (uV)

Temperature (Celcius)

Log Image

Model 2-85

IN 02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Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)
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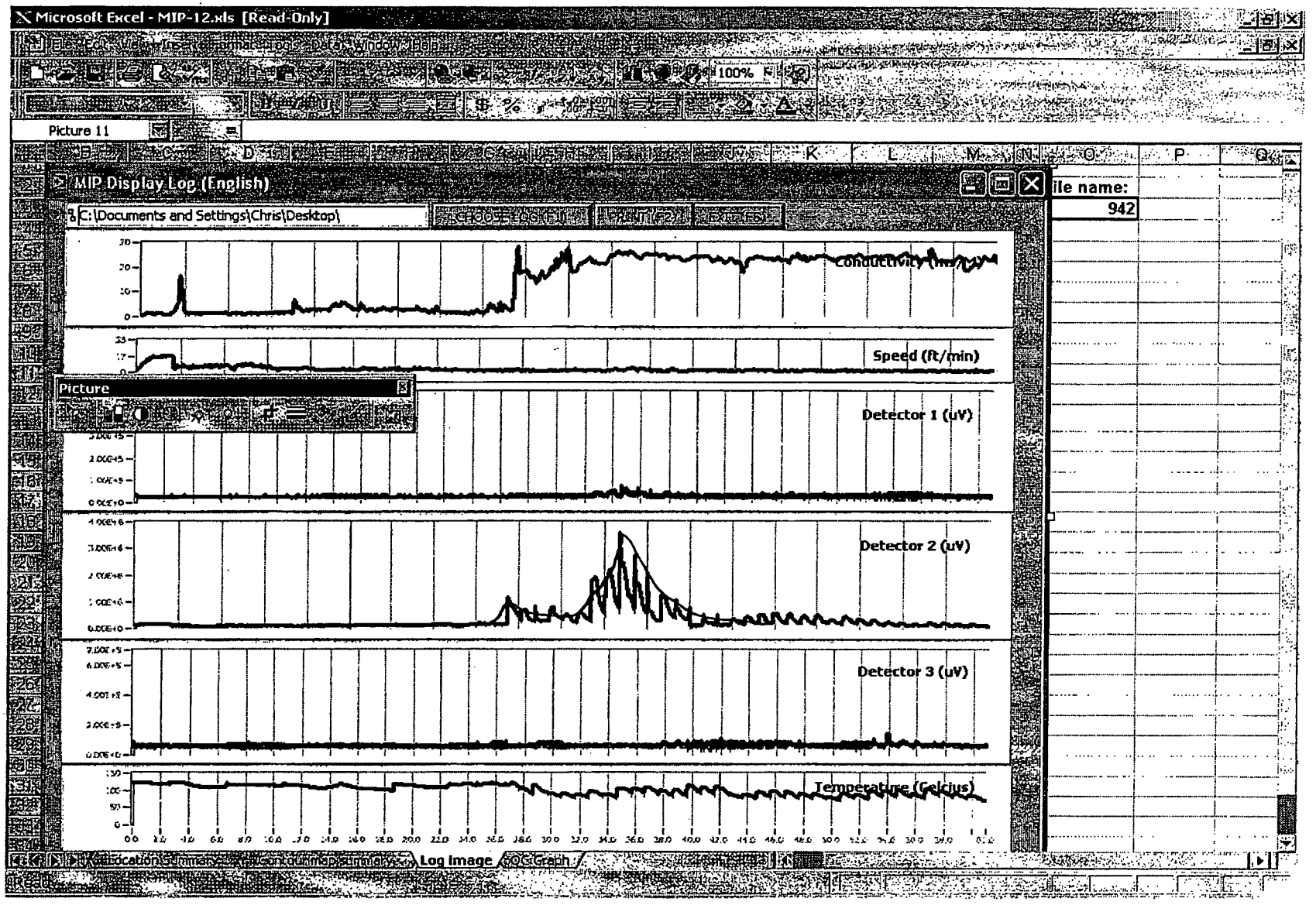
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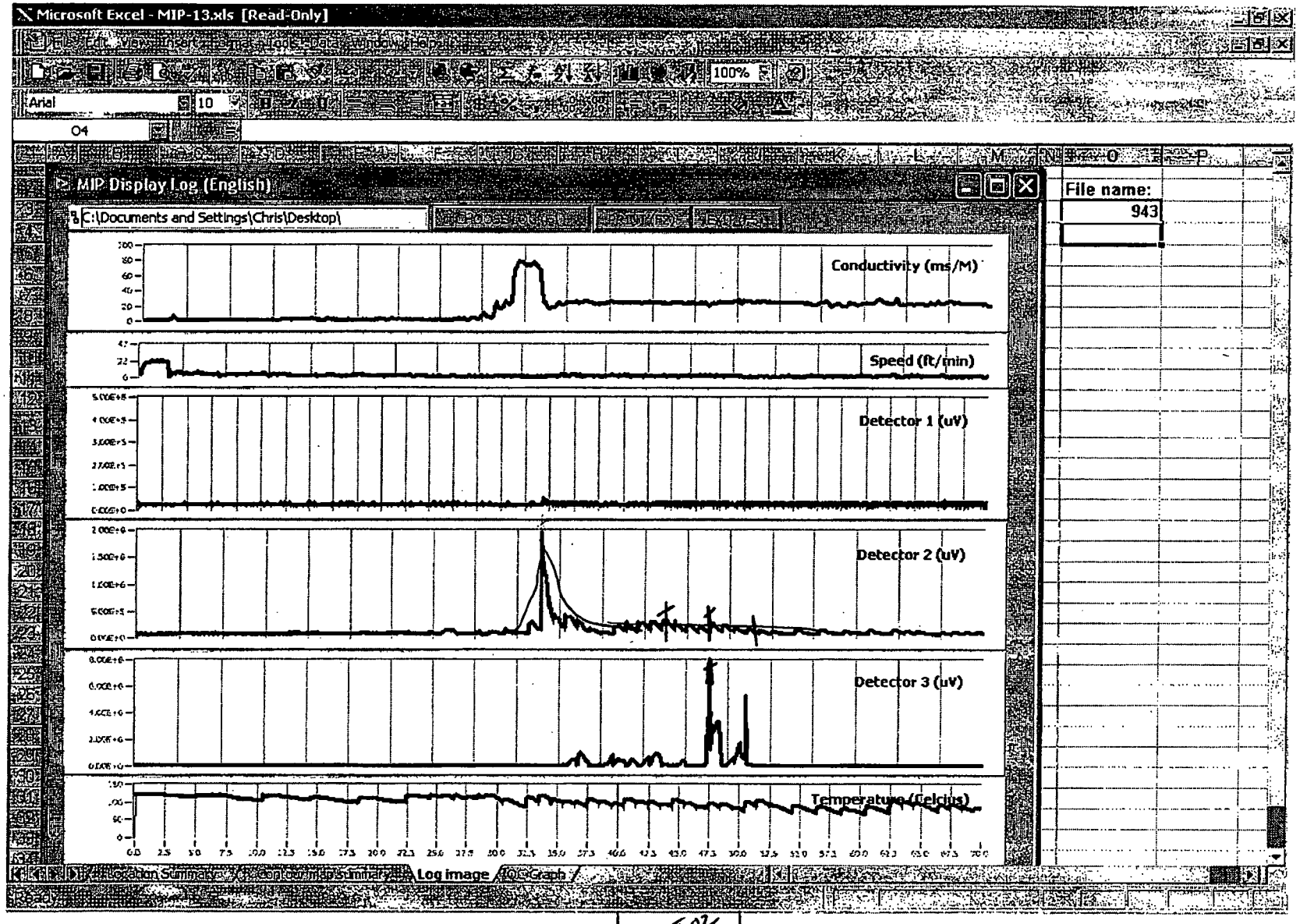
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Speed (ft/min)
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Temperature (Celcius)
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TOC Graph

JN502

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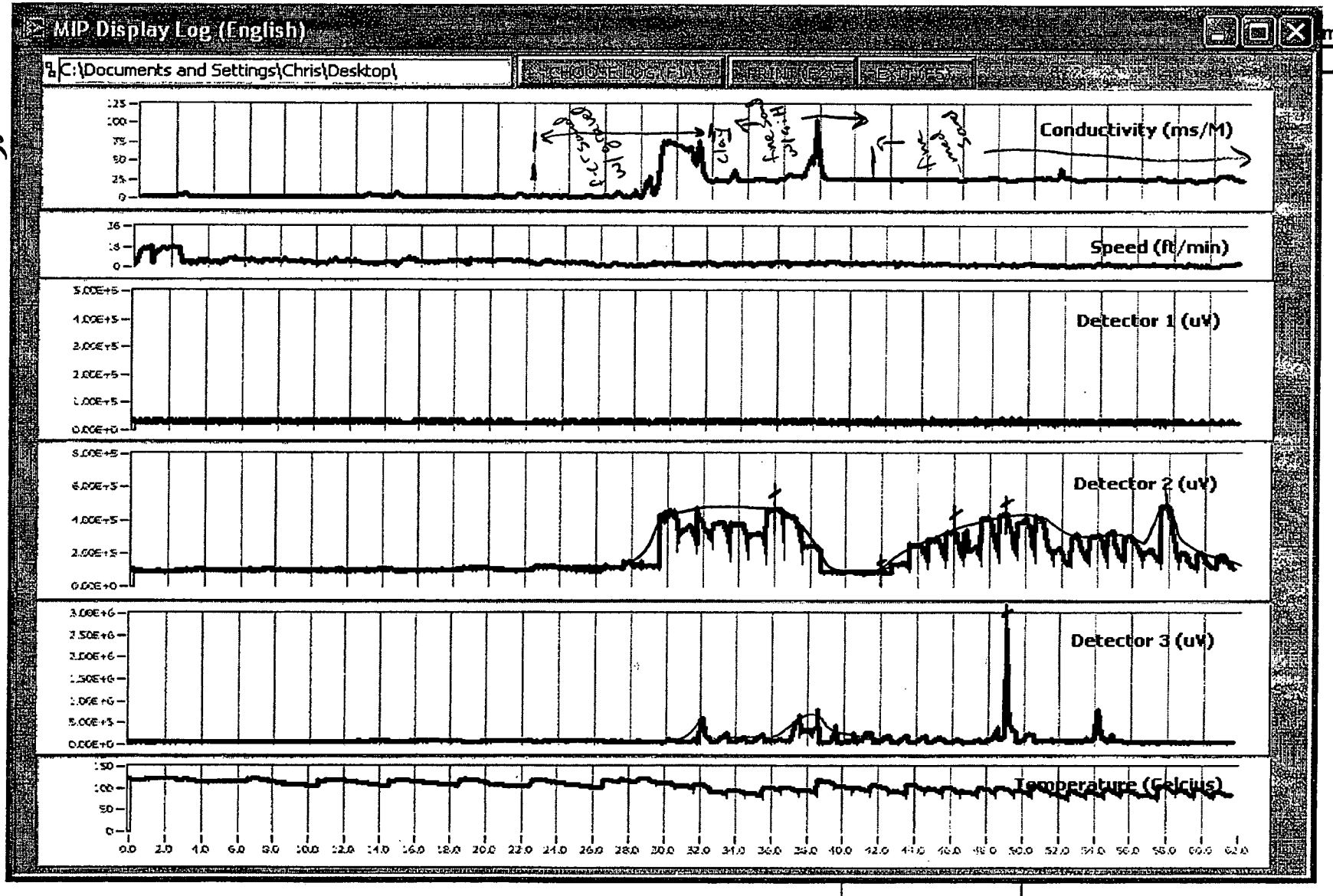


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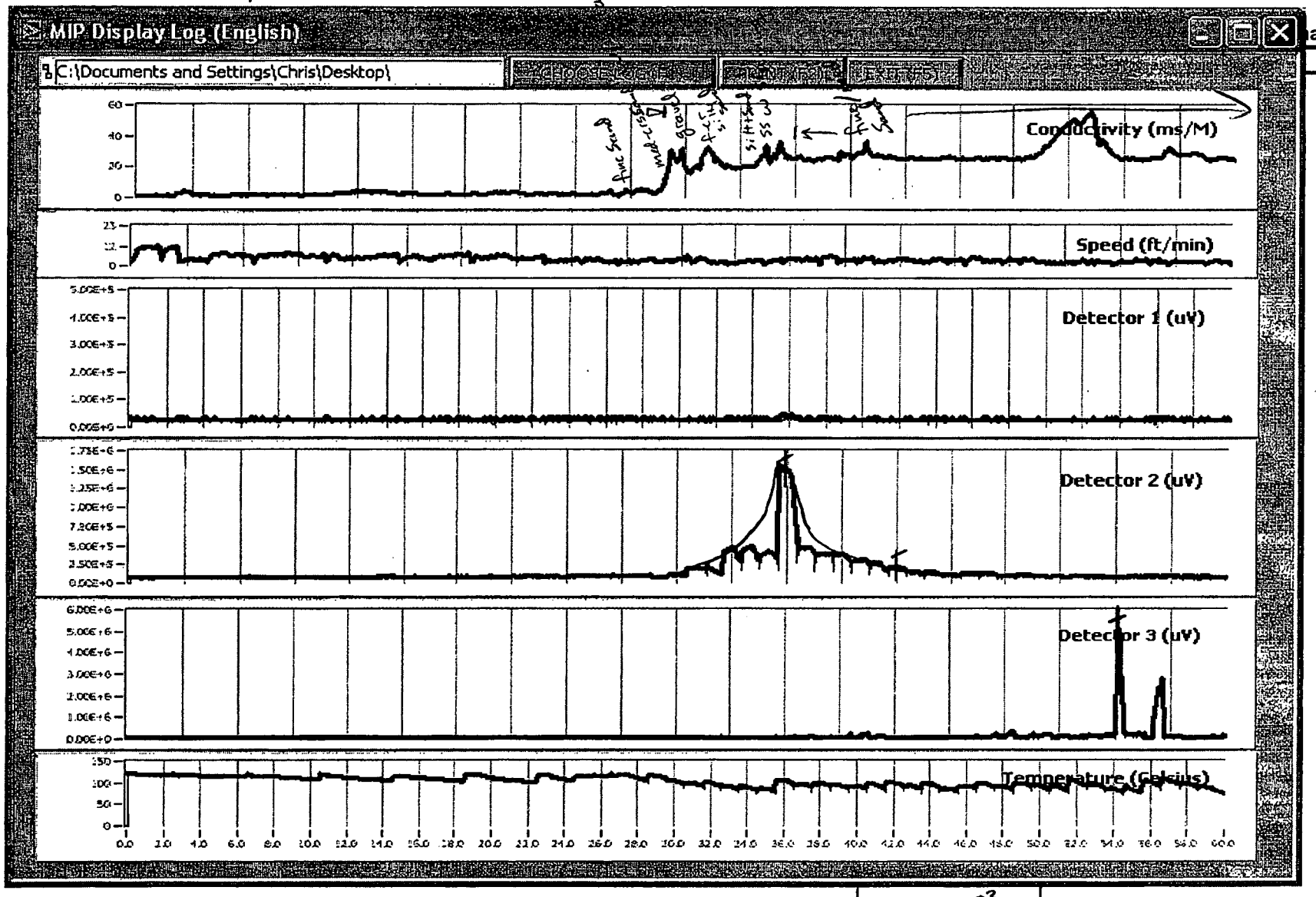
Inj 2

Manual 58-9

MIP-15

Match to SB-10

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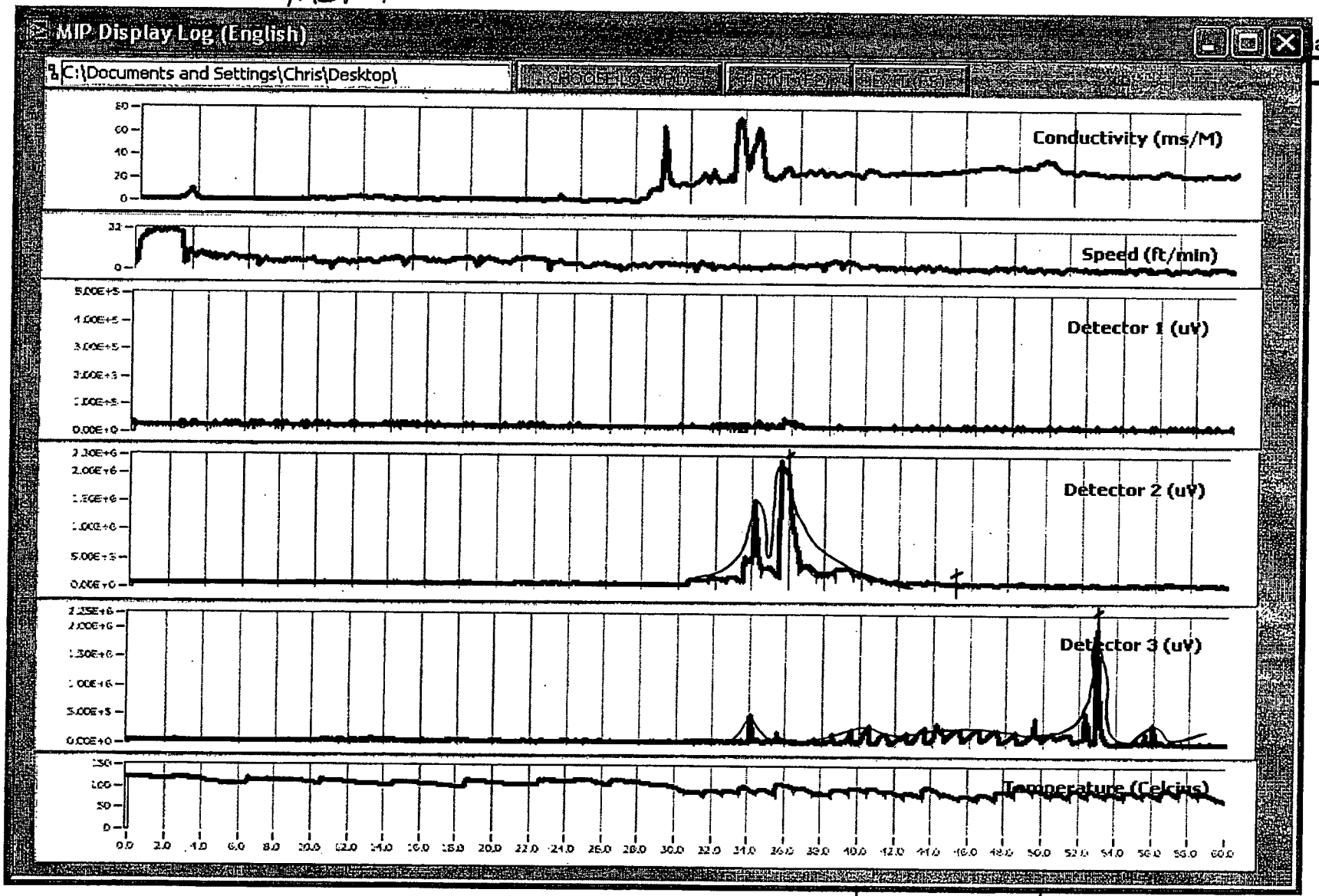


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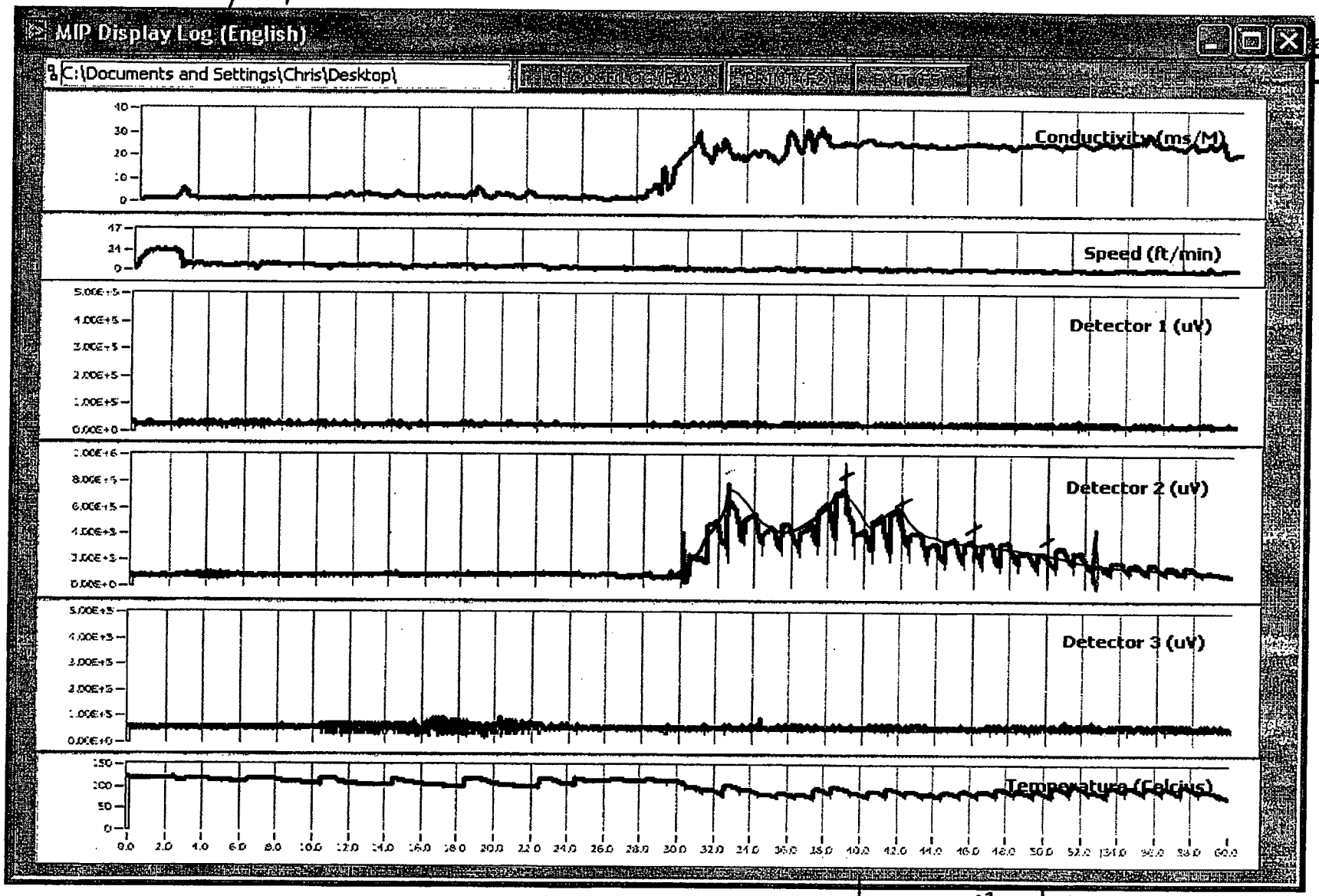


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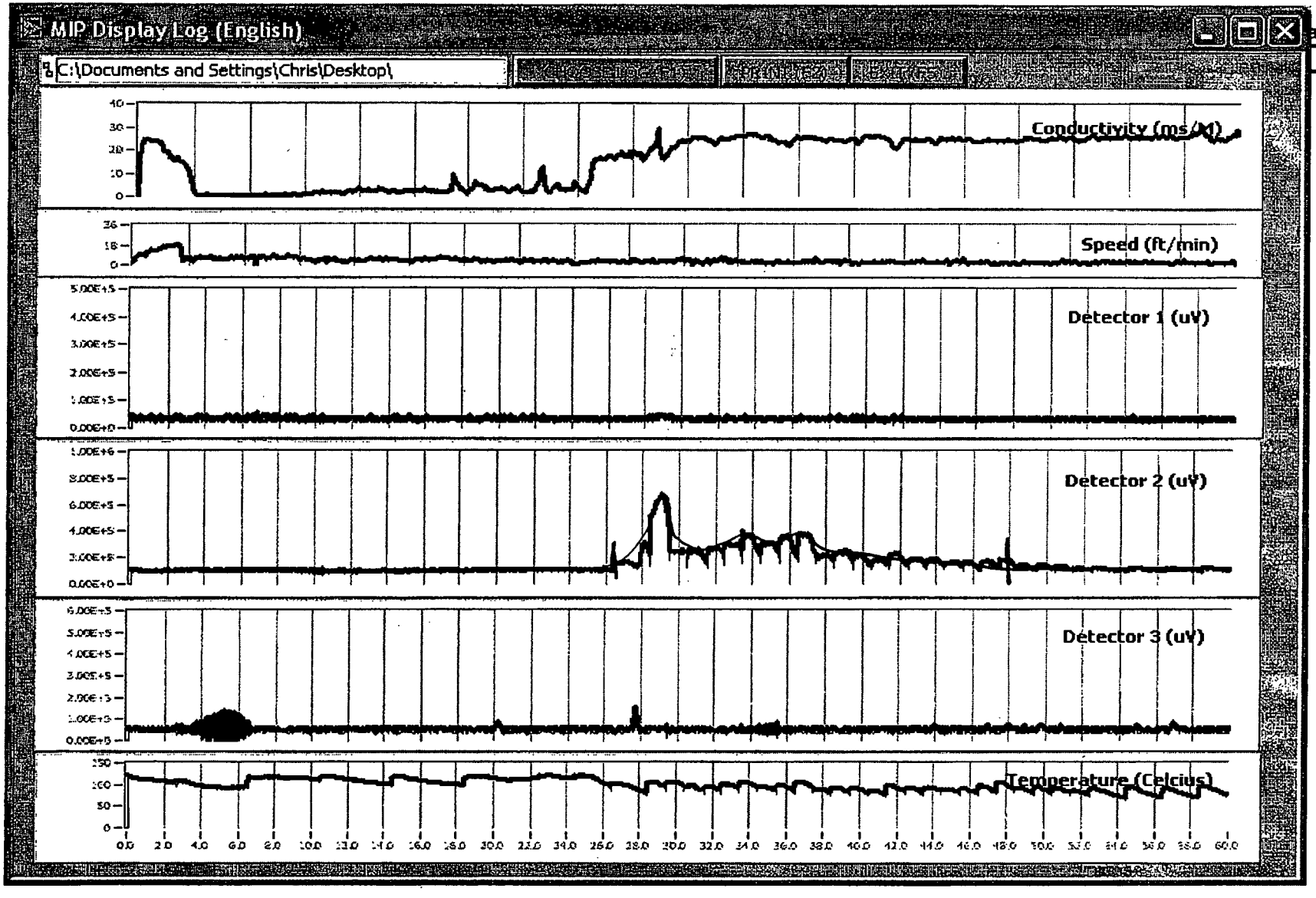


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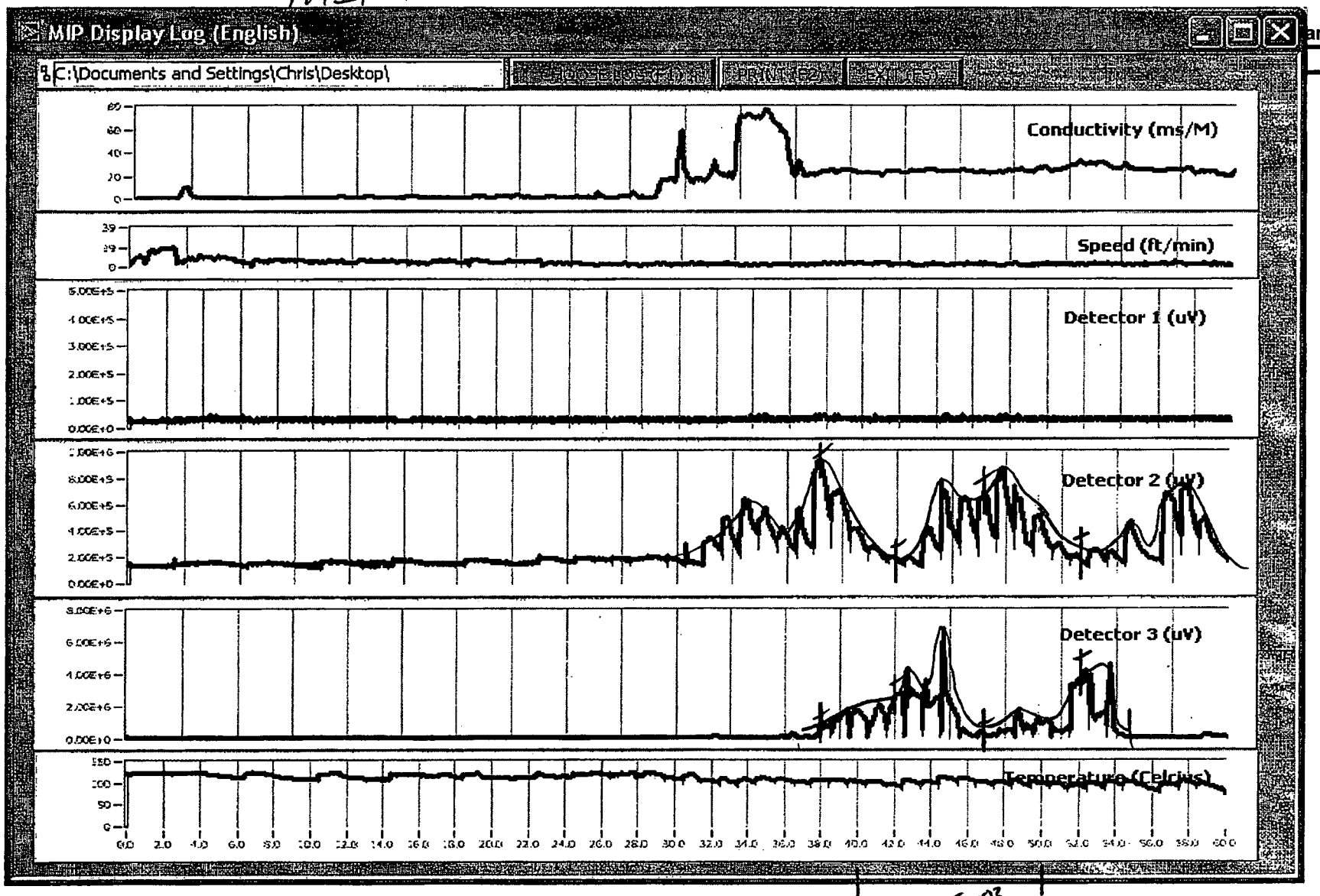
MIP-19

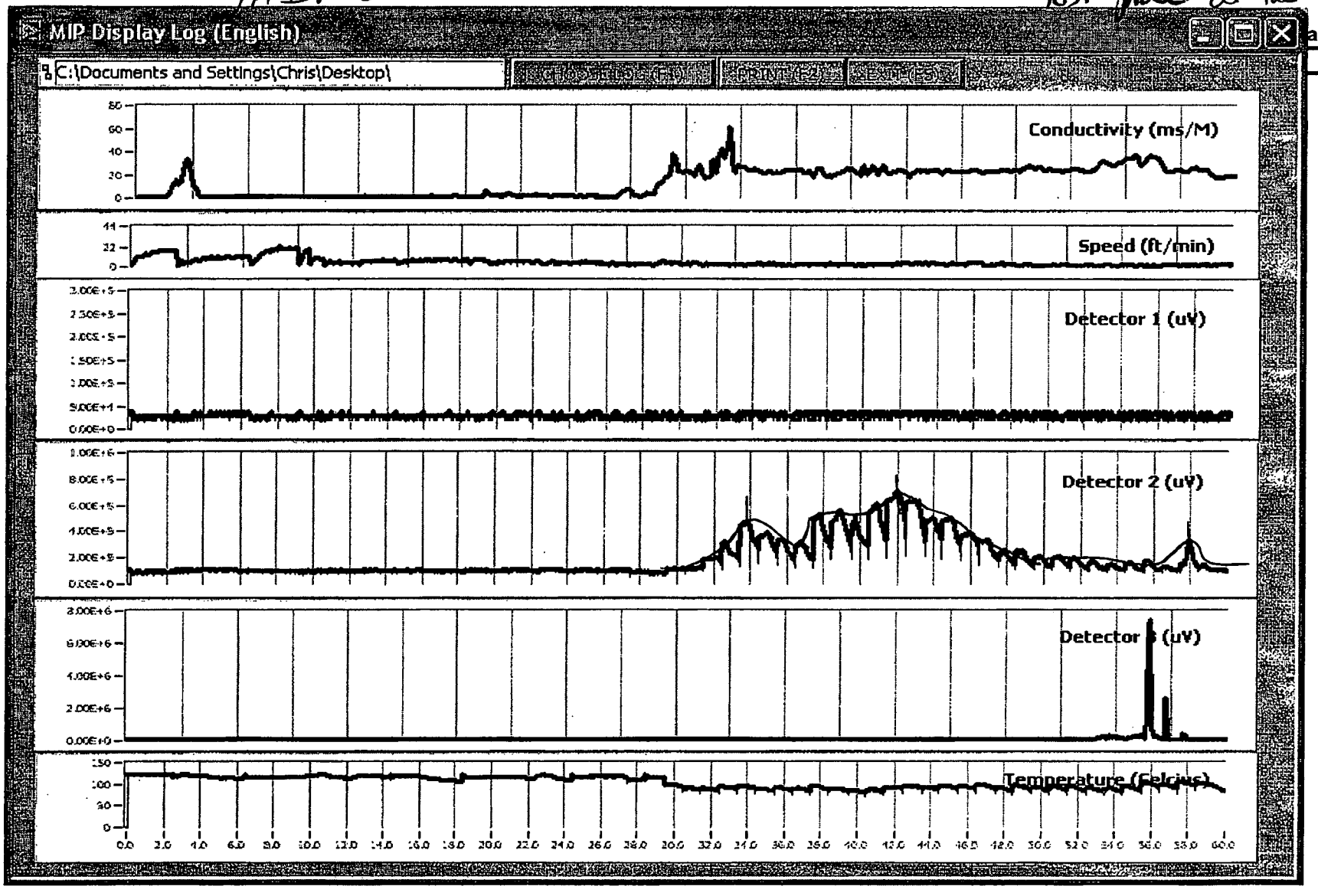



INJ-03

ame:
954

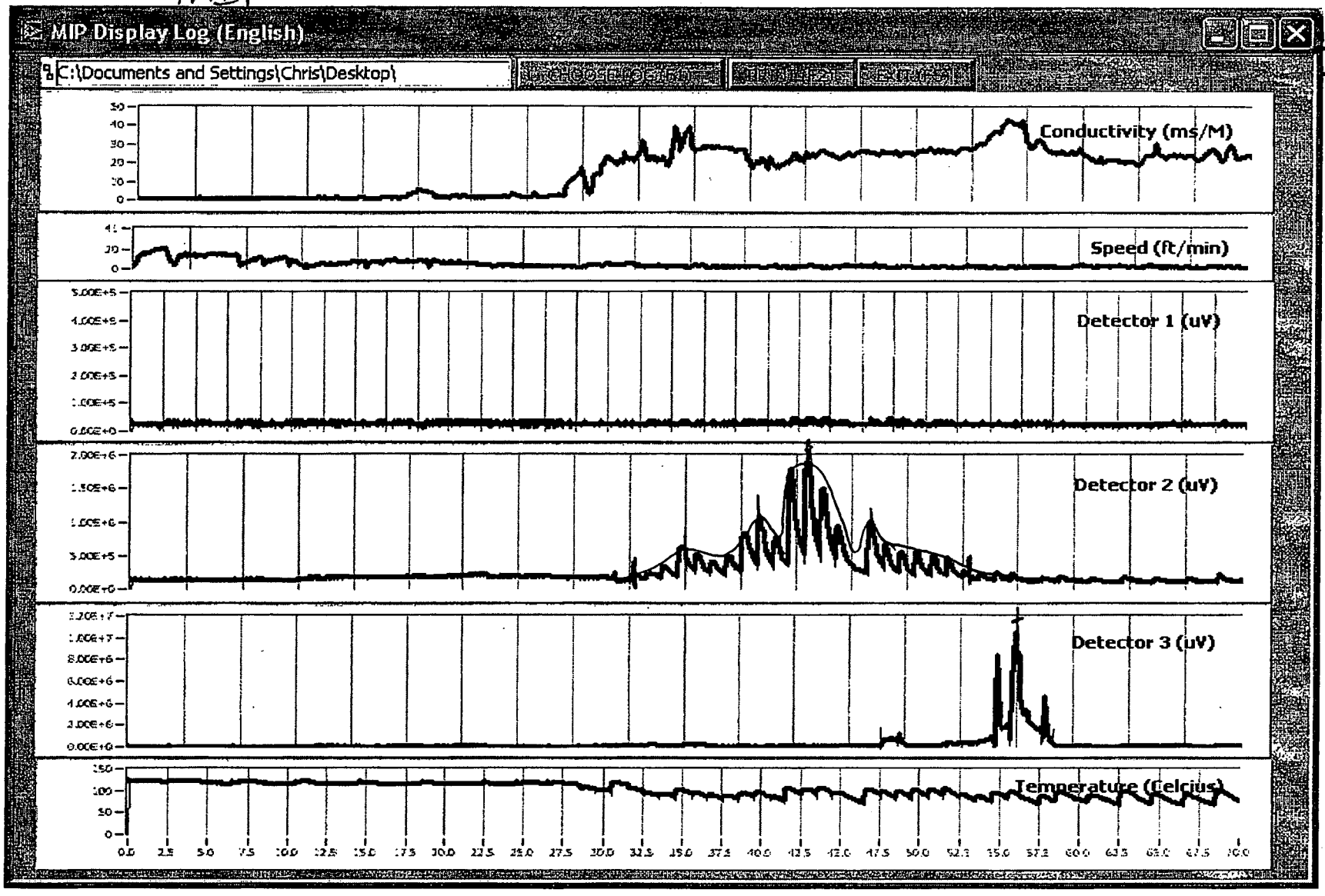
MIP-20

- lost probe at the bottom of Point



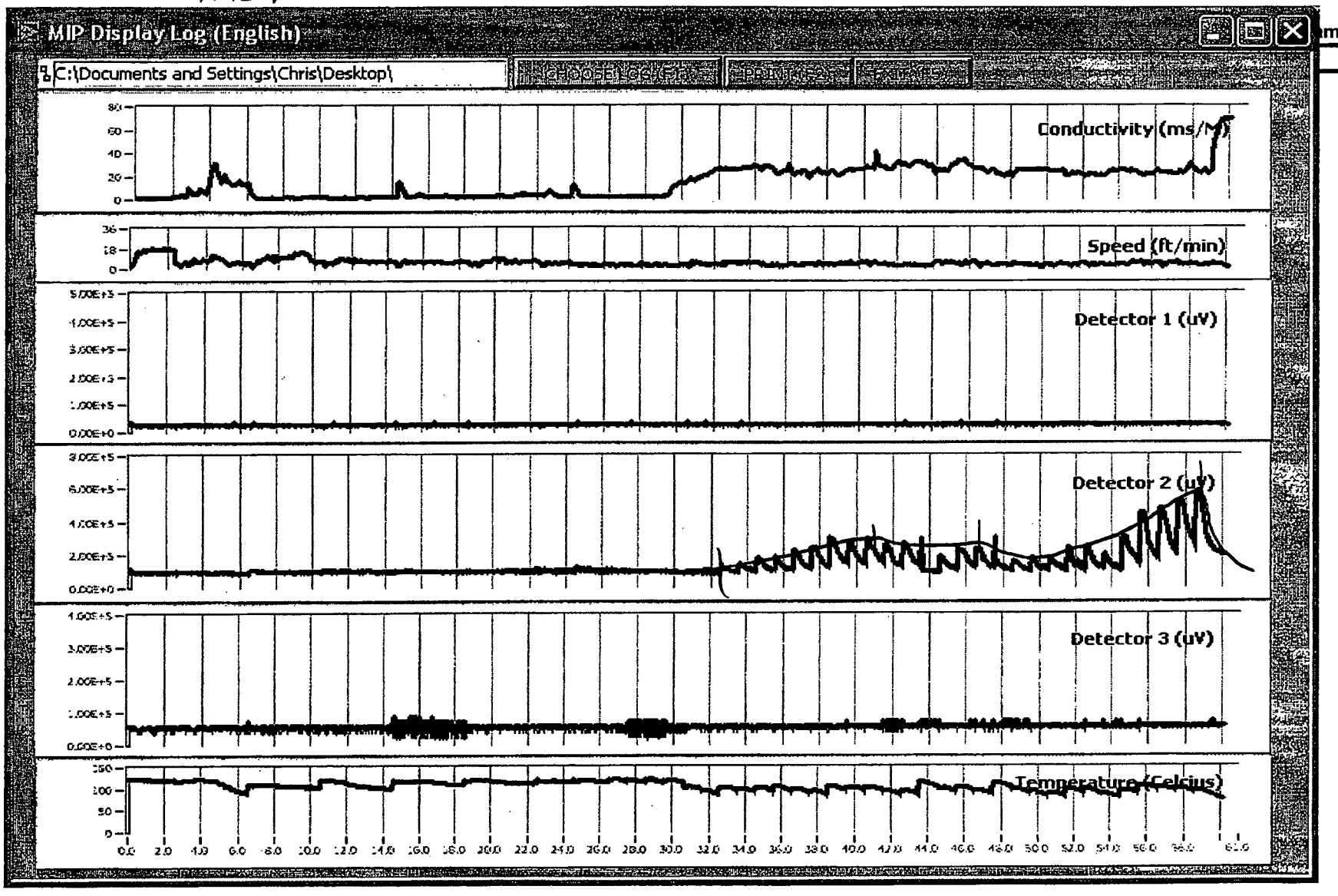

ame:
955

MIP-21


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

me:
957

MIP-22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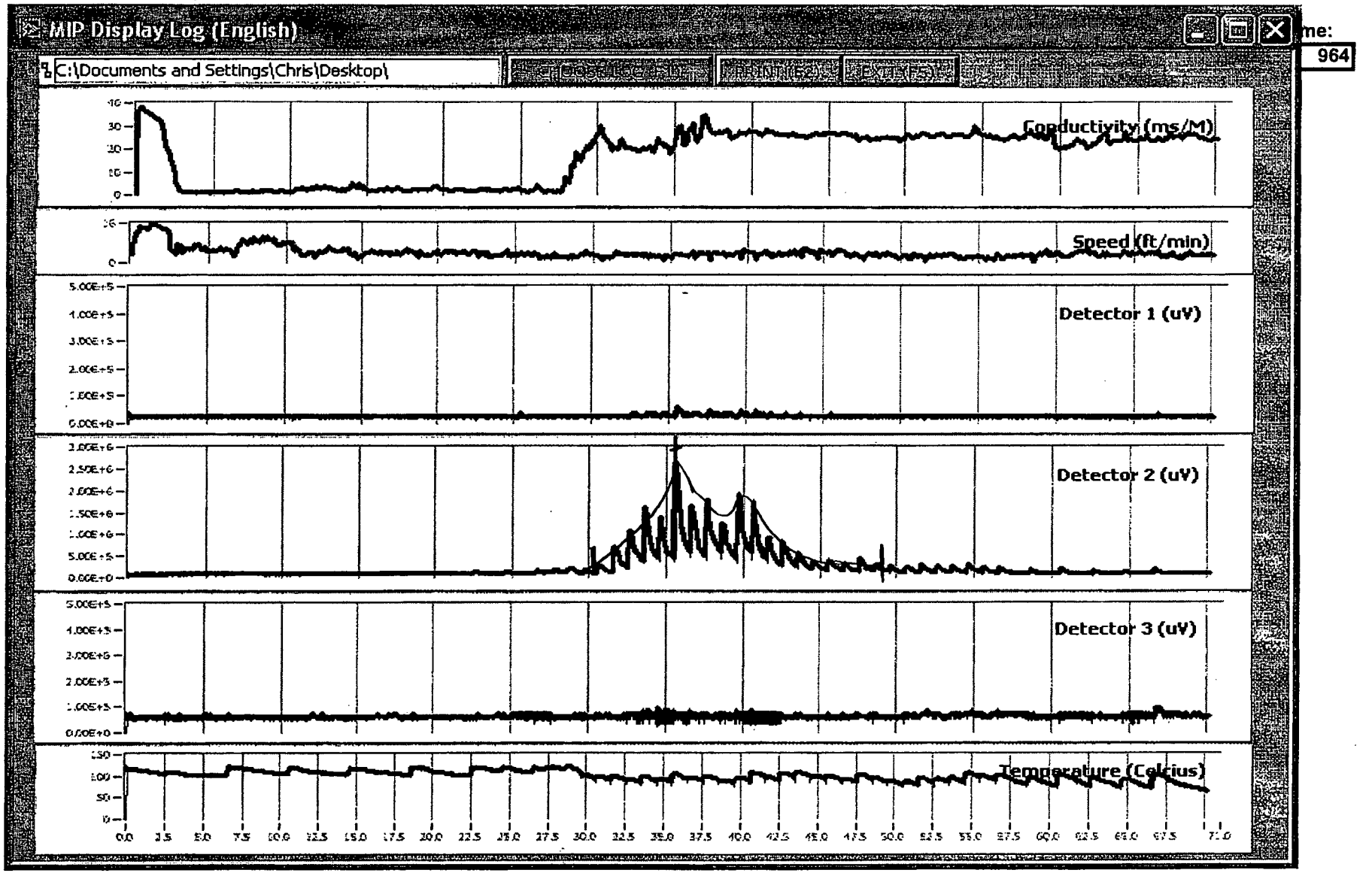
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/m)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

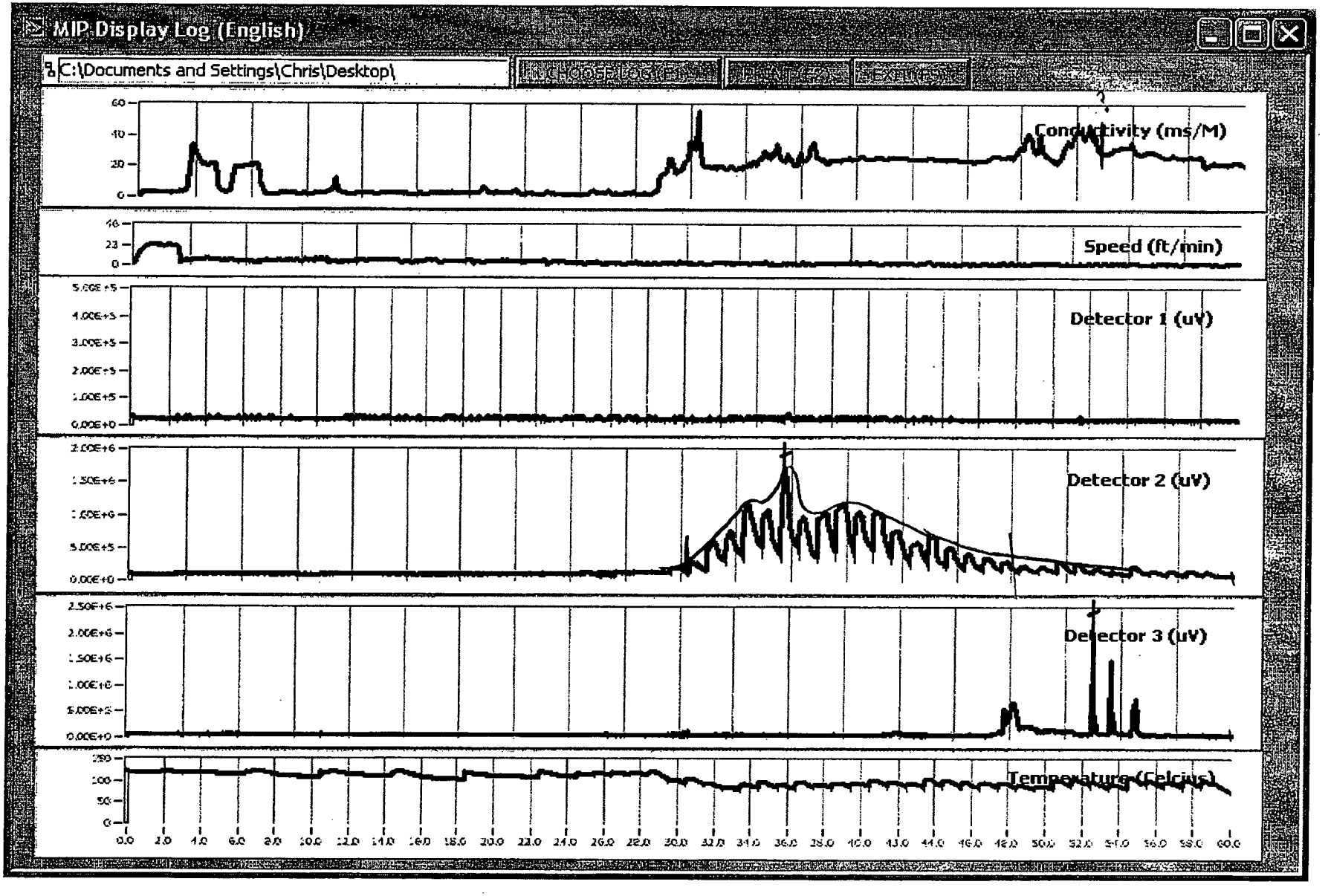
me:
963

MIP-23


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

me:
964

MIP-24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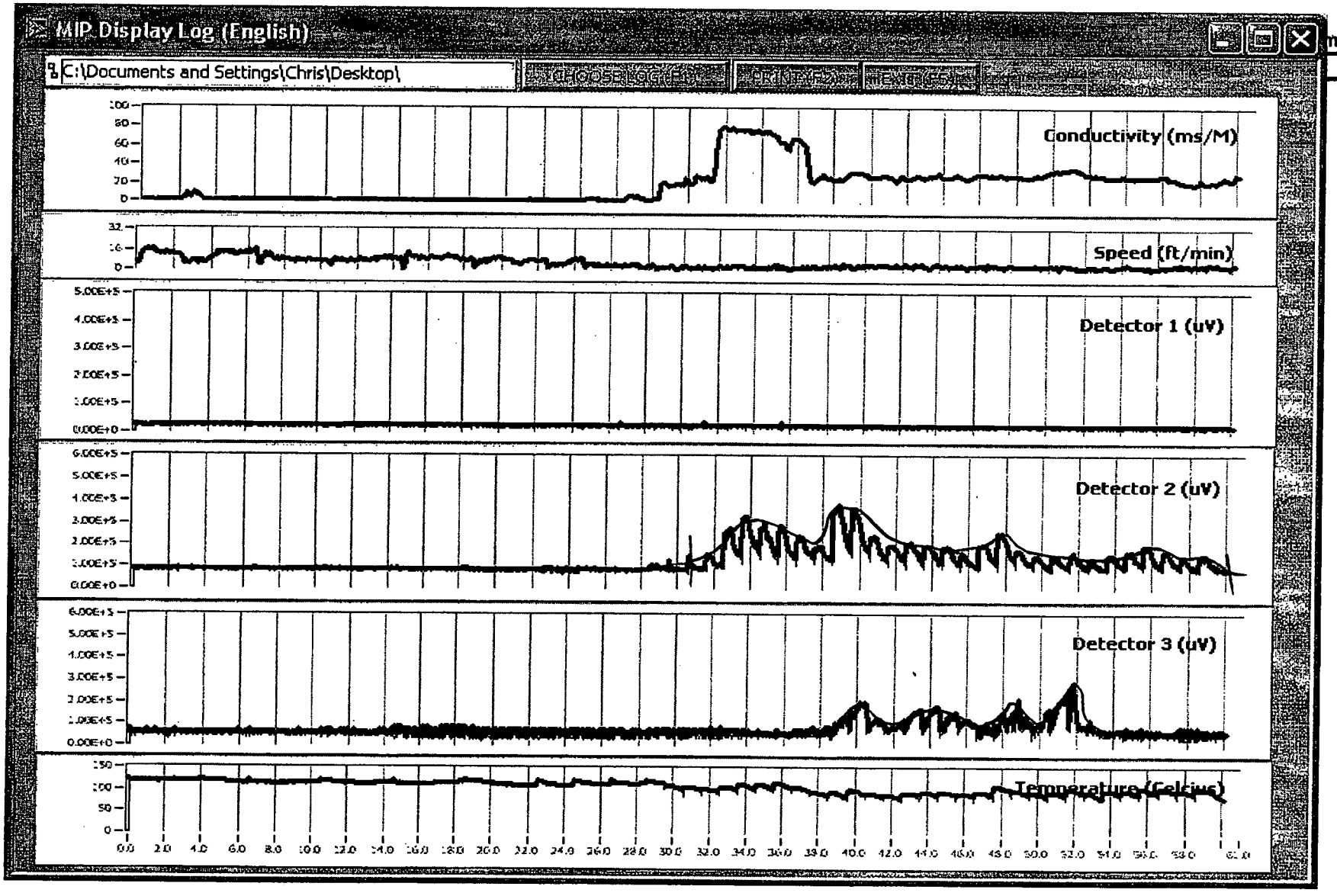
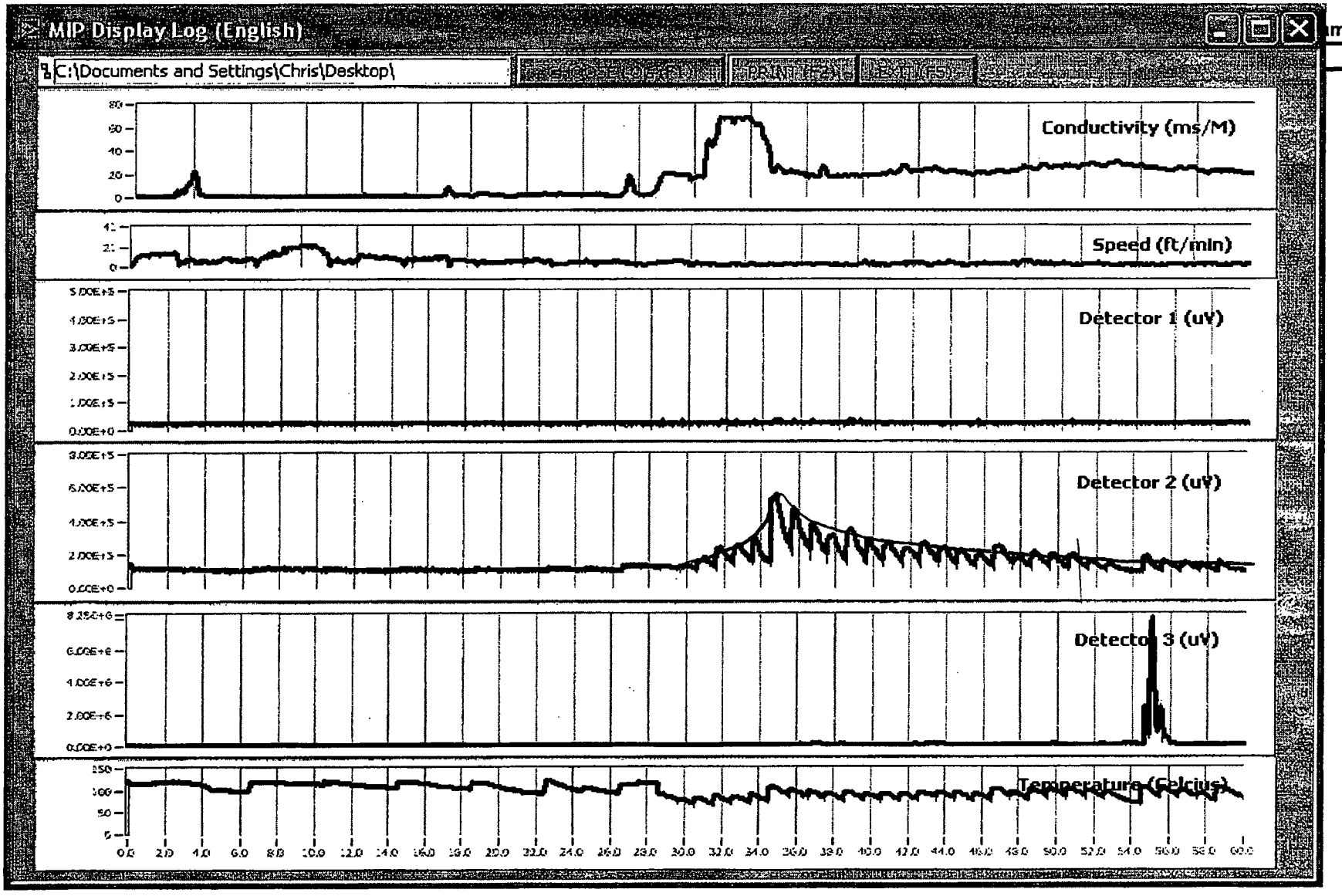
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

MIP-25


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

me:
968

MIP-26


MIP Display Log (English)
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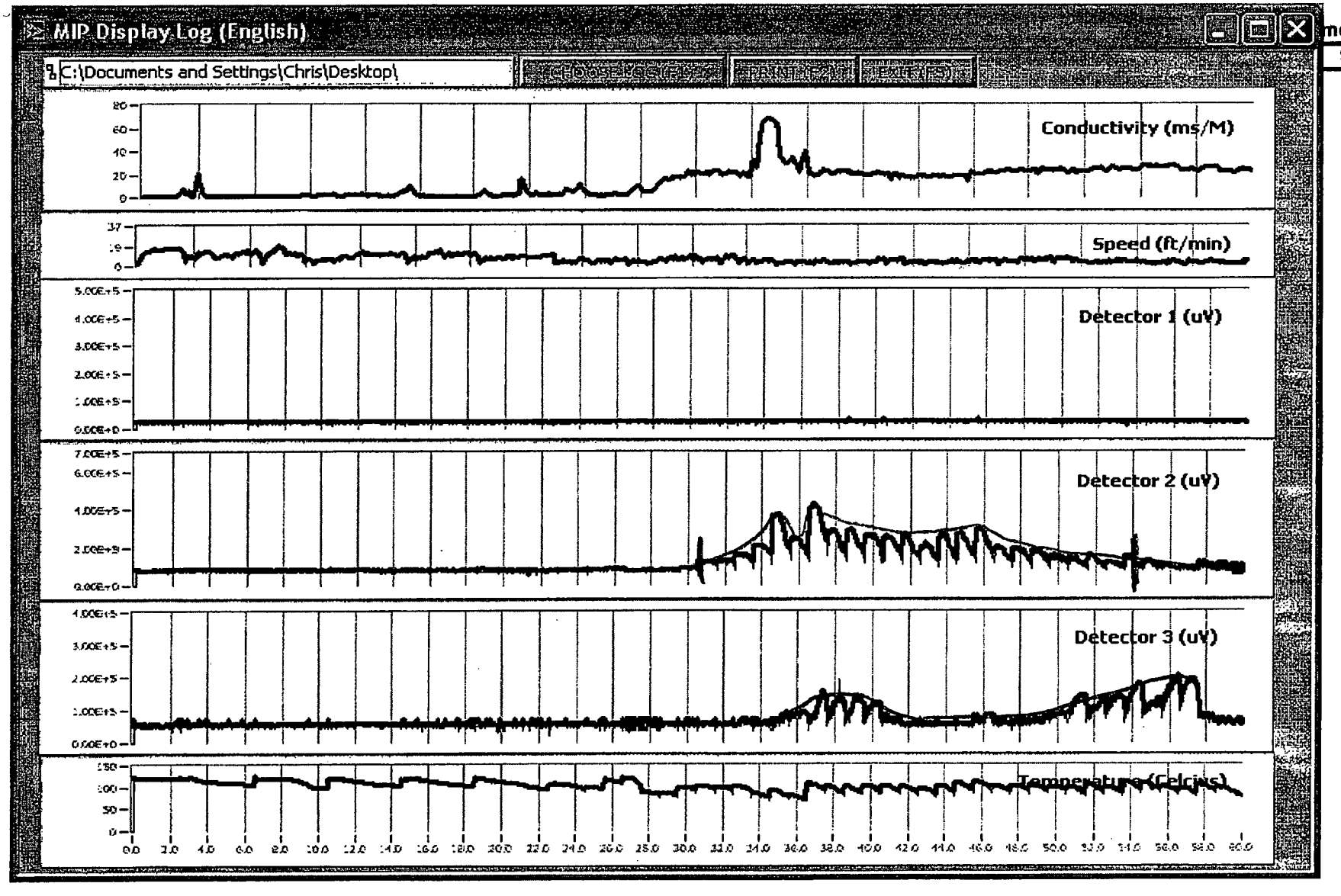
PRINT (F2)
EXIT (F5)
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

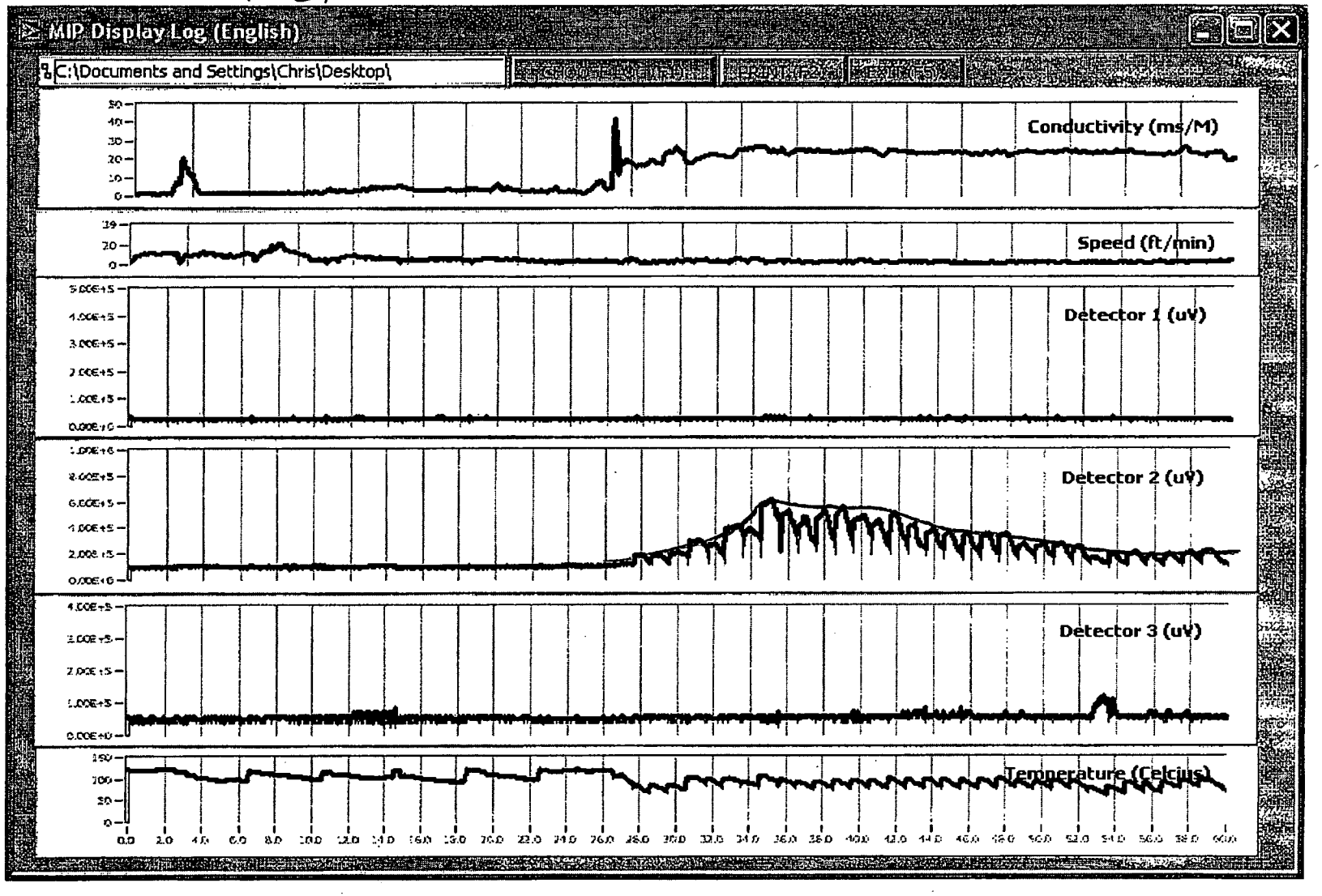
me:
970

MIP-27


MIP Display Log (English)
C:\Documents and Settings\Chris\Desktop\
Conductivity (ms/M)
Speed (ft/min)
Detector 1 (uV)
Detector 2 (uV)
Detector 3 (uV)
Temperature (Celcius)

me:
972

MIP-28




File name:
976

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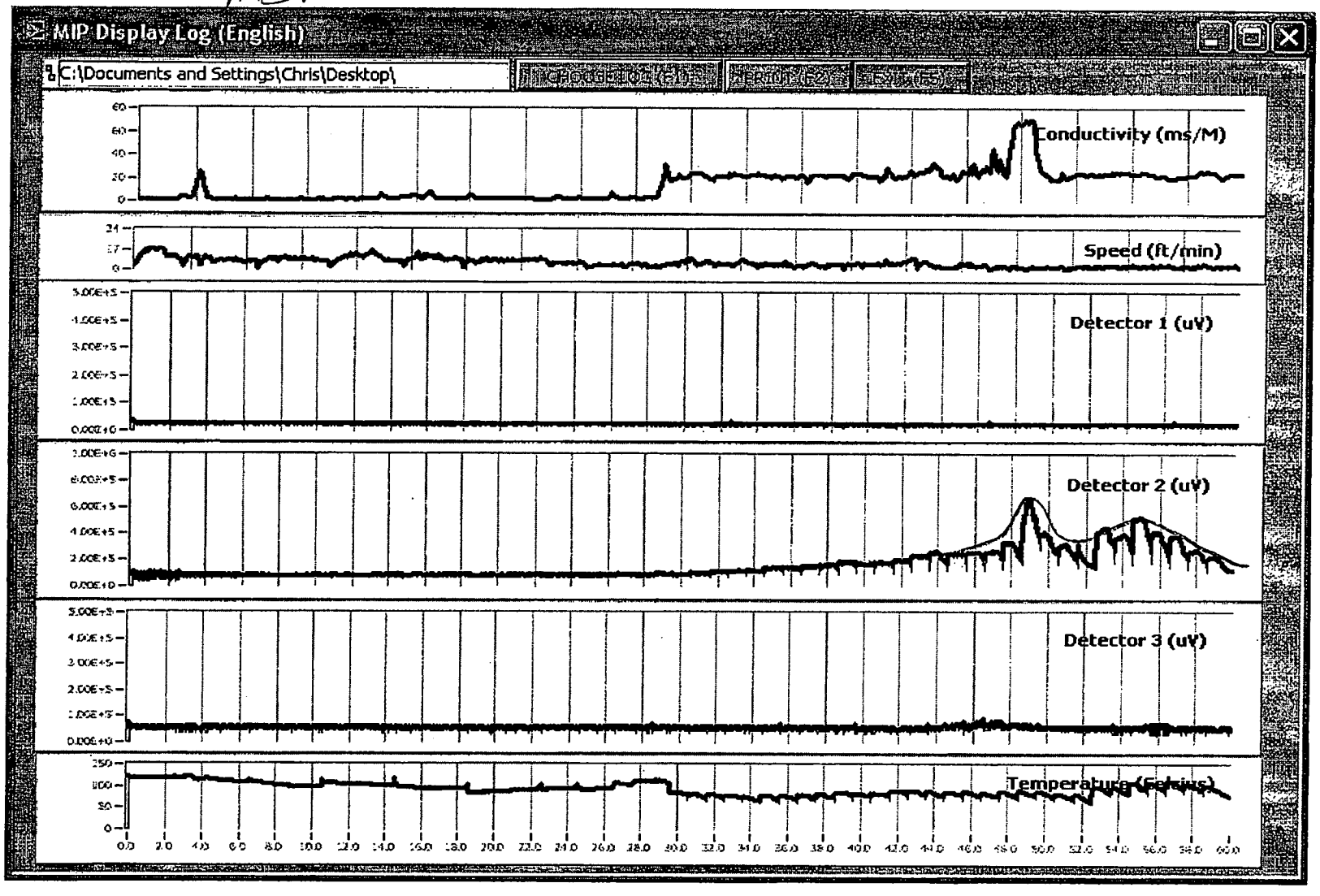


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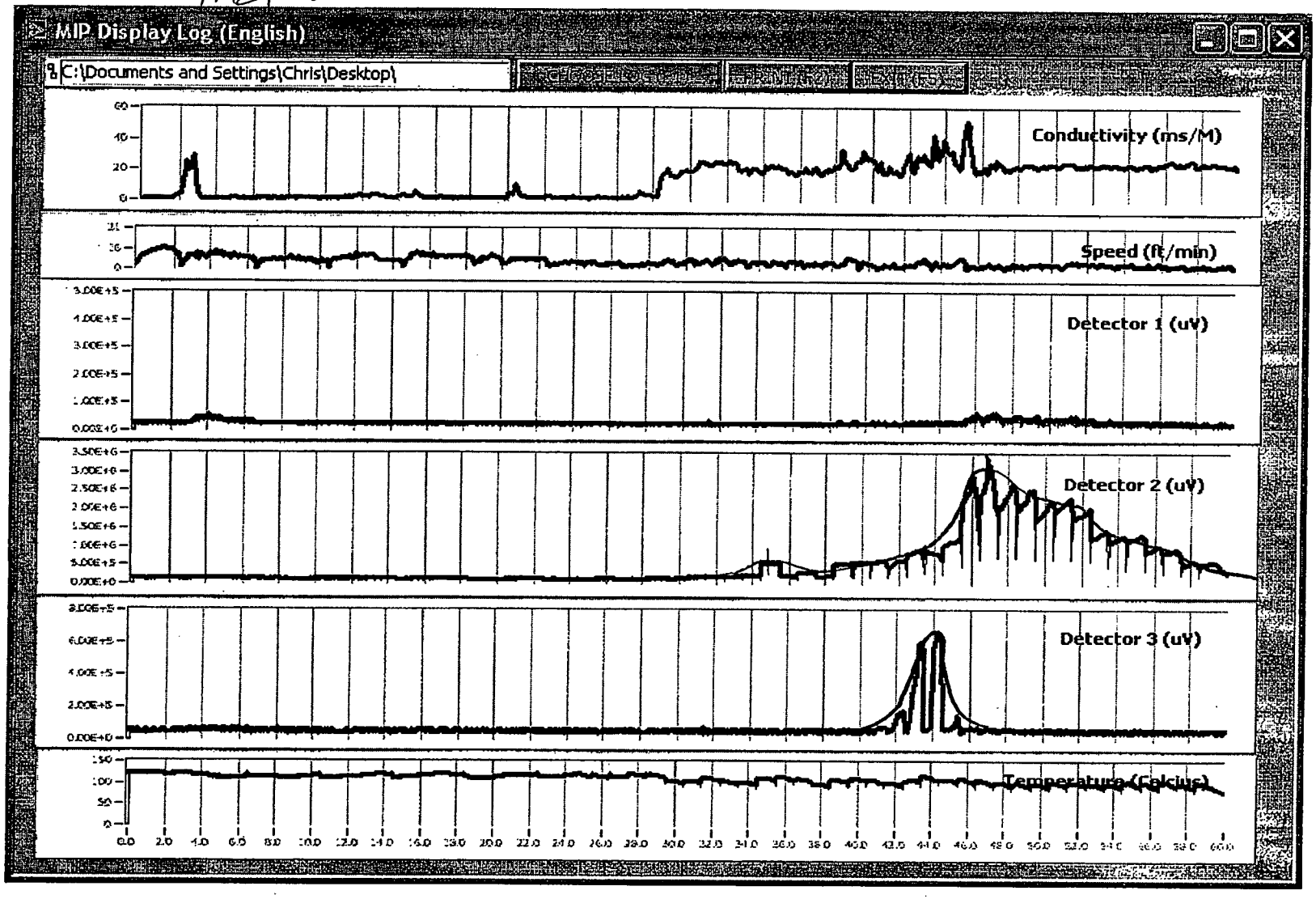
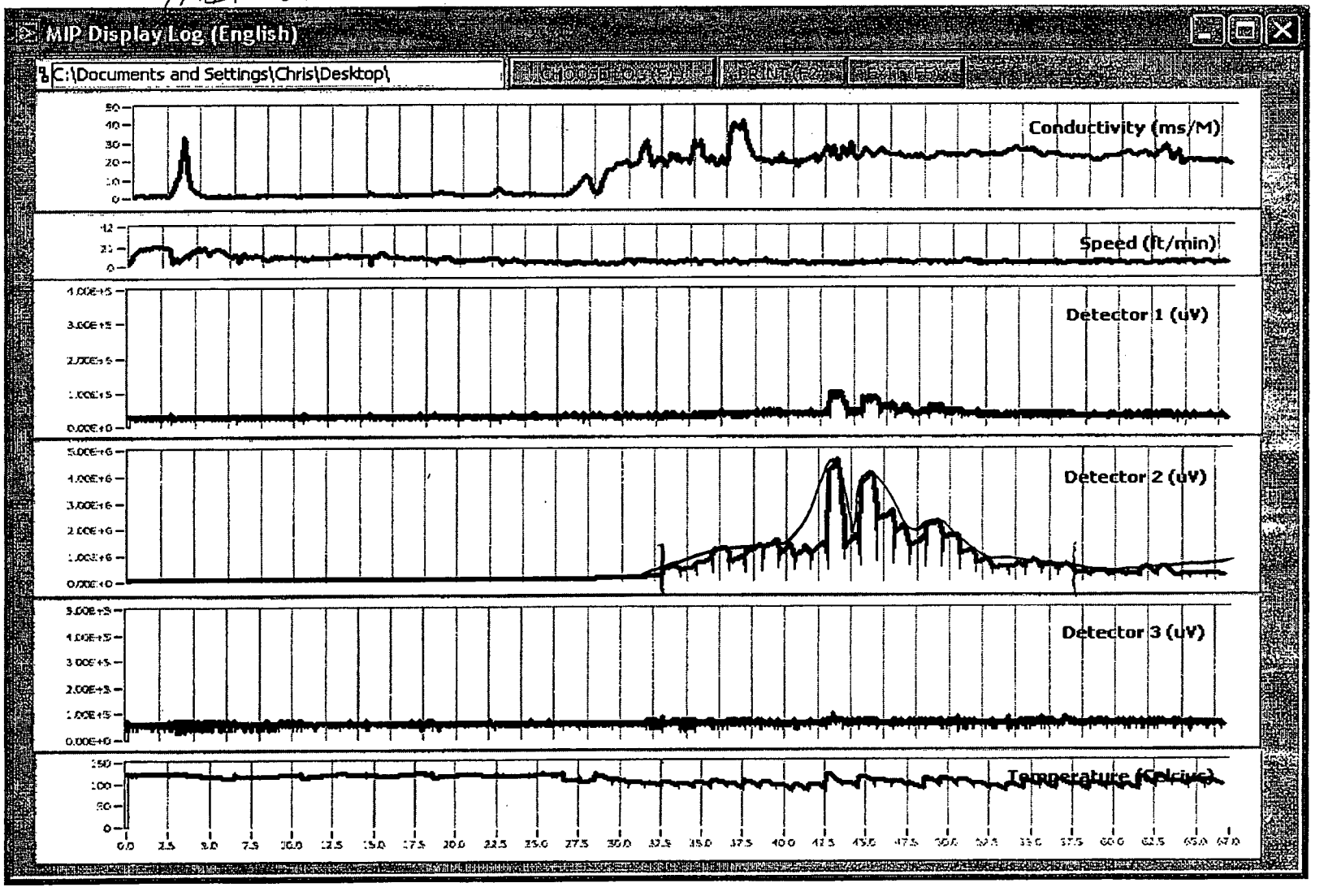



File name:
980

MIP-31




File name:
982

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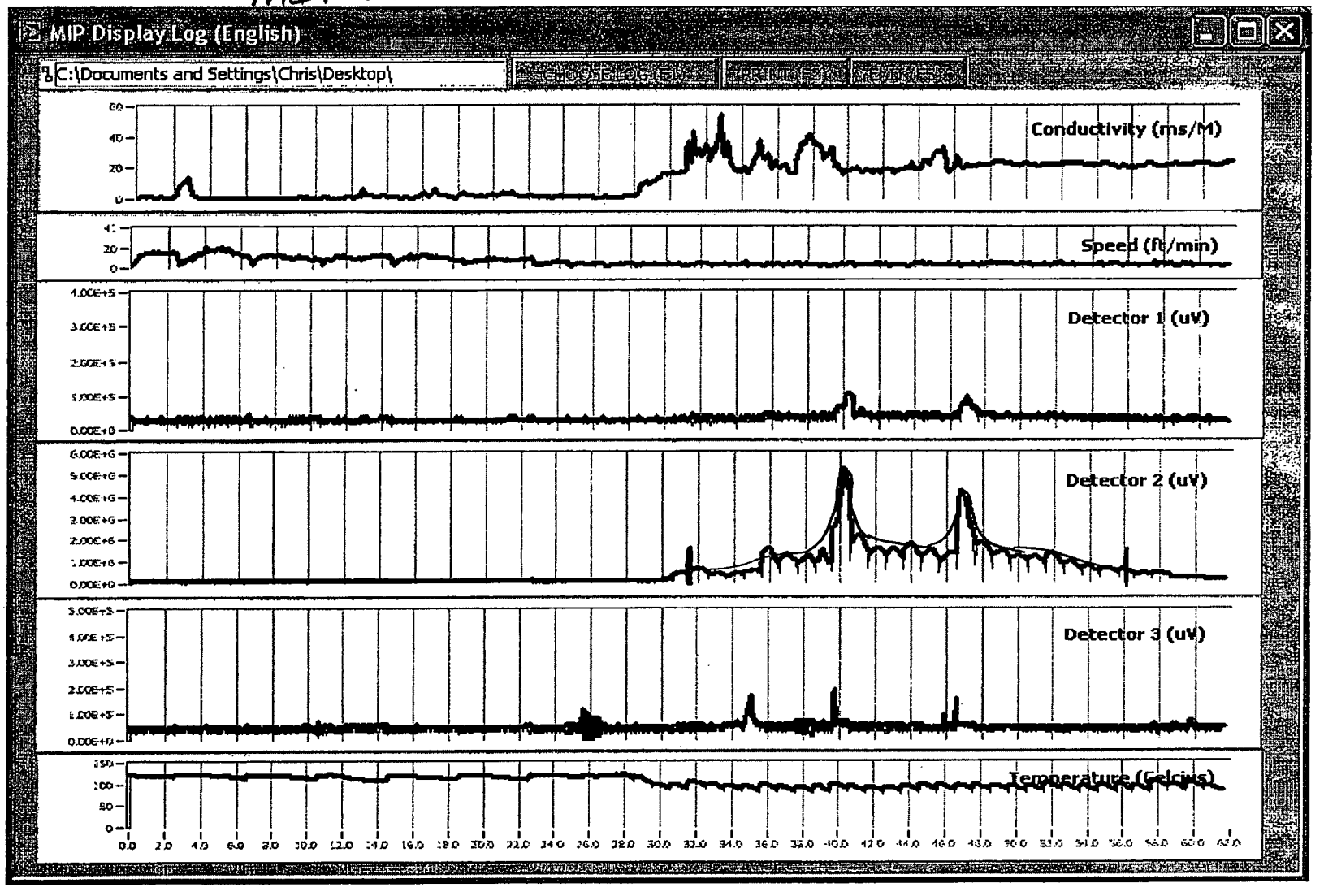
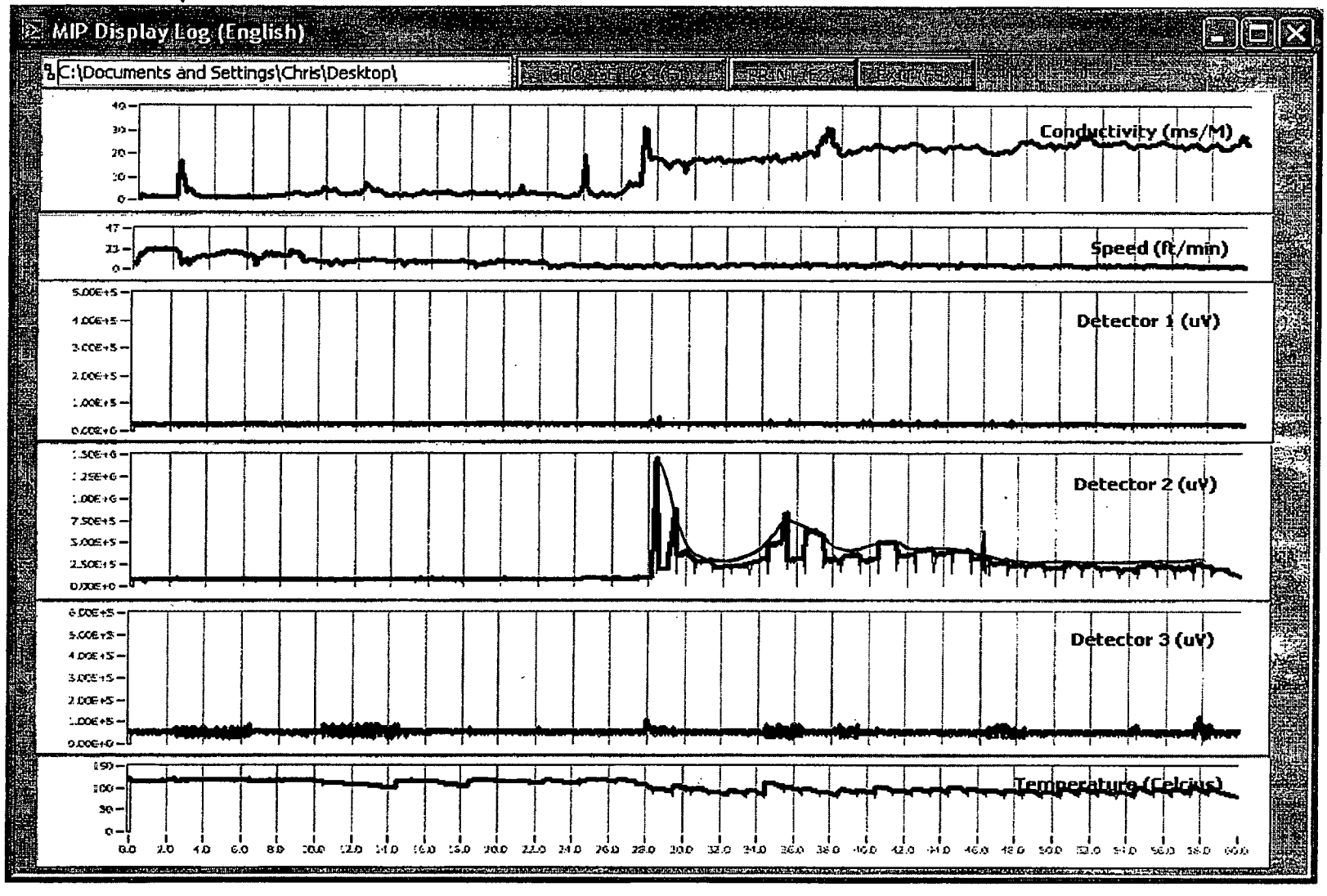


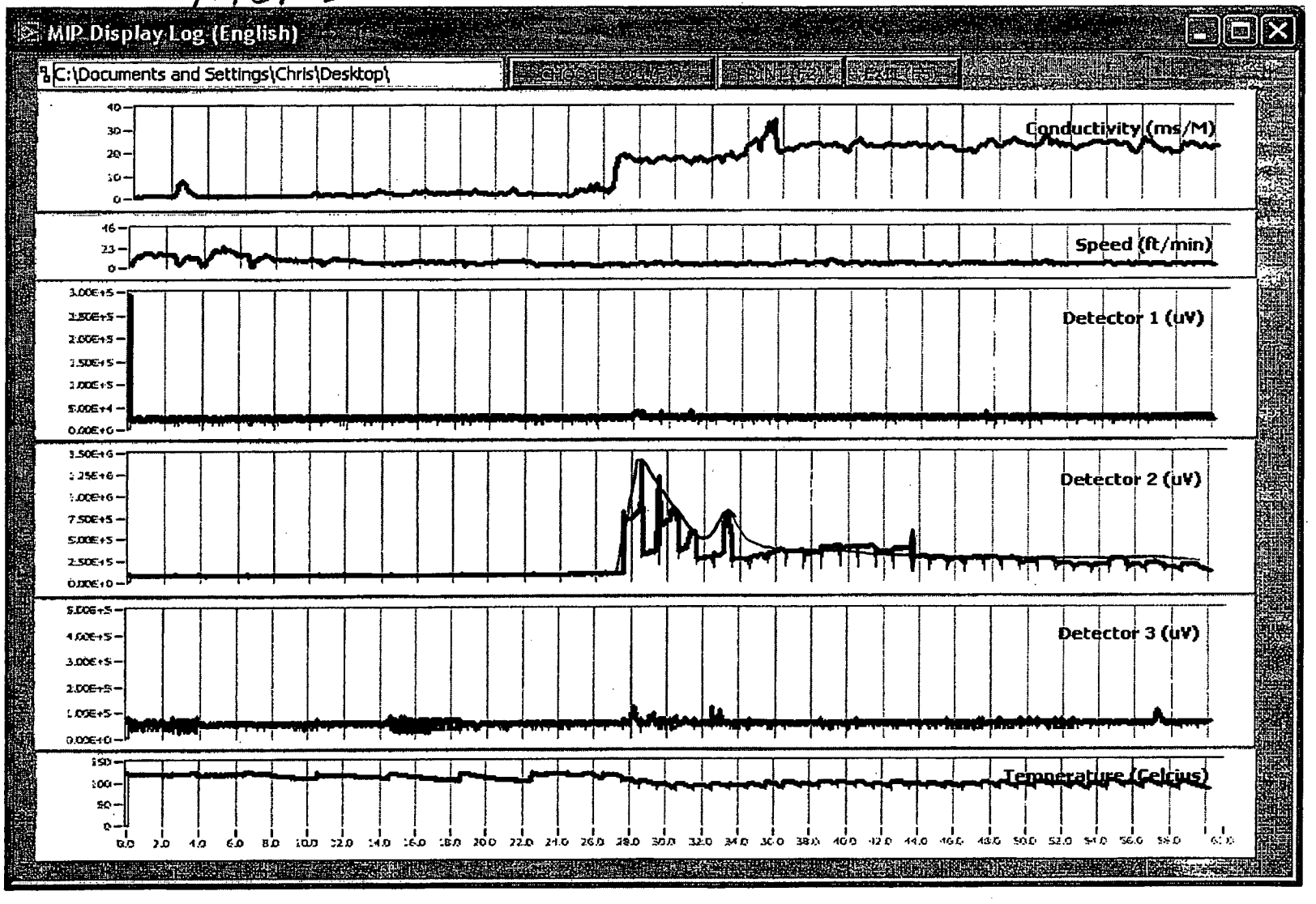

File name:
993

MIP-33



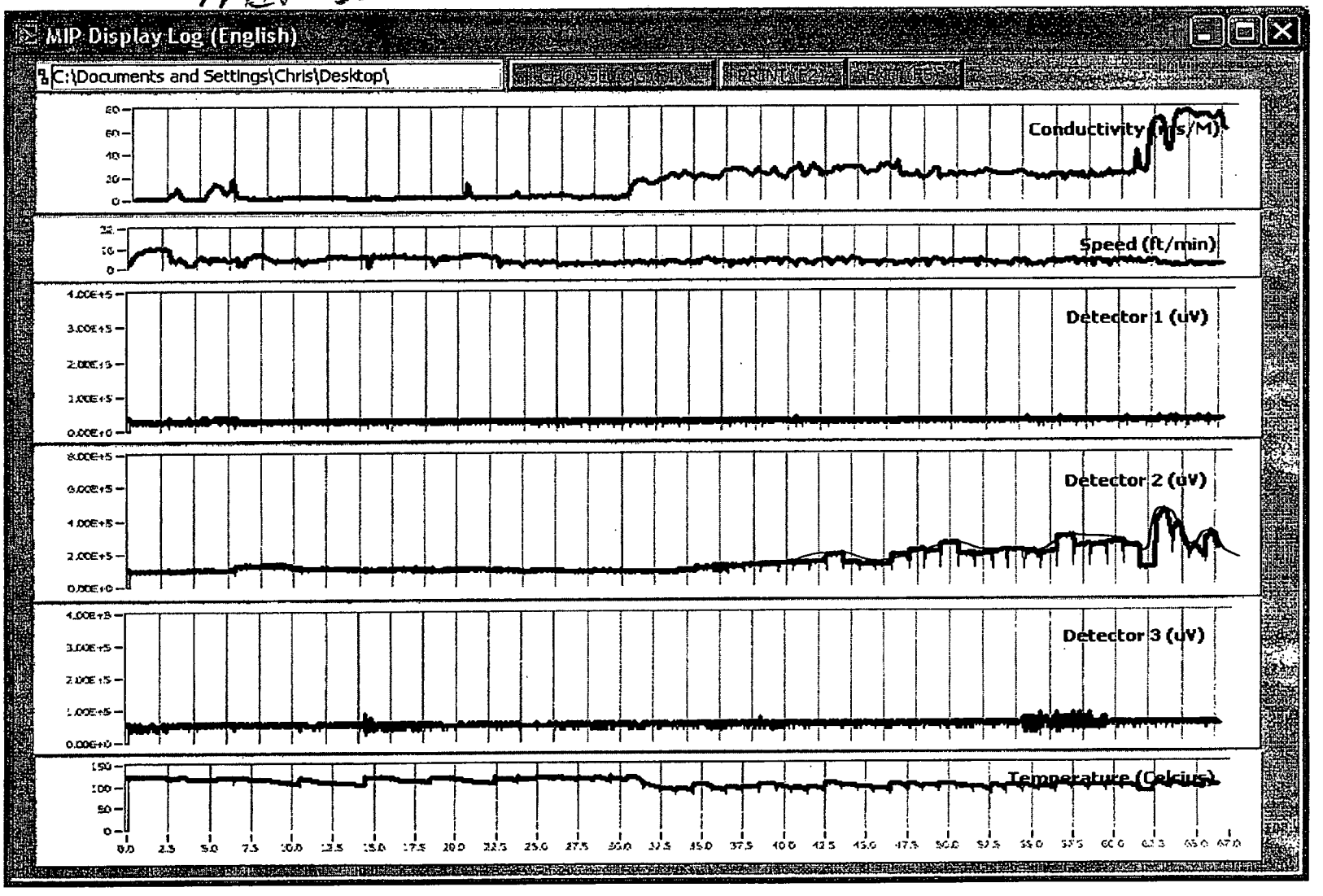

File name:
989

MIP-34



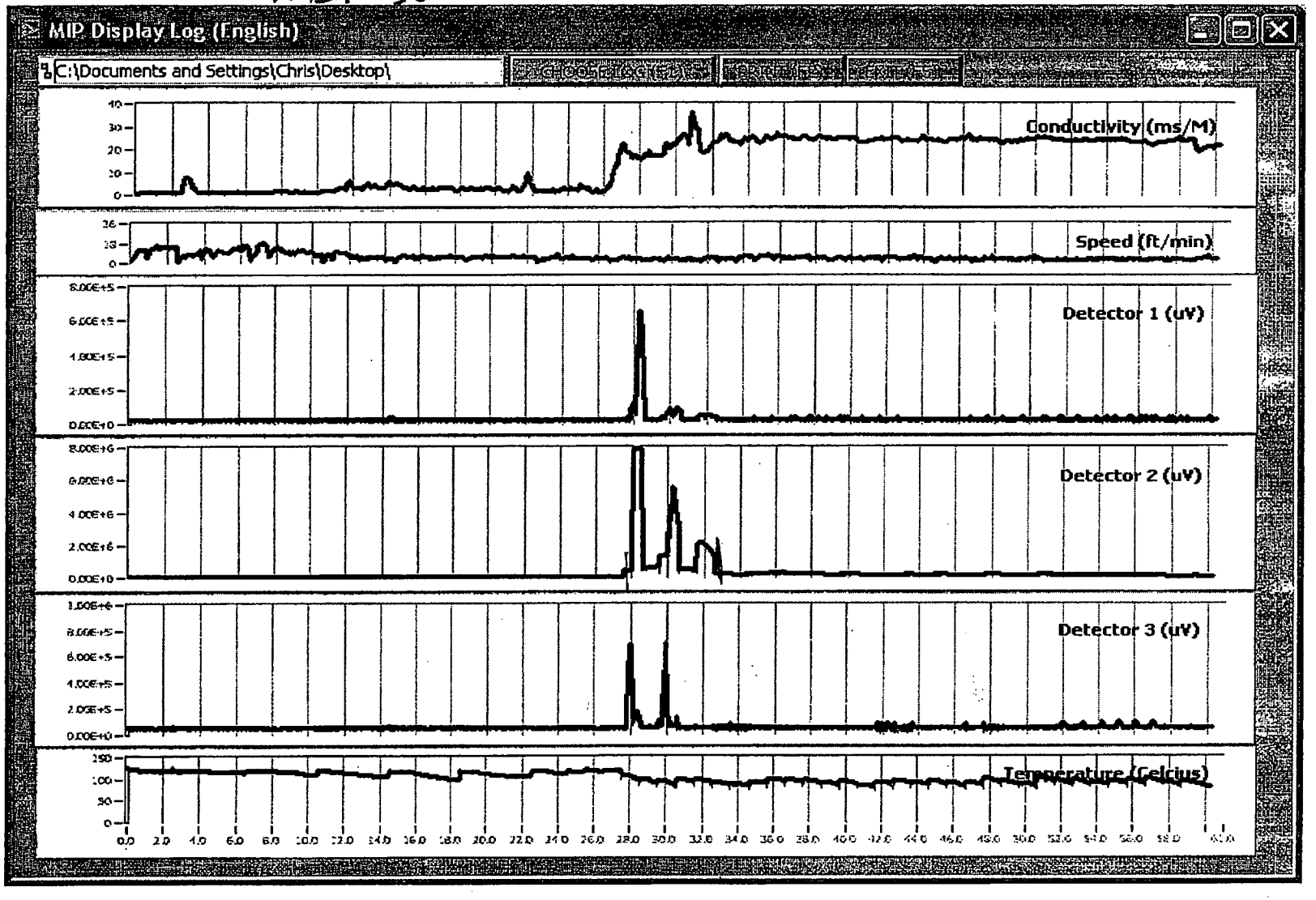

File name:
988

MIP-35




File name:
985

MIP-36




File name:
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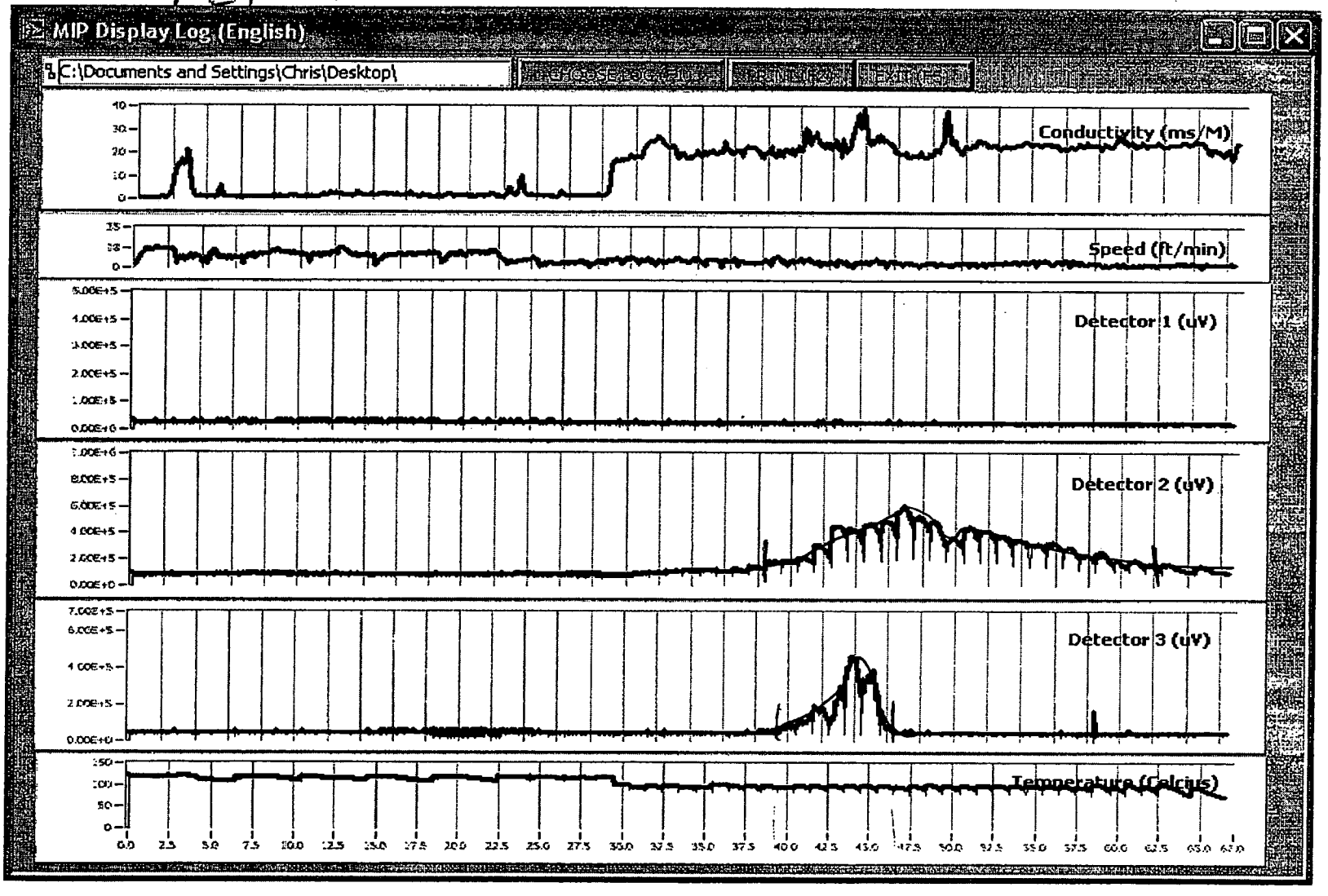
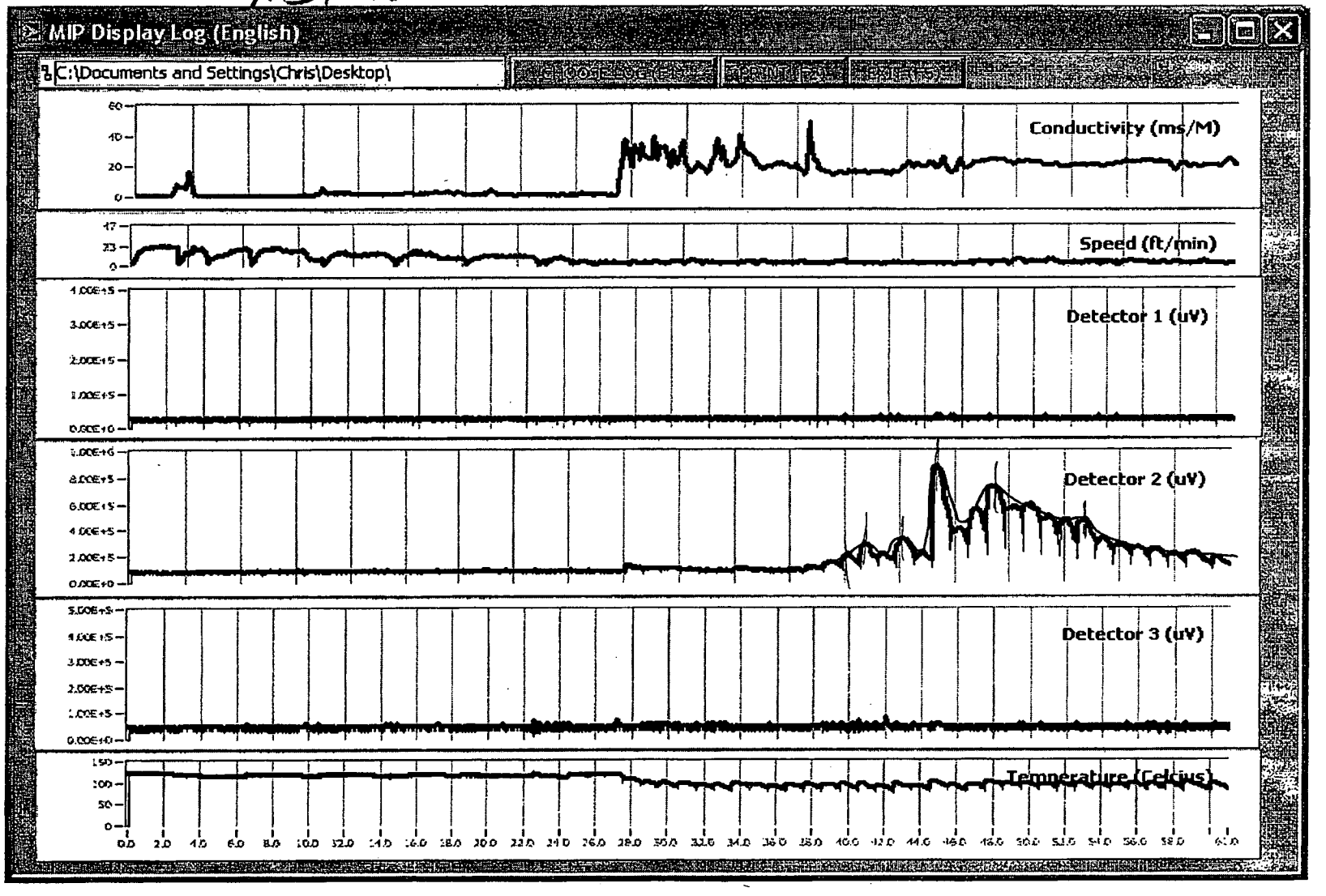
MIP-37




File name:
994

MIP-38




File name:
995

# APPENDIX B

# BORING LOGS

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | **10B** |
| Boring Depth: | 75 feet | MW #: | MW-10B |
| GW Encountered | 29 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 0727 3/31/05 |
| Location: | | End time/date: | 1145 3/31/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 10YR 2/2 (very dark brown) organic horizon |
| 0 | 0-2 | 1.5' | | | | | | ML | 10YR 2/2 (very dark brown) moist cohesive silt and clay. Decomposed organic material present. No odor. |
| 1 | | | | | 2.3 | | | ML | 10YR 4/2 (dark grayish brown) moist cohesive sandy silt. No odor. |
| 2 | 2-4 | 1.2' | | | | | | | |
| 3 | | | | | 2.3 | | | SW-SM | 10YR 4/3 (brown) moist, loose well-graded fine to medium sand with silt, very minor silt component. No odor. |
| 4 | 4-6 | 1.5' | | | | | | SW-SM | 10YR 4/3 (brown) moist grading to dry, loose well-graded sand with silt with mottling. Very minor silt component. No odor. |
| 5 | | | | | 2.3 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| 6 | 6-8 | 1.2' | | | | | | | |
| 7 | | | | | 2.3 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand with bedded layers of coarse sand. No odor. |
| 8 | 8-10 | 1.5' | | | | | | | |
| 9 | | | | | 4.7 | | | | |
| 10 | 10-12 | 1.2' | | | | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |
| 11 | | | | | 4.7 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with rocks up to 1.5 inch diameter. No odor. |

Boring Number: 10B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12<br>13 | 12-14 | 1.2' | | | 2.3 | | | SW | 10YR 4/3 (brown) dry, loose well-graded fine to coarse sand with gravel and rocks up to 2-inch diameter. No odor. |
| 14<br>15 | 14-16 | 1.8 | | | 2.3 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand with bedded bands of coarse sand. Mottled between 15 and 17 feet bgs. No odor. |
| 16<br>17 | 16-18 | 1.5 | | | 4.7 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand with bedded layers of coarse sand. No odor. |
| 18<br>19 | 18-20 | 1.5 | | | 2.3 | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand with gravel. No odor. |
| 20<br>21 | 20-22 | 1.5 | | | 2.3 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 22<br>23 | 22-24 | 1.8 | | | 2.3 | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 24<br>25 | 24-26 | 1.5 | | | 2.3 | | | | Same as above |
| 26<br>27 | 26-28 | 0.5 | | | 2.3 | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with gravel. Limited recovery due to rock lodged in sampler. No odor. |
| 28 | 28-29 | 1.0 | | | | | | SW | 10YR 3/2 (very dark grayish brown) moist grading to wet (at 29 feet bgs), loose well-graded medium to coarse sand with gravel. No odor. |

Boring Number: 10B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 1.0 | | Water | 2.3 | | | SW | Same as above. Wet at 29 feet below ground surface |
| 30, 31 | 30-32 | 1.0 | | | 2.3 | | | GW | 10YR 4/3 (brown) wet, loose well-graded gravel with coarse sand and silt component. Rocks up to 3-inches in diameter present. No odor. |
| 32, 33 | 32-34 | 0.5 | | | 2.3 | | | | Same as above |
| 34, 35 | 34-36 | 1.0 | | | 4.7 | | | SM | 10YR 4/3 (brown) wet, cohesive silty sand. Mottled bands to 36 feet bgs. No odor. |
| 36, 37 | 36-38 | 0.1 | | | 7.1 | | | SM | 10YR 4/3 (brown) wet, cohesive silty sand with occasional pebbles. No odor/sheen. Limited recovery. |
| 38, 39 | 38-40 | 0.0 | | | -- | | | -- | No recovery 38-40 foot interval. |
| 40, 41 | 40-42 | 0.1 | | | 2.3 | | | SM | 10YR 4/3 (brown) wet, cohesive silty sand with occasional pebbles. No odor. Limited recovery. |
| 42, 43 | 42-44 | 1.8 | | | 2.3 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor. |
| 44 | 44-46 | 1.0 | | | 2.3 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor |
| 45 | | | | | | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to medium sand. No odor. |

| Boring Number: | 10B | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 46-48 | 1.0 | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. Angular rocks up to 2-inches in diameter present. No odor. |
| 47 | | | | | 2.3 | | | | |
| 48 | 48-50 | 2.0 | | | | | | | Same as above |
| 49 | | | | | 2.3 | | | SP | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine sand. Mild odor. Sampled 48-50 interval as "most impacted." |
| 50 | 50-52 | 1.5 | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 51 | | | | | 0.0 | | | | |
| 52 | 52-54 | 1.0 | | | | | | SP | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine sand. Mild odor. |
| 53 | | | | | 4.7 | | | | |
| 54 | 54-56 | 1.5 | | | | | | | |
| 55 | | | | | 2.3 | | | SP | 10YR 4/3 (brown) wet, mildly cohesive very fine sand. No odor. No observed silt component. |
| 56 | 56-58 | 1.0 | | | | | | | |
| 57 | | | | | 2.3 | | | | |
| 58 | 58-60 | 1.0 | | | | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor. |
| 59 | | | | | 2.3 | | | | |
| 60 | 60-62 | 1.0 | | | | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 61 | | | | | 4.7 | | | | |
| 62 | 62-63 | 1.8 | | | | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |

Boring Number: 10B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | 1.8 | | | 4.7 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 64<br>65 | 64-66 | 1.0 | | | 4.7 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 66<br>67 | 66-68 | 1.0 | | | 4.7 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 68<br>69 | 68-70 | 1.5 | | | 4.7 | | | | Same as above |
| 70<br>71 | 70-72 | 2.0 | | | 4.7 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine and medium sand. No odor.<br>Sampled 70-71 interval |
| 72<br>73 | 72-74 | 1.8 | | | 4.7 | | | SP | 10YR 4/3 (brown) wet, mildly cohesive well-graded very fine sand. No silt component. No odor. |
| 74<br>75 | 74-76 | 1.0 | | | | | | | End of boring at 75 feet below ground surface. |
| 76<br>77 | 76-78 | | | | | | | | |
| 78<br>79 | 78-80 | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | 11A |
| Boring Depth: | 57 feet | MW #: | PES-MW-11A |
| GW Encountered | 29 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 0725 3/29/05 |
| Location: | | End time/date: | 0950 3/29/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | 0 | | | | | | -- | No recovery 0 to 4 feet bgs due to augering through frost. |
| 1 | | | | | -- | | | | |
| 2 | 2-4 | 0 | | | | | | | |
| 3 | | | | | -- | | | | |
| 4 | 4-6 | 1.5 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| 5 | | | | | 2.4 | | | SW | 10YR 5/4 (yellowish brown) dry, loose well-graded fine to medium sand with mottling at 5.75 feet bgs. |
| 6 | 6-8 | 1.0 | | | | | | | |
| 7 | | | | | 4.9 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with occasional pebbles. No odor |
| 8 | 8-10 | 1.5 | | | | | | SP | 10YR 6/3 (pale brown) dry, loose poorly-graded fine sand with bands of lamination. No odor |
| 9 | | | | | 4.7 | | | SW | 10YR 6/6 (brownish yellow) dry, loose well-graded mottled fine and medium sand with occasional pebbles. No odor. |
| 10 | 10-12 | 1.0 | | | | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |
| 11 | | | | | 4.9 | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand with gravel. No odor. |

| Boring Number: 11A | Project : NIROP Pilot-Scale 2005 | Project #: 5427 |
|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.5 | | | | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand with gravel. No odor. |
| | | | | | | | | SP | 10YR 6/3 (pale brown) dry, loose poorly-graded fine sand. No odor. |
| 13 | | | | | 4.9 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 14 | 14-16 | 1.5 | | | | | | | Same as above |
| 15 | | | | | 4.9 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| 16 | 16-18 | 1.0 | | | | | | SP | 10YR 6/4 (light yellowish brown) dry, loose poorly-graded mottled fine sand. No odor. |
| 17 | | | | | 4.9 | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |
| 18 | 18-20 | 1.5 | | | | | | SW | 10YR 6/2 (light brownish gray) dry, loose well-graded fine to coarse sand. No odor. |
| 19 | | | | | 4.9 | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand with bedded coarse sand. No odor. |
| 20 | 20-22 | 1.5 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand with occasional angular pebbles. No odor. |
| 21 | | | | | 4.9 | | | SW | 10YR 5/3 (brown) dry grading to moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 22 | 22-24 | 1.5 | | | | | | | Same as above |
| 23 | | | | | 4.9 | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded fine sand. No odor. |
| 24 | 24-26 | 1.2 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to medium sand. No odor. |
| 25 | | | | | 4.9 | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 26 | 26-28 | 1.5 | | | | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded fine sand. No odor. |
| 27 | | | | | 4.9 | | | | |
| 28 | 28-29 | 0.5 | | | | | | GW | 10YR 4/2 (dark grayish brown) moist grading to wet (at 29 feet bgs) well-graded rounded and angular gravel with fine to coarse sand. No odor. |

| Boring Number: | 11A | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.5 | | water | 4.9 | | | GW | 10YR 4/2 (dark grayish brown) moist grading to wet (at 29 feet bgs) well-graded rounded and angular gravel with fine to coarse sand. No odor. |
| 30<br>31 | 30-32 | 1.2 | | | 4.9 | | | GW | 10YR 4/2 (dark grayish brown) wet, loose well-graded rounded and angular gravel with fine to coarse sand with rocks up to 2 inches in diameter. No odor. |
| 32<br>33 | 32-34 | 0.8 | | | 4.9 | | | | Same as above |
| 34<br>35 | 34-36 | 1.2 | | | 7.4 | | | SM | 10YR 3/3 (dark brown) wet, cohesive silty sand with <5% coarse sand component. No odor. |
| | | | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 36<br>37 | 36-38 | 0.5 | | | 9.8 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Limited recovery. |
| 38<br>39 | 38-40 | 0.0 | | | -- | | | -- | No recovery 38-40 feet bgs. |
| 40<br>41 | 40-42 | 0.5 | | | 4.9 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to medium sand. No odor. |
| | | | | | | | | SW | 10YR 4/2 (dark grayish brown) wet, cohesive well-graded fine to medium sand with silt. No odor. |
| 42<br>43 | 42-44 | 1.2 | | | 7.4 | | | SM | 10YR 4/2 (dark grayish brown) wet, cohesive silty sand with occasional pebbles and fine sand component. No odor. Sampled at 42'-44' interval. |
| 44<br>45 | 44-46 | -- | | | 9.8 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| | | | | | | | | SW | 10YR 3/3 (dark brown) wet, loose well-graded fine to coarse sand. No odor. |

Boring Number: 11A Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.8 | | | 7.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand with mottled bands of 10YR 5/6 (yellowish brown) fine sand. No odor. |
| 48<br>49 | 48-50 | 1.8 | | | 7.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Sample collected at 48'-50' interval FD-2 |
| 50<br>51 | 50-52 | 1.0 | | | 4.9 | | | SP | 10YR 4/3 (brown) wet, mildly cohesive very fine sand. No silt component. No odor. |
| 52<br>53 | 52-54 | 1.0 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 54<br>55 | 54-56 | 0.5 | | | 4.9 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 56<br>57 | 56-58 | | | | 4.9 | | | SP | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine sand. No odor. |
| | | | | | | | | | End of boring at 57 feet below ground surface |
| 58<br>59 | 58-60 | | | | | | | | |
| 60<br>61 | 60-62 | | | | | | | | |
| 62 | 62-63 | | | | | | | | |

Boring Number: 11A Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | 12B |
| Boring Depth: | 65 feet | MW #: | MW-12B |
| GW Encountered | 29 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 0736 4/5/05 |
| Location: | | End time/date: | 1045 4/5/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | 1.5 | | | | | | SP-SC | 10YR 3/3 (dark brown) cohesive, moist grading to frozen poorly-graded fine sand with clay and organic material. No odor. |
| 1 | | | | | 0.0 | | | SP | 10YR 6/4 (light yellowish brown) frozen due to frost layer loose poorly-graded fine sand. No odor. |
| 2 | 2-4 | 1.5 | | | | | | SP | GLEY 5/10G (greenish gray) frozen, loose poorly-graded fine sand. No odor. |
| 3 | | | | | 1.3 | | | CL | 10YR 6/1 (gray) mottled to 10YR 6/8 (brownish yellow) moist, cohesive lean clay with sand and occasional pebbles. No odor. |
| 4 | 4-6 | 1.8 | | | | | | | |
| 5 | | | | | 0.0 | | | SP | 10YR 4/2 (dark grayish brown) moist, loose poorly-graded fine sand. No odor. |
| 6 | 6-8 | 1.5 | | | | | | | |
| 7 | | | | | 0.0 | | | SW | 10YR 4/4 (dark yellowish brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 8 | 8-10 | 1.5 | | | | | | SW | 10YR 4/4 (dark yellowish brown) moist, loose well-graded fine to medium sand mottled to 10YR 5/6 (yellowish brown). No odor. |
| 9 | | | | | 1.3 | | | | |
| 10 | 10-12 | 1.5 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with gravel. No odor. |
| 11 | | | | | 0.0 | | | | |

Boring Number: 12B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12<br>13 | 12-14 | 1.5 | | | 0.0 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 14<br>15 | 14-16 | 1.5 | | | 0.0 | | | SW | Same as above. |
| 16<br>17 | 16-18 | 0 | | | -- | | | -- | No recovery 16 to 18 feet below ground surface. |
| 18<br>19 | 18-20 | 1.8 | | | 1.3 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 20<br>21 | 20-22 | 1.8 | | | 1.3 | | | | Same as above |
| 22<br>23 | 22-24 | 1.5 | | | 0.0 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with gravel and rocks up to 2 inches in diameter. No odor. |
| 24<br>25 | 24-26 | 1.2 | | | 1.3 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand with bedded bands of coarse sand. No odor. |
| 26<br>27 | 26-28 | 0.0 | | | -- | | | -- | No recovery 26 to 28 feet below ground surface. |
| 28 | 28-29 | 1.8' | | | | | | SW | 10YR 5/3 (brown) moist grading to wet, loose well-graded fine to medium sand. No odor or sheen. |

Boring Number: 12B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 1.8 | | water | 0.0 | | | SW | 10YR 5/3 (brown) wet at 29 feet bgs, loose well-graded fine to medium sand. No odor or sheen. |
| 30 | 30-32 | 1.8 | | | | | | SW | 10YR 5/2 (grayish brown) wet, loose well-graded fine to coarse sand. No odor. |
| 31 | | | | | 0.0 | | | | |
| 32 | 32-34 | 1.8 | | | | | | SW | 10YR 5/3 (brown) wet, loose well-graded fine to coarse sand. No odor. |
| 33 | | | | | 0.0 | | | | |
| 34 | 34-36 | 1.8 | | | | | | SW | 10YR 5/3 (brown) wet, loose well-graded fine to coarse sand. No odor. |
| 35 | | | | | 0.0 | | | | |
| 36 | 36-38 | 1.8 | | | | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to coarse sand. No odor |
| 37 | | | | | 1.3 | | | | |
| 38 | 38-40 | 1.8 | | | | | | | Same as above |
| 39 | | | | | 1.3 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to coarse sand w/ gravel and rounded rocks up to 2.5 inches diameter. No odor. |
| 40 | 40-42 | 1.5 | | | | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to coarse sand. No odor. |
| 41 | | | | | 0.0 | | | | |
| 42 | 42-44 | 1.8 | | | | | | | Same as above. |
| 43 | | | | | 0.0 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to coarse sand with rounded gravel. No odor. |
| 44 | 44-46 | 1.5 | | | | | | | Same as above. |
| 45 | | | | | 0.0 | | | | |

Boring Number: 12B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 46-48 | 1.0 | | | 1.3 | | | SW | 10YR 4/1 (dark gray) wet, loose well-graded fine to coarse sand. No odor. |
| 47 | | | | | | | | | |
| 48 | 48-50 | 1.0 | | | 1.3 | | | SW | 10YR 4/1 (dark gray) wet, loose well-graded fine to coarse sand. No odor. |
| 49 | | | | | | | | | |
| 50 | 50-52 | 1.5 | | | 0.0 | | | | Same as above |
| 51 | | | | | | | | SP | 10YR 5/1 (gray) wet, loose poorly-graded fine sand No odor |
| 52 | 52-54 | 1.8 | | | 0.0 | | | | Same as above |
| 53 | | | | | | | | | |
| 54 | 54-56 | 1.5 | | | 0.0 | | | SP | 10YR 5/1 (gray) wet, loose poorly-graded fine sand No odor. |
| 55 | | | | | | | | GW | 10YR 5/1 (gray) wet, loose well-graded rounded gravel with coarse to fine sand. No odor. |
| 56 | 56-58 | 0.0 | | | -- | | | -- | No recovery 56 to 58 feet below ground surface |
| 57 | | | | | | | | | |
| 58 | 58-60 | 1.5 | | | 0.0 | | | SW | 10YR 4/1 (dark gray) wet, loose well-graded fine to coarse sand. No odor |
| 59 | | | | | | | | GW | 10YR 4/1 (dark gray) wet, loose well-graded rounded gravel with coarse sand and rocks up to 2 inches in diameter. No odor. |
| 60 | 60-62 | 1.0 | | | 0.0 | | | SW | 10YR 4/1 (dark gray) wet, loose well-graded fine to coarse sand. No odor. |
| 61 | | | | | | | | | |
| 62 | 62-63 | 1.0 | | | 0.0 | | | SW | 10YR 4/1 (dark gray) wet, loose well-graded fine to coarse sand with gravel and rocks up to 3 inch in diameter. No odor. |

Boring Number: 12B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | 1.0 | | | 0.0 | | | CL | 10YR 4/2 (dark grayish brown) wet, friable tight lean clay with silt and occasional pebbles. No odor Sampled 62-63 interval for "screened interval" sample. |
| 64 | 64-66 | 1.0 | | | 1.3 | | | | End of boring at 65 feet below ground surface |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | 14B |
| Boring Depth: | 75 feet | MW #: | MW-14B |
| GW Encountered | 29 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1005 4/1/05 |
| Location: | | End time/date: | 1018 4/4/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | 2.0 | | | 2.5 | | | SP | 10YR 3/2 (very dark grayish brown) moist, cohesive well-graded fine sand with organic material and silt. No odor. |
| 2, 3 | 2-4 | 1.8 | | | 2.5 | | | SP | Same as above |
| | | | | | | | | SP-SM | 10YR 4/4 (dark yellowish brown) moist, cohesive poorly-graded fine sand with silt. No odor. |
| 4, 5 | 4-6 | 1.5 | | | 2.5 | | | SP | 10YR 5/4 (yellowish brown) moist, loose poorly-graded fine sand. No odor. |
| 6 | 6-8 | 1.5 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 7 | | | | | 2.5 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| 8, 9 | 8-10 | 1.0 | | | 2.5 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 10, 11 | 10-12 | 1.2 | | | 2.5 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with rocks up to 2 inches diameter. No odor. |

Boring Number: 14B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12<br>13 | 12-14 | 0.5 | | | 2.5 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| 14<br>15 | 14-16 | 1.5 | | | 2.5 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand with mottling to 10YR 5/8 (yellowish brown) and bedded layers of coarse sand.<br>Same as above |
| 16<br>17 | 16-18 | 1.5 | | | 2.5 | | | SP | 10YR 6/3 (pale brown) dry, loose poorly-graded fine sand. No odor.<br>Same as above |
| 18<br>19 | 18-20 | 1.5 | | | 2.5 | | | | |
| 20<br>21 | 20-22 | 1.5 | | | 0.0 | | | SW | 10YR 4/2 (dark grayish brown) dry, loose well-graded fine to coarse sand. No odor. |
| 22<br>23 | 22-24 | 1.5 | | | 5.1 | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |
| 24<br>25 | 24-26 | 1.5 | | | 2.5 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with gravel. No odor. |
| 26<br>27 | 26-28 | 1.2 | | | 2.5 | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to medium sand. No odor |
| 28 | 28-29 | 1.5 | | | 5.1 | | | SW | 10YR 4/3 (brown) moist grading to wet at 29 feet bgs, loose well-graded fine to coarse sand. No odor. |

Boring Number: 14B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 1.5 | | water | 5.1 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine to coarse sand. No odor. |
| 30 | 30-32 | 1.5 | | | | | | SP | 10YR 5/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 31 | | | | | 5.0 | | | SW | 10YR 5/3 (brown) wet, loose well-graded fine to coarse sand with gravel. No odor |
| 32 | 32-34 | 1.8 | | | | | | | |
| 33 | | | | | 7.5 | | | SM | 10YR 4/3 (brown) wet, cohesive silty sand with occasional pebbles. No odor. |
| 34 | 34-36 | 1.5 | | | | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine to coarse sand with gravel and very minor silt component. No odor. |
| 35 | | | | | 7.5 | | | | |
| 36 | 36-38 | 1.0 | | | | | | SW | 10YR 3/2 (very dark grayish brown) wet, loose well-graded fine to coarse sand. Very minor silt component. No odor. |
| 37 | | | | | 5.0 | | | | |
| 38 | 38-40 | 1.5 | | | | | | SW | 10YR 3/2 (very dark grayish brown) wet, loose well-graded fine to medium sand. Dark band of sand 10YR 3/1 (very dark gray) observed at 39 feet bgs. Mild odor in this dark band. |
| 39 | | | | | 5.0 | | | ML | 10YR 4/3 (brown) 3-inch think layer of cohesive silt with sand. No odor |
| 40 | 40-42 | 1.0 | | | | | | ML | 10YR 4/3 (brown) wet, cohesive silt with sand with occasional pebbles. No odor. Sampled at 40'-42' interval as foot above bottom of silt layer. |
| 41 | | | | | 5.0 | | | | |
| 42 | 42-44 | 1.0 | | | | | | ML | 10YR 4/3 (brown) wet, cohesive silt with sand with occasional pebbles. No odor. Sampled 42'. |
| 43 | | | | | 5.0 | | | | |
| 44 | 44-46 | 1.0 | | | | | | SW | 10YR 3/3 (dark brown) wet, loose well-graded fine to coarse sand with gravel. No odor. |
| 45 | | | | | 5.0 | | | | |

Boring Number: 14B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.5 | | | 7.5 | | | SP | 10YR 3/2 (very dark grayish brown) wet, loose poorly-graded fine sand. Dark band of 10YR 2/2 (very dark brown) fine sand with mild odor at 47.5 feet bgs. Otherwise no odor in recovered soil |
| 48<br>49 | 48-50 | 1.0 | | | 7.5 | | | SP | 10YR 4/2 (drark grayish brown) wet, loose poorly-graded very fine sand. No odor. |
| 50<br>51 | 50-52 | 1.0 | | | 5.0 | | | SP | 10YR 3/2 (very dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 52<br>53 | 52-54 | 1.0 | | | 5.0 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded very fine sand. No odor. |
| 54<br>55 | 54-56 | 1.0 | | | 5.0 | | | | Same as above |
| 56<br>57 | 56-58 | 1.0 | | | 5.0 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 58<br>59 | 58-60 | 1.5 | | | 5.0 | | | | Same as above |
| 60<br>61 | 60-62 | -- | | | 5.0 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded very fine sand. No odor. |
| 62 | 62-63 | 1.2 | | | | | | SW | 10YR 3/3 (dark brown) wet, loose well-graded fine to medium sand. No odor or staining. |

Boring Number: 14B Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | 1.2 | | | 5.0 | | | SW | 10YR 3/3 (dark brown) wet, loose well-graded fine to medium sand. No odor or staining. |
| 64<br>65 | 64-66 | 0.0 | | | -- | | | | No recovery from 64 to 66 feet bgs. |
| 66<br>67 | 66-68 | 2.0 | | | 5.0 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine to medium sand. No odor. |
| 68<br>69 | 68-70 | 1.0 | | | 5.0 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 70<br>71 | 70-72 | 1.5 | | | 2.5 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. Sampled 70-72 interval as center of well screen. |
| 72<br>73 | 72-74 | 1.0 | | | 5.0 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine and medium sand. No odor. |
| 74<br>75 | 74-76 | 1.0 | | | | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 76<br>77 | 76-78 | | | | | | | | End of boring at 75 feet below ground surface |
| 78<br>79 | 78-80 | | | | | | | | |

EMR INCORPORATED

# VISUAL CLASSIFICATION OF SOILS

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | 13A |
| Boring Depth: | 45 feet | MW #: | MW-13A |
| GW Encountered | 30 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1053 3/28/05 |
| Location: | | End time/date: | 1310 3/28/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | -- | | | -- | | | | No recovery from 0 to 4 feet below ground surface due to augering through frost. |
| 2, 3 | 2-4 | -- | | | -- | | | | |
| 4, 5 | 4-6 | 1.5 | | | 2.5 | | | SP | 10YR 4/6 (dark yellowish brown) moist, loose poorly-graded fine sand. No odor. |
| | | | | | | | | SP | 10YR 4/3 (brown) moist, loose poorly-graded fine sand. No odor. |
| 6, 7 | 6-8 | 1.8 | | | 5.1 | | | SW | 10YR 3/1 (very dark gray) dry, loose well-graded fine to medium sand with roots and decomposing organic material. This band 1-inch thick. No odor. |
| | | | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 8, 9 | 8-10 | 1.5 | | | 5.1 | | | SP | 10YR 5/2 (grayish brown) dry, loose poorly-graded fine sand. No odor. |
| | | | | | | | | SW | 10YR 4/3 (brown) dry, loose well-graded fine to coarse sand mottled to 10YR 5/8 (yellowish brown). No odor. |
| 10, 11 | 10-12 | 1.2 | | | 2.5 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine mottled sand. No odor. |

Boring Number: 13A Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.5 | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded medium to coarse sand with gravel. No odor. |
| 13 | | | | | 5.1 | | | SW | 10YR 5/3 (brown) moist grading to dry, loose well-graded fine to medium sand. No odor. |
| 14 | 14-16 | 1.8 | | | | | | SP | 10YR 5/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 15 | | | | | 5.1 | | | SW | 10YR 5/3 (brown) wet, loose well-graded fine to coarse sand with gravel. No odor. |
| 16 | 16-18 | 1.5 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 17 | | | | | 2.5 | | | | |
| 18 | 18-20 | 1.0 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 19 | | | | | 10.2 | | | | |
| 20 | 20-22 | 1.0 | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 21 | | | | | 2.5 | | | | |
| 22 | 22-24 | 1.5 | | | | | | GW | 10YR 3/3 (dark brown) moist, loose well-graded gravel with fine to coarse sand. No odor. |
| 23 | | | | | 2.5 | | | | |
| 24 | 24-26 | 1.5 | | | | | | SW | 10YR 3/3 (dark brown) moist, well-graded fine to coarse sand bedded with GLEY 2.5/5B (bluish black) coarse and medium sand. No odor. |
| 25 | | | | | 2.5 | | | SM | 10YR 3/3 (dark brown) wet, cohesive silty sand with occasional pebbles. |
| 26 | 26-28 | 1.0 | | | | | | SM | 10YR 3/3 moist, cohesive silty sand with occasional pebbles. No odor. Sampled at 26' bgs. |
| 27 | | | | | 2.5 | | | | Sampled at 27' bgs<br>Same as above |
| 28 | 28-29 | 1.5 | | | 2.5 | | | SP | 10YR 3/4 (dark yellowish brown) wet, loose poorly-graded fine sand. No odor. |

Boring Number: 13A Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 1.5 | | | 2.5 | | | SP | 10YR 3/4 (dark yellowish brown) moist grading to wet, poorly-graded fine sand. No odor. |
| 30 | 30-32 | 1.5 | | water | 5.1 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand with occasional pebbles. No odor. Wet at 30 feet bgs. |
| 31 | | | | | | | | | |
| 32 | 32-34 | 1.0 | | | 15.3 | | | | Same as above |
| 33 | | | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 34 | 34-36 | 1.8 | | | 10.2 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. 1-inch thick band of 10YR 4/1 (dark gray) fine sand at 35.5 feet bgs. No odor. |
| 35 | | | | | | | | | |
| 36 | 36-38 | 1.5 | | | 5.1 | | | SP | 10YR 3/3 (dark brown) wet, loose poorly-graded fine sand with laminated bands from 37 to 38 feet below ground surface. No odor. |
| 37 | | | | | | | | | |
| 38 | 38-40 | 1.5 | | | 5.1 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to coarse sand. No odor. |
| 39 | | | | | | | | | |
| 40 | 40-42 | 1.0 | | | 2.5 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 41 | | | | | | | | | |
| 42 | 42-44 | 2.0 | | | 5.1 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Sampled at 42 feet bgs. |
| 43 | | | | | | | | | |
| 44 | 44-46 | 1.0 | | | 5.1 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor. |
| 45 | | | | | | | | | End of boring at 45 feet below ground surface |

Boring Number: 13A Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 46-48 | | | | | | | | |
| 47 | | | | | | | | | |
| 48 | 48-50 | | | | | | | | |
| 49 | | | | | | | | | |
| 50 | 50-52 | | | | | | | | |
| 51 | | | | | | | | | |
| 52 | 52-54 | | | | | | | | |
| 53 | | | | | | | | | |
| 54 | 54-56 | | | | | | | | |
| 55 | | | | | | | | | |
| 56 | 56-58 | | | | | | | | |
| 57 | | | | | | | | | |
| 58 | 58-60 | | | | | | | | |
| 59 | | | | | | | | | |
| 60 | 60-62 | | | | | | | | |
| 61 | | | | | | | | | |
| 62 | 62-63 | | | | | | | | |

Boring Number: 13A Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | DJW - EMR, Inc. | Boring #: | SB-1 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 34 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | March 16, 2005 |
| Location: | | End time/date: | March 16, 2005 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | 0.0 | | | | | | | No recovery 0'-4' below ground surface due to augering through frost layer. |
| 2, 3 | 2-4 | 0.0 | | | | | | | |
| 4 | 4-6 | 1.6 | | | | | | SP | 10YR 4/6 (dark yellowish brown) dry, loose poorly-graded medium sand. No odor or stain. |
| 5 | | | | | 4.2 | | | SP | 10YR 4/4 (dark yellowish brown) dry, loose poorly-graded medium sand. No odor or stain. |
| 6, 7 | 6-8 | 1.6 | | | 4.2 | | | | Same as above |
| 8, 9 | 8-10 | 1.8 | | | 4.2 | | | | Same as above |
| 10, 11 | 10-12 | 1.8 | | | 8.5 | | | SP | 10YR 5/4 (yellowish brown) dry, loose poorly-graded medium sand. No odor or stain. |

| Boring Number: SB-1 | Project : NIROP Pilot-Scale 2005 | Project #: 5427 |
|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12<br>13 | 12-14 | 1.8 | | | 6.3 | | | SP | 10YR 7/3 (very pale brown) dry, loose poorly-graded fine sand. No odor or stain. |
| 14<br>15 | 14-16 | 1.0 | | | 6.3 | | | SP | 10YR 7/3 (very pale brown) dry, loose poorly-graded fine sand. 2-inch diameter cobble recovered in sampler. No odor or stain. |
| 16<br>17 | 16-18 | 1.8 | | | 8.5 | | | | Same as above |
| 18<br>19 | 18-20 | 1.8 | | | 8.5 | | | SW | 10YR 6/3 (pale brown) dry, loose well-graded fine to medium sand. No odor or stain. |
| 20<br>21 | 20-22 | 1.8 | | | 6.3 | | | SW | 10YR 6/3 (pale brown) dry, loose well-graded fine to medium sand. 4-inch thick layer of well-graded coarse to medium sand between 21.6' and 22' bgs. No odor or stain. |
| 22<br>23 | 22-24 | 1.5 | | | 6.3 | | | SW | Same. Alternates between 22-23 (SW fine to med sand) and 23-24 (med to coarse sand). Dry, no odor, no stain. |
| 24<br>25 | 24-26 | ND | | | 4.2 | | | SW | Same. Medium to coarse well-graded sand with some small cobbles and pebbles. No odor/stain. |
| 26<br>27 | 26-28 | ND | | | 6.3 | | | SP | 10YR 4/4 (dark yellowish brown) loose coarse to very coarse poorly-graded sand with pebbles. No odor/stain. |
| 28 | 28-29 | 1.6 | | | | | | SM | 10YR 4/2 (dark grayish brown) moist, loose poorly-graded silty sand with occasional pebbles and rocks up to 2-inch diameter. No odor. |

| Boring Number: | SB-1 | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 1.6 | | | 19.1 | | | SM | 10YR 4/2 (dark grayish brown) moist, loose poorly-graded silty sand with occasional pebbles and rocks up to 2-inch diameter. No odor. |
| 30<br>31 | 30-32 | 0.5 | | | 63.8 | | | ML | 10YR 4/2 (dark grayish brown) moist, cohesive blocky silt with sand and occasional pebbles and rocks up to 1-inch diameter. No odor. |
| 32<br>33 | 32-34 | 1.8 | | | 8.5 | | | ML | 10YR 4/3 (brown) moist grading to wet at 34' bgs, cohesive silt with occasoinal pebbles and 10YR 3/1 (very dark gray) bands of staining. Mild odor. Sample collected at 32'-35' below ground surface<br><br>Wet at 34 feet below ground surface |
| 34 | 34-36 | 1.8 | | water | | | | ML | 10YR 4/2 (dark grayish brown) wet, silt with poorly-graded fine sand. Mild odor. |
| 35 | | | | | 10.6 | | | ML | 10YR 4/1 (dark gray) wet silt with occasional pebbles. Mild odor. Sampled at 35'-36' bgs. |
| 36<br>37 | 36-38 | 1.6 | | | 51.0 | | | ML | 10YR 2/1 (black) wet silt with poorly-graded fine sand. Stained with mild odor.<br><br>Sample collected at 37'-38' bgs. |
| 38<br>39 | 38-40 | 2.0 | | | 8.5 | | | SP-SM | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine sand with silt. Mild odor. |
| 40 | 40-42 | 1.5 | | | | | | ML | 10YR 3/2 (very dark grayish brown) wet, cohesive silt with poorly-graded fine sand. No odor. |
| 41 | | | | | 8.5 | | | SM | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine silty sand. No odor. |
| 42<br>43 | 42-44 | 1.8 | | | 8.5 | | | SM | 10YR 4/3 (brown) wet, cohesive poorly-graded fine silty sand. No odor |
| 44<br>45 | 44-46 | 1.6 | | | 4.2 | | | SM | 10YR 4/3 (brown) wet, cohesive poorly-graded fine silty sand. No odor. Same as above. |

Boring Number: SB-1 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.5 | | | 6.3 | | | SM | 10YR 4/3 (brown) wet, cohesive poorly-graded fine silty sand. No odor. Same as above. |
| 48<br>49 | 48-50 | 2.0 | | | 6.3 | | | SM | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine silty sand. No odor. |
| 50<br>51 | 50-52 | 2.0 | | | 6.3 | | | SM | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine silty sand. No odor. |
| 52<br>53 | 52-54 | 1.8 | | | 8.5 | | | SM | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine silty sand. No odor. |
| 54<br>55 | 54-56 | 1.8 | | | 8.5 | | | SM | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine silty sand. No odor.<br>Sample collected at 54'-56' bgs. |
| 56<br>57 | 56-58 | 1.3 | | | 10.6 | | | SM | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine silty sand. No odor. |
| | | | | | | | | SP-SC | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine sand with clay. No odor. |
| 58<br>59 | 58-60 | 1.5 | | | 8.5 | | | SP-SC | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine sand with clay. No odor.<br>End of boring at 60 feet below ground surface. |
| 60<br>61 | 60-62 | | | | | | | | |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-1 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

| | | | |
|---|---|---|---|
| **EMR Project Name:** | | **Drilling Information** | |
| *NIROP Pilot-Scale 2005* | | Drilling Contractor: | Bergerson-Caswell |
| **EMR Project Number:** | | Drilling Method: | Hollow Stem Auger |
| *5427* | | Drillers Name: | Dave Lenzmeier |
| **Note:** | | Borehole Diameter: | 8-1/4 inch |
| adjacent to Inj-2 | | Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | DJW - EMR, Inc. | Boring #: | SB-2 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 28 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 03-15-05 |
| Location: | 2' NE of INJ #2 | End time/date: | 03-15-05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | -- | | | -- | | | -- | No sampling 0-4 feet bgs. Augered through frost. |
| 2, 3 | 2-4 | -- | | | -- | | | | |
| 4, 5 | 4-6 | 2.0 | | | 2.1 | | | SP | 10YR 4/4 (dark yellowish brown) grading to 10YR 6/4 (light yellowish brown) homogeneous, loose poorly-graded coarse sand. No odor. Rootlets present. Color change occurs at 5 feet |
| 6, 7 | 6-8 | 2.0 | | | 2.1 | | | SP | Same as above. 10YR 6/4; dry; no odor. |
| 8, 9 | 8-10 | 2.0 | | | 2.1 | | | SP | Same as above. 10YR 6/4; dry; no odor. |
| 10 | 10-12 | 2.0 | | | | | | SP | Same as above. 10YR 6/4; dry; no odor. |
| 11 | | | | | | | | SP | 3.5-inch lens of cohesive, homogeneous poorly-graded fine sand with clay; moist; no odor. |
| | | | | | 0.0 | | | SP | Same as above. 10YR 6/4; dry; no odor. |

Boring Number: SB-2 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12<br>13 | 12-14 | 2.0 | | | 2.1 | | | SP | 10YR 8/3 (very pale brown) loose; homogeneous poorly-graded fine sand; dry; no odor. |
| 14 | 14-16 | 1.75 | | | | | | SW | 10YR 5/6 (yellowish brown) loose, homogeneous, well-graded coarse sand with gravel, moist, no fines, no odor (1.1 feet thick) |
| 15 | | | | | 0.0 | | | SP | 10YR 8/3 (very pale brown) loose, homogeneous, poorly-graded fine sand, moist. |
| 16 | 16-18 | 2.0 | | | | | | SP | 6-inch lens of poorly-graded coarse sand. 10YR 5/6 (yellowish brown), moist, no odor. |
| 17 | | | | | 0.0 | | | SP | 10YR 8/3 (very pale brown) loose, homogeneous, poorly-graded fine sand, moist. |
| 18<br>19 | 18-20 | 2.0 | | | 0.0 | | | SW | 10YR 6/4 (light yellowish brown) loose, well-graded medium sand grading to a coarse sand at 19.8 feet bgs; dry; no odor, a two-inch diameter cobble in sampler. |
| 20<br>21 | 20-22 | 1.2 | | | 0.0 | | | SP | 10YR 6/3 (pale brown) loose, poorly-graded medium sand, dry, no odor. (same as above); 3-inch clast of rock in top of sampler |
| 22<br>23 | 22-24 | 1.5 | | | 4.2 | | | SW | 10YR 4/4 (dark yellowish brown) loose, well-graded coarse sand grading to very coarse; no odor or oil, a 2-inch feldspathic cobble present. |
| 24<br>25 | 24-26 | 0.25 | | | 0.0 | | | SP | 10YR 5/6 (yellowish brown) loose, poorly-graded medium sand, moist, no odor. Rock at 24 feet prevented recovery. |
| 26<br>27 | 26-28 | 0.25 | | | 0.0 | | | | Same as above; rock again hit at 26 feet preventing recovery. |
| 28 | 28-29 | 0.25 | | water | | | | | Same as above; rock again hit at 28 feet preventing recovery. Very wet - spoon has water in it. |

Boring Number: SB-2 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.25 | | | 0.0 | | | | Same as above; rock again hit at 28 feet preventing recovery. Very wet - spoon has water in it. |
| 30<br>31 | 30-32 | 0.1 | | | 0.0 | | | | No recovery except 3 rock fragments measuring 2 to 3 inches in diameter. |
| 32<br>33 | 32-34 | 1.6 | | | 0.0 | | | ML | 10YR 5/4 (yellowish brown) homogeneous, claey silt, wet, dense, no vegetable oil, no odor. |
| 34<br>35 | 34-36 | 1.5 | | | 4.2 | | | SM | 10YR 5/4 (yellowish brown) homogeneous silty sand, fine and poorly-graded, wet, no odor or oil. |
| 36<br>37 | 36-38 | 1.8 | | | 6.3 | | | ML | 10YR 5/4 (yellowish brown) sandy silt, wet, high silt content. |
| | | | | | | | | ML | 10YR 2/1 (black) sandy silt, sharp odor, color grades to 10YR 5/4 (yellowish brown) at 38 feet. Color contact more sand than overlying silt. |
| 38<br>39 | 38-40 | 1.75 | | | 10.6 | | | SP | 10YR 5/3 (brown) loose, homogeneous poorly-graded fine to medium sand, moist to wet, faint odor, no oil or stain.<br>Sample collected at 37'-38' bgs. |
| 40<br>41 | 40-42 | 1.5 | | | 8.5 | | | SP | 10YR 6/3 (pale brown) loose, homogeneous poorly-graded fine sand, wet, no odor or stain. |
| 42<br>43 | 42-44 | 1.5 | | | 8.5 | | | SP | Same as above. Faint odor. |
| 44<br>45 | 44-46 | 1.6 | | | 4.2 | | | SP | 10YR 6/3 (pale brown) loose, homogeneous poorly-graded fine sand, wet, increasing odor. |

Boring Number: SB-2 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 2.0 | | | 2.1 | | | SP | 10YR 4/3 (brown) loose, homogeneous poorly-graded fine to medium sand, wet, some black discoloration/staining, moderate odor. |
| 48<br>49 | 48-50 | 2.0 | | | 4.2 | | | SP | Same as above. Some light staining/discoloration Some odor. |
| 50<br>51 | 50-52 | 1.7 | | | 12.7 | | | SP | Same as above, fine sand, light odor. |
| 52<br>53 | 52-54 | 2.0 | | | 24.7 | | | SP | 10YR 3/1 (very dark gray) homogeneous, silky-fine sand, wet, staining black and light odor, grading to silt but is not blocky. |
| 54<br>55 | 54-56 | 2.0 | | | 36.1 | | | SP | 10YR 3/2 (very dark grayish brown) homogeneous fine sand, poorly-graded, light odor, black staining loose, wet. |
| 56<br>57 | 56-58 | -- | | | 46.8 | | | SP | 10YR 5/3 (brown) poorly-graded medium sand, loose, wet, no stain, light odor, graded to a fine sand by 58 feet bgs. |
| 58<br>59 | 58-60 | -- | | | 61.7 | | | SP | Same as above. Poorly-graded fine sand, no stain, no impact all fine sand, moist, no odor.<br>Sample collected at 60 feet bgs. |
| 60<br>61 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface. |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-2 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | SJC - EMR, Inc. | Boring #: | SB-3 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | approx 29 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1055 3/14/05 |
| Location: | | End time/date: | 1530 3/14/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | 0.0 | | | -- | | | | No recovery 0 to 4 feet below ground surface due to frost. |
| 1 | | | | | | | | | |
| 2 | 2-4 | 0.0 | | | -- | | | | |
| 3 | | | | | | | | | |
| 4 | 4-6 | 80% | | | | | | SW | NR<br>10YR 4/3 (brown) loose, homogenous, dry, well-graded sand with silt. Occasional pebbles. |
| 5 | | | | | | | | SP | 10YR 6/2 (light brownish gray) loose, homogenous dry poorly-graded sand with occasional pebbles, sands are weakly bedded with slight changes to define layers, clast size ranges from medium to coarse only very minor amounts of silt. |
| 6 | 6-8 | 1.3 | | | | | | | |
| 7 | | | | | | | | | Same as above. |
| 8 | 8-10 | 1.5 | | | | | | SW | 10YR 6/2 (light brownish gray) loose, bedded, dry, well-graded sand, fine to medium grained, rare small pebbles. |
| 9 | | | | | | | | SW | Same as above only more coarse, contact with above is sharp, diameter becoming greater with depth to coarse sand at 10 feet. |
| 10 | 10-12 | 1.0 | | | | | | SW-SM | 10YR 6/2 (light brownish gray) loose, dry fine sand with silt, laminated. Laminations are 1/2-inch wide and defined by darker horizons, well graded |
| 11 | | | | | | | | | |

| Boring Number: | SB-3 | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 2.0 | | | | | | | 10YR 6/2, same as last unit. |
| 13 | | | | | | | | SP | 10YR 4/2 (dark grayish brown) loose, homogenous poorly-graded coarse sand with gravel. Mottled. Gravel clasts up to 1.5-inch diameter. |
| 14 | 14-16 | 1.6 | | | | | | SW | 10YR 5/4 (yellowish brown) loose, homogenous, well-graded coarse sand, one decomposed clase at 14.5 feet, dry, medium to coarse grained. |
| 15 | | | | | | | | | |
| 16 | 16-18 | 1.0 | | | | | | SP | 10YR 6/6 (brownish yellow) loose, weakly bedded poorly-graded medium to coarse sand with occasional pebbles, mottled orange to gray. Dry. |
| 17 | | | | | | | | SW | 10YR 6/2 (light brownish gray) loose, weakly laminated, well-graded fine sand with minor silt, occasional pebbles to 3/4-inch diameter. |
| 18 | 18-20 | 1.8 | | | | | | | 10YR 6/2 (light brownish gray) loose, graded fine to coarse sand, coarsening with depth to coarse sand with clasts to 3/4-inch' dry. |
| 19 | | | | | | | | | |
| 20 | 20-22 | 1.6 | | | | | | SP | 10YR 6/2 (light brownish gray) loose, homogenous medium to coarse sand with occasional clasts up to 1.5-inches diameter; dry, poorly-graded. |
| 21 | | | | | | | | | |
| 22 | 22-24 | 0.4 | | | | | | SP | 10YR 5/2 (grayish brown) otherwise same as above Driller said that it felt like they were pushing a rock with the sampler. |
| 23 | | | | | | | | | |
| 24 | 24-26 | 1.4 | | | | | | SP | 10YR 5/4 (yellowish brown) loose, graded coarse to medium poorly-graded sand, fining with depth to 25.5 feet then corsening again, otherwise homogenous. |
| 25 | | | | | | | | | |
| 26 | 26-28 | 0.0 | | | | | | | No recovery, possibly due to rock. |
| 27 | | | | | | | | | |
| 28 | 28-29 | 0.2 | | water | | | | | 10YR 3/4 (dark yellowish brown) loose, fine gravel (average clast approx. 1/4-inch) saturated, no veg. oil; limited recovery; water in sampler. |

| Boring Number: SB-3 | Project : NIROP Pilot-Scale 2005 | Project #: 5427 |
|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.2 | | | | | | | 10YR 3/4 (dark yellowish brown) loose, fine gravel (average clast approx. 1/4-inch) saturated, no veg. oil; limited recovery; water in sampler. |
| 30 | 30-32 | 0.2 | | | | | | | No recovery - slough in sampler |
| 31 | | | | | | | | | 10YR 4/2 (dark grayish brown) firm, homogenous, non-elastic silt with minor fine sand. Occasional clasts up to 3/4-inch diameter; slight vegetable oil odor in slough on top of silt; low plasticity, no/low dilatancy. |
| 32 | 32-34 | 1.0 | | | | | | | |
| 33 | | | | | | | | | Same as above except no visible clasts. Samples collected from 30'-32' and 32'-34'. No PID at 32' sample material. |
| 34 | 34-36 | 0.8 | | | | | | | 10YR 4/2 (dark grayish brown) firm, homogenous, non-elastic silt with pebbles; wet; no dilatancy, low plasticity. |
| 35 | | | | | | | | | |
| 36 | 36-38 | 1.8 | | | | | | SP | 10YR 4/3 (brown) loose, homogenous, poorly-graded sand, fine to medium grained, saturated; minor amounts of pebbles, no veg oil odor. Minor silt content from 36'-37' with quick dilatancy. |
| 37 | | | | | | | | | |
| 38 | 38-40 | 1.4 | | | | | | SP | 10YR 4/2 (dark grayish brown) loose, homogenous poorly-graded fine sand with silt, only rare pebbles mild "fish-like" odor at 39' bgs. Quick dilatancy. |
| 39 | | | | | | | | | |
| 40 | 40-42 | 1.4 | | | | | | SP | 10YR 4/2 (dark grayish brown) loose, homogenous very poorly-graded fine sand with silt; very rare pebbles; mild veg oil odor; black staining from 41.5' to 42' (magnatite?); saturated. Sampling this interval as veg oil impacted - 42 feet bgs. |
| 41 | | | | | | | | | |
| 42 | 42-44 | 1.2 | | | | | | | 10YR 2/1 (black) soft, homogenous non-elastic silt with minor fine sand; saturated; black from magnatite?; moderate veg oil odor. |
| 43 | | | | | | | | | |
| 44 | 44-46 | 1.0 | | | | | | | Same as above but black staining is lessening; odor still pronounced. |
| 45 | | | | | | | | | |

Boring Number: SB-3 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 46-48 | 1.8 | | | | | | SP | 10YR 5/2 (grayish brown) loose, homogenous fine sand with silt; very poorly-graded; some black staining; saturated; mild veg. Oil odor. Maybe slough. |
| 47 | | | | | | | | | 10YR 2/1 (black) to 10YR 5/2 (grayish brown) soft homogenous non-elastic silt with fine sand; moderate veg oil odor; 75% stained black; saturated; slightly clayey/cohesive at 47.74 feet. |
| 48 | 48-50 | 1.6 | | | | | | SP | 10YR 4/6 (dark yellowish brown) loose, homogenous, very poorly-graded fine sand with minor silt; saturated, quick dilatancy. Mild veg oil odor. |
| 49 | | | | | | | | | |
| 50 | 50-52 | 2.0 | | | | | | SP | 10YR 3/2 (very dark grayish brown) loose, homogenous very poorly-graded fine sand with silt; saturated; quick dilatancy; mild veg oil odor. |
| 51 | | | | | | | | | 10YR 4/3 (brown) same as above except color change is gradational. |
| 52 | 52-54 | 2.0 | | | | | | SP | 10YR 3/2 (very dark grayish brown) loose, homogenous very poorly-graded fine sand with minor silt; saturated; quick dilatancy; mild veg oil odor. |
| 53 | | | | | | | | | |
| 54 | 54-56 | 1.6 | | | | | | SP | Same as above. |
| 55 | | | | | | | | | |
| 56 | 56-58 | 2.0 | | | | | | SP | Same as above. |
| 57 | | | | | | | | ML | 10YR 4/4 (dark yellowish brown) soft, homogenous non-elastic silt; saturated; quick dilatancy, mild veg oil odor. |
| 58 | 58-60 | | | | | | | SP | 10YR 3/2 (very dark grayish brown) loose, homogenous very poorly-graded fine sand with minor silt; saturated; quick dilatancy; mild veg oil odor. |
| 59 | | | | | | | | | Sampled at 60 feet below ground surface. |
| 60 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface. |
| 61 | | | | | | | | | |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-3 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:** bentonite grount encountered
No impacted soil encountered

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-4 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 30 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 0803 3/24/05 |
| Location: | | End time/date: | 1035 3/24/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | 0.0 | | | -- | | | | No recovery 0'-4' below ground surface due to frost layer. |
| 2, 3 | 2-4 | 0.0 | | | -- | | | | |
| 4 | 4-6 | 1.5 | | | | | | SW | 10YR 6/3 (pale brown) dry, loose well-graded fine and medium sand. No odor. |
| 5 | | | | | 2.4 | | | SW | 10YR 4/3 (brown) dry, loose well-graded fine and medium sand. No odor. |
| 6 | 6-8 | 1.2 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine and medium sand, no odor. |
| 7 | | | | | 2.4 | | | | |
| 8 | 8-10 | 1.0 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine and medium sand. No odor. |
| 9 | | | | | 2.4 | | | | |
| 10 | 10-12 | 1.5 | | | | | | SW | Same as above |
| 11 | | | | | 2.4 | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |

Boring Number: SB-4 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.5 | | | | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |
| 13 | | | | | 2.4 | | | SW | 10YR 4/1 (dark gray) moist, loose well-graded fine to coarse sand with gravel and rock up to 1.5-inch diameter. No odor. |
| 14 | 14-16 | 1.8 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| 15 | | | | | 2.4 | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand with occasional pebbled. No odor |
| 16 | 16-18 | 1.8 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 17 | | | | | 2.4 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| | | | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand . No odor. |
| 18 | 18-20 | 1.5 | | | | | | SP | 10YR 5/4 (yellowish brown) moist, loose poorly-graded fine sand. No odor. |
| 19 | | | | | 2.4 | | | SW | 10YR 5/2 (grayish brown) moist loose well-graded fine and medium sand with occasional rounded pebbles and rock up to 1-inch diameter. No odor. |
| 20 | 20-22 | 1.5 | | | | | | SW | 10YR 5/2 (grayish brown) moist, loose well-graded fine to coarse sand. No odor. |
| 21 | | | | | 2.4 | | | | |
| 22 | 22-24 | 0.8 | | | | | | | |
| 23 | | | | | 2.4 | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand. No odor. |
| 24 | 24-26 | 0.0 | | | | | | | No recovery 24'-26' |
| 25 | | | | | -- | | | | |
| 26 | 26-28 | 0.5 | | | | | | SW | 10YR 3/3 (dark brown) moist, loose well-graded medium to coarse sand with gravel and rock up to 1-inch diameter. Limited recovery. |
| 27 | | | | | 2.4 | | | | |
| 28 | 28-29 | 0.5 | | | | | | ML | 10YR 4/4 (dark yellowish brown) moist grading to wet cohesive silt with sand. No odor. Limited recovery. |

Boring Number: SB-4 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.5 | | water | 2.4 | | | ML | Same as above. Wet at 30 feet bgs. |
| 30<br>31 | 30-32 | 1.0 | | | 2.4 | | | ML | 10YR 4/3 (brown) cohesive, wet silt with sand and occasional pebbles. No odor<br>Sample collected at 30 feet bgs.<br>Sample collected at 31 feet bgs. |
| 32<br>33 | 32-34 | 1.8 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) mildly cohesive wet poorly-graded fine sand. No odor. |
| 34<br>35 | 34-36 | ND | | | 2.4 | | | SW | 10YR 3/3 (dark brown) wet, loose well-graded fine and medium sand with occasional pebbles. Mostly fine sand components. No odor. |
| 36<br>37 | 36-38 | 1.8 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, mildly cohesive poorly-graded fine sand; no odor; 1/4-inch thick band of bentonite grout observed in sampler at 36.5 feet bgs. otherwise homogenous fine sand and color throughout sampler. |
| 38<br>39 | 38-40 | 1.0 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, mildly cohesive poorly-graded fine sand. No odor. |
| 40<br>41 | 40-42 | 1.8 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand; no odor; homogenous throughout recovery. |
| 42<br>43 | 42-44 | 1.5 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. Sample collected at 42'-44' bgs. |
| 44<br>45 | 44-46 | 1.8 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand; homogenous throughout recovery. |

Boring Number: SB-4 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.5 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand; laminated bands of 10YR 4/1 (dark gray) between 47 and 48 feet bgs. No odor. |
| 48<br>49 | 48-50 | 1.5 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand; stained bands of 10YR 4/1 (dark gray) at 49 feet bgs. No odor. |
| 50<br>51 | 50-52 | 1.8 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand; no staining or lamination, no odor. |
| 52<br>53 | 52-54 | 1.8 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand; homogenous, no odor.<br>Sample collected at 52'-54' bgs. |
| 54<br>55 | 54-56 | 1.5 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 56 | 56-58 | 1.3 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 57 | | | | | | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine and medium sand. No odor. |
| 58<br>59 | 58-60 | 1.8 | | | 2.4 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand; 2-inch thick band or 10YR 5/8 (yellowish brown) mottled medium sand at 59 feet bgs. No odor. |
| 60<br>61 | 60-62 | | | | | | | | End of boring at 60 feet bgs. |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-4 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-5 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 29.5 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1245 3/24/05 |
| Location: | | End time/date: | 0910 3/25/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | 0.0 | | | -- | | | | No recovery 0'-4' bgs due to augering through frost. |
| 1 | | | | | | | | | |
| 2 | 2-4 | 0.0 | | | -- | | | | |
| 3 | | | | | | | | | |
| 4 | 4-6 | 1.5 | | | 2.4 | | | SW | 10YR 4/6 (dark yellowish brown) moist, loose well-graded fine to medium sand. No odor. |
| 5 | | | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to coarse sand. No odor. |
| 6 | 6-8 | 1.2 | | | | | | | |
| 7 | | | | | | | | SW | 10YR 6/2 (light brownish gray) dry, loose well-graded fine to medium sand. No odor. |
| 8 | 8-10 | 1.5 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand with occasional pebbles. No odor. |
| 9 | | | | | | | | | |
| 10 | 10-12 | 1.8 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| | | | | | | | | SW | 10YR 4/3 (brown) dry, loose bedded band 3-inch thick of fine to coarse sand and gravel. No odor. |
| 11 | | | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |

| Boring Number: | SB-5 | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.8 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| 13 | | | | | 2.4 | | | SW | 10YR 5/2 (grayish brown) moist, loose well-graded fine to coarse sand with gravel and rocks up to 1.5-inch diameter. No odor. |
| 14 | 14-16 | 1.5 | | | | | | SP | 10YR 5/3 (brown) moist, loose poorly-graded fine sand with occasional rounded pebbles. No odor. |
| 15 | | | | | 2.4 | | | | |
| 16 | 16-18 | 1.5 | | | | | | SW | 10YR 5/8 (yellowish brown) moist, loose well-graded medium and coarse sand. No odor. |
| 17 | | | | | 2.4 | | | SP | 10YR 6/2 (light brownish gray) moist, loose poorly-graded fine sand with occasional pebbles. No odor. Mottled at 18.2 feet bgs. |
| 18 | 18-20 | 1.8 | | | | | | SW | 10YR 5/2 (grayish brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 19 | | | | | 2.4 | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded fine sand with occasional pebbles. No odor. |
| 20 | 20-22 | 1.2 | | | | | | SW | 10YR 5/2 (grayish brown) moist, loose well-graded fine to coarse sand with occasional pebbles and rock up to 1-inch diameter. Mottled bands from 20.5 to 21.0 feet bgs; laminated bands from 21.0 to 22.0 feet bgs. No odor. |
| 21 | | | | | 2.4 | | | | |
| 22 | 22-24 | 1.5 | | | | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with rock up to 1.5-inch diameter. No odor. |
| 23 | | | | | 2.4 | | | | |
| 24 | 24-26 | 1.5 | | | | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with gravel and rocks up to 2-inch diameter. No odor. |
| 25 | | | | | 2.4 | | | | |
| 26 | 26-28 | 1.5 | | | | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 27 | | | | | 4.9 | | | | |
| 28 | 28-29 | 1.0 | | | | | | ML | 10YR 4/2 (dark grayish brown) moist grading to wet, cohesive silt with occasional pebbles. No odor. |

Boring Number: SB-5 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | | | water | 4.9 | | | | Same as above<br>Wet at 29.5 feet bgs. |
| 30<br>31 | 30-32 | 1.5 | | | 5.0 | | | ML | 10YR 4/3 (brown) wet, cohesive silt with sand and occasional pebbles. No odor. |
| 32<br>33 | 32-34 | 1.0 | | | 7.5 | | | SP | 10YR 4/2 (dark grayish brown) wet, mildly cohesive poorly-graded fine sand. No odor. |
| 34<br>35 | 34-36 | 1.2 | | | 5.0 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor. |
| 36<br>37 | 36-38 | 1.2 | | | 2.5 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 38<br>39 | 38-40 | 1.5 | | | 2.5 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Occasional pebbles in the 38'-39' interval. |
| 40<br>41 | 40-42 | 1.0 | | | 2.5 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 42<br>43 | 42-44 | 1.5 | | | 5.0 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor.<br>Sample collected at 42'-44' bgs. |
| 44<br>45 | 44-46 | 1.2 | | | 5.0 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded sand. No odor. |
| | | | | | | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |

Boring Number: SB-5 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.0 | | | 2.5 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand with bands of lamination 10YR 4/1 (dark gray) throughout recovered soil. No odor. |
| 48<br>49 | 48-50 | 1.2 | | | 5.0 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand with a single band of lamination 10YR 4/1 (dark gray) at 49.0 feet bgs. No odor. Sample collected at 48'-50' bgs. |
| 50<br>51 | 50-52 | 1.0 | | | 2.5 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. No lamination observed. |
| 52<br>53 | 52-54 | 1.0 | | | 5.0 | | | SP | 10YR 4/4 (dark yellowish brown) wet, loose poorly-graded fine sand. No odor. |
| 54<br>55 | 54-56 | 1.2 | | | 5.0 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 56<br>57 | 56-58 | 1.0 | | | 5.0 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine to medium sand. No odor. |
| 58<br>59 | 58-60 | 1.0 | | | 7.5 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to medium sand. No odor. |
| 60<br>61 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-5 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

EMR INCORPORATED

# VISUAL CLASSIFICATION OF SOILS

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-6 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 30 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1050 3/23/05 |
| Location: | | End time/date: | 1400 3/23/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | -- | | | -- | | | | No recovery 0'-4' bgs due to to augering through frost. |
| 1 | | | | | | | | | |
| 2 | 2-4 | -- | | | -- | | | | |
| 3 | | | | | | | | | |
| 4 | 4-6 | 1.5 | | | 2.4 | | | SW | 10YR 5/6 (yellowish brown) moist, loose well-graded fine and medium sand. No odor. |
| 5 | | | | | | | | SW | 10YR 5/4 (yellowish brown) moist, loose well-graded fine and medium sand. No odor. |
| 6 | 6-8 | 1.5 | | | 0.0 | | | SW | 10YR 5/3 (brown) moist grading to dry, loose well-graded fine to coarse sand. No odor. |
| 7 | | | | | | | | SP | 10YR 5/2 (grayish brown) dry, loose poorly-graded fine sand. No odor. |
| 8 | 8-10 | 1.0 | | | 2.4 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine and medium sand. No odor. |
| 9 | | | | | | | | | |
| 10 | 10-12 | 1.8 | | | 2.4 | | | SW | 10YR 5/8 (yellowish brown) 3-inch mottled band of fine to medium sand. No odor. |
| 11 | | | | | | | | SP | 10YR 6/2 (light brownish gray) dry, loose poorly-graded fine sand. No odor. |

Boring Number: SB-6 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.5 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| 13 | | | | | 2.4 | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand with gravel. No odor. |
| 14 | 14-16 | 1.8 | | | | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand. No odor. |
| 15 | | | | | 0.0 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand, 1/4-inch thick band of 10YR 2/1 (black) stained soil at 15.5 feet bgs. No odor. |
| 16 | 16-18 | 1.0 | | | | | | SW | 10YR 5/4 (yellowish brown) moist, loose well-graded fine to coarse sand. No odor. |
| 17 | | | | | 0.0 | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 18 | 18-20 | 1.2 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand. No odor. |
| 19 | | | | | 2.4 | | | | |
| 20 | 20-22 | 1.5 | | | | | | SW | 10Yr 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles and rocks up to 1/2-inch dia. |
| 21 | | | | | 0.0 | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. |
| 22 | 22-24 | 1.5 | | | | | | | |
| 23 | | | | | 0.0 | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with gravel with rounded rocks up to 1-inch dia. No odor; laminated bands throughout sample down to 26 feet bgs. |
| 24 | 24-26 | 1.8 | | | | | | | |
| 25 | | | | | 2.4 | | | SW | 10YR 3/3 (dark brown) moist, loose well-graded fine to coarse sand with gravel. Laminated bands of 10YR 3/1 (very dark gray) coarse and fine sand. No odor |
| 26 | 26-28 | 0.0 | | | | | | | No recovery 26'-28' bgs due to rock layer. |
| 27 | | | | | -- | | | | |
| 28 | 28-29 | 1.0 | | | | | | GW | 10YR 3/4 (dark yellowish brown) wet, loose well-graded blocky gravel and rock with fine to coarse poorly graded sand. No odor. |

Boring Number: SB-6 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 1.0 | | water | 0.0 | | | GW | 10YR 3/4 (dark yellowish brown) wet, loose well-graded blocky gravel and rock with fine to coarse poorly graded sand. No odor. Wet at 30' bgs |
| 30<br>31 | 30-32 | 0.0 | | | -- | | | | No recovery 30'-32' bgs. |
| 32<br>33 | 32-34 | 1.0 | | | 4.9 | | | GW | 10YR 4/3 (brown) wet, cohesive well-graded gravel with sand and silt. No odor. |
| 34<br>35 | 34-36 | 1.5 | | | 4.9 | | | | Same as above |
| | | | | | | | | SP | 10YR 4/1 (dark gray) wet, loose poorly-graded fine sand. Mild odor. 1.5-inch thick stained band of fine sand 10YR 3/1 (very dark gray) at 35.5 feet bgs. |
| 36<br>37 | 36-38 | 1.8 | | | 2.4 | | | SP | 10YR 2/1 (black) wet, loose poorly-graded fine sand. Strong odor, no sheen.<br>Sample collected at 36'-38' bgs. |
| 38<br>39 | 38-40 | 1.0 | | | 4.9 | | | SP | 10YR 2/1 (black) wet, loose poorly-graded fine sand. Strong odor. |
| 40<br>41 | 40-42 | 1.5 | | | 0.0 | | | SW | 10YR 4/1 (dark gray) wet, loose well-graded fine and medium sand with very minor silt component. Moderate odor. |
| 42<br>43 | 42-44 | 1.8 | | | 2.4 | | | SP | 10YR 4/1 (dark gray) wet, loose poorly-graded fine sand. Strong odor. |
| 44<br>45 | 44-46 | 1.5 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand with minor silt component. Moderate odor. |

Boring Number: SB-6 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.5 | | | 2.4 | | | SP | 10YR 5/2 (grayish brown) wet, loose poorly-graded fine sand with laminated bands of fine sand 10YR 3/1 (very dark gray). Strong odor. No sheen. |
| 48<br>49 | 48-50 | 2.0 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, mildly-cohesive poorly-graded fine sand. Strong odor, no sheen. Homogenous throughout recovery. |
| 50<br>51 | 50-52 | 1.5 | | | 2.4 | | | SP<br>SP | 1/2-inch band of stained 10YR 2/1 (black) fine sand at 51.3 feet bgs.<br>10YR 4/1 (dark gray) wet, mildly cohesive fine sand Moderate odor. |
| 52<br>53 | 52-54 | 1.0 | | | 2.4 | | | SP | 10YR 3/2 (very dark grayish brown) wet, mildly cohesive, poorly-graded fine sand. Mild odor. |
| 54<br>55 | 54-56 | -- | | | 4.9 | | | SW | 10YR 3/2 (very dark grayish brown) wet, mildly cohesive well-graded fine and medium sand with occasional pebbles. Laminated bands throughout sample core colored 10YR 2/1 (black). Mild odor. |
| 56<br>57 | 56-58 | -- | | | 2.4 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor. Sample collected at 56'-58' bgs. |
| 58<br>59 | 58-60 | -- | | | 4.9 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 60<br>61 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface. |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-6 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-7 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 30 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1500 3/22/05 |
| Location: | | End time/date: | 0928 3/23/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | -- | | | -- | | | | No recovery 0'-4' bgs due to augering through frost. |
| 1 | | | | | | | | | |
| 2 | 2-4 | -- | | | -- | | | | |
| 3 | | | | | | | | | |
| 4 | 4-6 | 1.5 | | | 2.4 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| 5 | | | | | | | | | |
| 6 | 6-8 | 1.5 | | | 2.4 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to coarse sand. No odor. |
| 7 | | | | | | | | SW | 10YR 4/3 (brown) dry grading to moist, loose well-graded fine to coarse sand. No odor. |
| 8 | 8-10 | 1.8 | | | 2.4 | | | | |
| 9 | | | | | | | | SP | 10YR 5/4 (yellowish brown) moist, loose poorly-graded fine sand. No odor. |
| 10 | 10-12 | 1.6 | | | 2.4 | | | GW | 10YR 5/4 (yellowish brown) moist, loose well-graded fine to coarse gravel. No odor |
| | | | | | | | | GW | 10YR 6/6 (brownish yellow) well-graded gravel and rock |
| 11 | | | | | | | | SP | 10YR 5/3 (brown) moist, loose poorly-graded fine sand. No odor. |

| Boring Number: | SB-7 | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.8 | | | | | | SP | 10YR 5/3 (brown) moist, loose poorly-graded fine sand. No odor. |
| 13 | | | | | 4.8 | | | SW | 10YR 3/2 (very dark grayish brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 14 | 14-16 | 1.5 | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to coarse sand. No odor. |
| 15 | | | | | 4.8 | | | SP | 10YR 5/3 (brown) moist, loose poorly-graded fine sand. No odor. |
| 16 | 16-18 | 1.5 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 17 | | | | | 2.4 | | | SP | 10YR 6/2 (light browish gray) moist, loose poorly-graded fine sand. No odor. |
| 18 | 18-20 | 1.6 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. Sand consists of mostly fine sand. No odor. |
| 19 | | | | | 4.8 | | | | |
| 20 | 20-22 | 0.3 | | | | | | SP | Limited recovery due to rock in sampler 10YR 5/3 (brown) moist, loose poorly-graded fine sand with occasional pebbles. No odor. |
| 21 | | | | | 4.8 | | | | |
| 22 | 22-24 | 1.5 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded medium to coarse sand with gravel. No odor. |
| 23 | | | | | 4.8 | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 24 | 24-26 | 1.2 | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded medium and coarse sand with angular gravel. Stained band 10YR 3/2 (very dark grayish brown) 2-inches thick at 25.5 feet bgs coarse sand and gravel. |
| 25 | | | | | 4.8 | | | | |
| 26 | 26-28 | 1.8 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded medium and coarse sand with gravel. No odor. Mottled at 26.25' bgs. |
| | | | | | | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded fine sand. No odor. |
| 27 | | | | | 4.8 | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with gravel. Laminated bands at 27.5' bgs. No odor. |
| 28 | 28-29 | 0.1 | | | | | | SW | 10YR 3/3 (dark brown) moist grading to wet at 30' bgs, loose well-graded fine to coarse sand with angular gravel. No odor. |

Boring Number: SB-7 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.1 | | | 4.8 | | | SW | 10YR 3/3 (dark brown) moist grading to wet at 30' bgs, loose well-graded fine to coarse sand with angular gravel. No odor. |
| 30 | 30-32 | 11.6 | | water | | | | CL | 10YR 4/3 (brown) wet, cohesive tight lean clay with silt and occasional pebbles. No odor. |
| 31 | | | | | 2.4 | | | CL | 10YR 4/3 (brown) wet, cohesive tight lean clay with medium to coarse sand and occasional pebble No odor. Very minor silt component. Sample collected at 32'-34' bgs. |
| 32 | 32-34 | 1.5 | | | | | | | |
| 33 | | | | | 2.4 | | | | |
| 34 | 34-36 | 1.4 | | | | | | | Same as above<br>Sample collected at 34'-36 bgs. |
| 35 | | | | | 4.9 | | | SP | 10YR 3/3 (dark brown) wet, loose poorly-graded fine sand. No odor. |
| 36 | 36-38 | 1.6 | | | | | | SM | 10YR 4/2 (dark grayish brown) wet, cohesive silty sand. No odor. |
| 37 | | | | | 4.9 | | | | |
| 38 | 38-40 | 1.5 | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 39 | | | | | 4.9 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine and medium sand. No odor. |
| 40 | 40-42 | 1.6 | | | | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to coarse sand bedded with layers of fine sand. No odor. |
| 41 | | | | | 4.9 | | | SW | 10YR 4/2 (dark grayish brown) wet, loose well-graded fine to medium sand. No odor. |
| 42 | 42-44 | 1.8 | | | | | | | |
| 43 | | | | | 4.9 | | | SP | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine sand. Mild odor, progressively more stained with depth. |
| 44 | 44-46 | 1.6 | | | | | | | |
| 45 | | | | | 2.4 | | | SP | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine sand. Mild odor. |

Boring Number: SB-7 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.8 | | | 4.9 | | | SP | 10YR 2/1 (black) wet, loose poorly-graded fine sand. Strong odor, no sheen.<br>Sample collected at 46'-48' bgs.<br>FD-1 sampled at 46'-48' bgs. |
| 48<br>49 | 48-50 | 1.5 | | | 4.9 | | | SP | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with very minor silt component. Mild odor. Stained with bands of 10YR 2/1 (black) fine sand. |
| | | | | | | | | SP | 10YR 3/2 (very dark grayish brown) grading to 10YR 3/3 (dark brown) wet, loose poorly-graded fine sand. Moderate odor. |
| 50<br>51 | 50-52 | 1.8 | | | 2.4 | | | SP | 10YR 4/4 (dark yellowish brown) wet, loose poorly-graded fine sand. Mild to no odor. |
| 52<br>53 | 52-54 | 0.5 | | | 2.4 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded sand. Mild odor. Limited sample recovery. |
| 54<br>55 | 54-56 | 1.8 | | | 2.4 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine and medium sand. No odor, no staining. |
| 56<br>57 | 56-58 | 1.8 | | | 4.9 | | | SW | 10YR 4/3 (brown) wet, loose well-graded fine and medium sand. No odor. |
| | | | | | | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 58<br>59 | 58-60 | 2.0 | | | 4.9 | | | SP | 10YR 4/3 (brown) wet, loose poorly-graded fine sand. No odor. |
| 60<br>61 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface. |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-7 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-8 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 30 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 1420 3/16/05 |
| Location: | | End time/date: | 1030 3/17/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | 0.0 | | | -- | | | | No recovery 0'-4' due to augering through frost. |
| 2, 3 | 2-4 | 0.0 | | | -- | | | | |
| 4, 5 | 4-6 | 1.7 | | | 4.2 | | | SW | 10YR 4/4 (dark yellowish brown) dry, loose well-graded fine to medium sand. No odor. |
| 6, 7 | 6-8 | 1.5 | | | 4.2 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| 8, 9 | 8-10 | 1.5 | | | 2.1 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| 10, 11 | 10-12 | 1.7 | | | 2.1 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |

Boring Number: SB-8 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.5 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine to medium sand. No odor. |
| | | | | | | | | | 10YR 6/4 (light yellowish brown) 6-inch thick rock layer |
| 13 | | | | | 4.2 | | | SW | 10YR 5/4 (yellowish brown) moist, loose well-graded fine to coarse sand. No odor. |
| 14 | 14-16 | 1.7 | | | | | | | |
| 15 | | | | | 2.1 | | | SP | 10YR 6/2 (light brownish gray) moist, loose poorly-graded fine sand. No odor. |
| 16 | 16-18 | 1.6 | | | | | | | |
| 17 | | | | | 4.2 | | | | |
| 18 | 18-20 | 1.5 | | | | | | SP | 10YR 6/2 (light brownish gray) moist, loose poorly-graded fine sand. No odor. |
| 19 | | | | | 4.2 | | | | |
| 20 | 20-22 | 1.4 | | | | | | | |
| 21 | | | | | 2.1 | | | SW | 10YR 5/2 (grayish brown) moist, loose well-graded fine to medium sand with pebbles and rock up to 1/2-inch diameter. No odor. |
| 22 | 22-24 | 1.5 | | | | | | SW | 10YR 6/2 (light brownish gray) moist, loose well-graded fine to medium sand. Lamination visible at 23.5 feet bgs. No odor. |
| 23 | | | | | 4.2 | | | | |
| 24 | 24-26 | 1.6 | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to coarse sand with gravel. Mild odor, no stains. |
| 25 | | | | | 4.2 | | | | |
| 26 | 26-28 | 1.5 | | | | | | SW | 10YR 4/3 (brown) moist, loose well-graded fine to coarse sand with gravel. No odor. No staining. |
| 27 | | | | | 4.2 | | | | |
| 28 | 28-29 | 0.2 | | | | | | SM | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine to coarse silty sand. No odor. Minimal recovery |

Boring Number: SB-8 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.2 | | water | 4.4 | | | SM | 10YR 3/1 (very dark gray) wet, loose poorly-graded fine to coarse silty sand. No odor. Minimal recovery |
| 30<br>31 | 30-32 | 0.1 | | | 2.2 | | | SW-SM | 10YR 4/3 (brown) wet, loose well-graded sand with silt. No odor. |
| 32<br>33 | 32-34 | 0.2 | | | 2.2 | | | SP | 10YR 4/3 (brown) wet, cohesive poorly-graded fine sand with silt. No odor. |
| 34<br>35 | 34-36 | 1.2 | | | 2.2 | | | SW | 10YR 3/1 (very dark gray) wet, cohesive well-graded fine to coarse sand with clay and gravel. No odor. |
| | | | | | | | | SP | 10YR 3/1 (very dark gray) wet, cohesive poorly-graded sand with silt. No odor. |
| 36<br>37 | 36-38 | 0.3 | | | 4.4 | | | SP | 10YR 3/1 (very dark gray) wet, cohesive poorly-graded sand with silt. No odor. |
| 38<br>39 | 38-40 | 1.0 | | | 2.2 | | | ML | 10YR 4/1 (dark gray) wet, cohesive poorly-graded fine silt with sand. No odor. |
| 40<br>41 | 40-42 | 1.4 | | | 2.2 | | | ML | 10YR 4/1 (dark gray) wet, cohesive poorly-graded fine silt with sand. No odor. |
| 42<br>43 | 42-44 | 1.3 | | | 4.4 | | | ML | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine sandy silt. No odor. |
| 44<br>45 | 44-46 | 0.2 | | | 4.4 | | | SP-SM | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine sand with silt. No odor.<br>Sample collected at 46' bgs. |

Boring Number: SB-8 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | ND | | | 4.4 | | | ML | 10YR 4/2 (dark grayish brown) wet, cohesive silt with fine poorly-graded sand. Some 10YR 3/1 (very dark gray) staining at 46'-47' bgs. No odor. |
| 48<br>49 | 48-50 | ND | | | 6.6 | | | SP-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with silt. Mild odor. Sampled "most impacted" at 48'-50' bgs. |
| 50<br>51 | 50-52 | ND | | | 4.4 | | | SP-SM | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine sand with silt. No odor<br>Sample collected at 51' bgs. |
| 52<br>53 | 52-54 | ND | | | 4.4 | | | SP-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with silt. No odor. Dark stained band of 10YR 3/1 at 53.5' bgs. |
| 54<br>55 | 54-56 | ND | | | 4.4 | | | SP-SM | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine sand with silt. No odor. |
| 56<br>57 | 56-58 | ND | | | 4.4 | | | SW | 10YR 4/3 (brown) wet, cohesive well-graded fine to coarse sand. No odor.<br>Sample collected at 56' bgs. |
| 58<br>59 | 58-60 | ND | | | 4.4 | | | SW | 10YR 4/3 (brown) wet, cohesive well-graded fine to coarse sand. No odor. |
| 60<br>61 | 60-62 | | | | | | | | |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-8 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:**
*NIROP Pilot-Scale 2005*
**EMR Project Number:**
*5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-9 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 28 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 0910 3/21/05 |
| Location: | | End time/date: | 1220 3/21/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0, 1 | 0-2 | 0.0 | | | -- | | | | No recovery 0'-4' bgs due to augering through frost. |
| 2, 3 | 2-4 | 0.0 | | | -- | | | | |
| 4 | 4-6 | 1.8 | | | | | | SW | 10YR 4/4 (dark yellowish brown) dry, loose well-graded fine to medium sand with occasional pebbles. |
| 5 | | | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) dry, loose poorly-graded fine sand. No odor. Bedded 10YR 4/3 (brown) poorly-graded fine sand at 5.8' bgs. |
| 6, 7 | 6-8 | 1.2 | | | 0.0 | | | SP | 10YR 5/2 (grayish brown) dry, loose poorly-graded fine sand; homogenous throughout recovery. No odor. |
| 8, 9 | 8-10 | 1.4 | | | 0.0 | | | SP | 10YR 5/2 (grayish brown) dry, loose poorly-graded fine sand with bedded 1-inch thick bands of 10YR 5/6 (yellowish brown) poorly-graded fine sand after 9' bgs. No odor. |
| 10 | 10-12 | 1.4 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded medium sand. No odor. |
| 11 | | | | | 2.4 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded medium sand with gravel. No odor. |

| Boring Number: | SB-9 | Project : | NIROP Pilot-Scale 2005 | Project #: | 5427 |
|---|---|---|---|---|---|

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 1.5 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |
| 13 | | | | | 4.9 | | | SW | 10YR 4/2 (dark grayish brown) well-graded fine to coarse sand with blocky gravel and rocks up to 2-inch diameter. No odor. |
| 14 | 14-16 | 1.2 | | | | | | | |
| 15 | | | | | 2.4 | | | SP | 10YR 5/3 (brown) moist, loose poorly-graded fine sand. No odor. |
| 16 | 16-18 | 1.4 | | | | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded medium sand. No odor. |
| 17 | | | | | 2.4 | | | SP | 10YR 5/2 (grayish brown) moist loose poorly-graded fine sand bedded with 2"-4" thick bands of 10YR 5/3 (brown) well-graded medium to coarse moist, loose sands at 18.5 feet bgs. No odor. |
| 18 | 18-20 | 1.5 | | | | | | | |
| 19 | | | | | 0.0 | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 20 | 20-22 | 1.6 | | | | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to medium sand. No odor. Dark colored 10YR 3/1 (very dark gray) 2-inch thick band of coarse sand at 21' bgs. |
| 21 | | | | | 0.0 | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand. No odor. |
| 22 | 22-24 | 1.8 | | | | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with occasional pebbles. No odor. |
| 23 | | | | | 2.4 | | | | |
| 24 | 24-26 | 1.5 | | | | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with angular gravel. No odor. |
| | | | | | | | | SP | 10YR 5/2 (grayish brown) moist, loose band of fine sand 3-inch thick at 25 feet bgs. |
| 25 | | | | | 0.0 | | | SW | 10YR 4/2 (dark grayish brown) moist, loose well-graded fine to coarse sand with angular gravel. No odor. |
| 26 | 26-28 | 1.4 | | | | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded fine sand. No odor. This horizon approx. 5-inch thick. |
| 27 | | | | | 0.0 | | | SW | 10YR 5/3 (brown) moist, loose well-graded fine to coarse sand with gravel. No odor. |
| 28 | 28-29 | 0.2 | | Water | | | | SW | 10YR 4/4 (dark yellowish brown) wet, loose well-graded fine to coarse sand. No odor or sheen. |

Boring Number: SB-9 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | 0.2 | | | 0.0 | | | SW | 10YR 4/4 (dark yellowish brown) wet, loose well-graded fine to coarse sand. No odor or sheen. |
| 30<br>31 | 30-32 | 0.3 | | | 0.0 | | | SW | 10YR 4/4 (dark yellowish brown) wet, cohesive well-graded medium to coarse sand with gravel and silt. No odor. Minimal recovery. |
| 32<br>33 | 32-34 | 0.4 | | | 0.0 | | | | Same as above. |
| | | | | | | | | CL | 10YR 4/4 (dark yellowish brown) wet, cohesive tight lean clay with fine sand. No odor. |
| 34 | 34-36 | 1.0 | | | | | | SP-SM | 10YR 4/4 (dark yellowish brown) wet, cohesive poorly-graded fine sand with silt. Mild odor. |
| 35 | | | | | 4.9 | | | SP-SM | 10YR 3/1 (very dark gray) wet, cohesive poorly-graded fine sand with silt. Strong odor, no sheen. Sample collected at 34'-36' bgs |
| 36 | 36-38 | 1.0 | | | | | | SP-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with silt. Moderate odor. |
| 37 | | | | | 2.4 | | | SP-SM | 10YR 3/1 (very dark gray) wet, cohesive poorly-graded fine sand with silt. Moderate odor. |
| 38<br>39 | 38-40 | 1.9 | | | 0.0 | | | SP-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with silt. Moderate odor. |
| 40<br>41 | 40-42 | 0.3 | | | 4.9 | | | SW-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive well-graded fine to medium sand. Mild odor. Minimal recovery. Very minor silt component. |
| 42<br>43 | 42-44 | 1.6 | | | 0.0 | | | SW-SM | 10YR 3/1 (very dark gray) wet, cohesive well-graded fine to medium sand. Mild odor. Very minor silt component. |
| 44<br>45 | 44-46 | 0.4 | | | 0.0 | | | SW-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive well-graded fine to medium sand with minor silt component. Mild odor. |

Boring Number: SB-9 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46<br>47 | 46-48 | 1.0 | | | 0.0 | | | SW-SM | 10YR 4/2 (dark grayish brown) wet, cohesive well-graded fine to medium sand with silt. Laminated bands throughout recovery. Mild odor. Sample collected at 46' bgs. |
| 48 | 48-50 | 1.0 | | | | | | SP-SM | 10YR 4/2 (dark grayish brown) wet, cohesive poorly-graded fine sand with silt. Mild odor. Occastional pebbles. |
| 49 | | | | | 4.9 | | | SP-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with silt. Mild odor. |
| 50 | 50-52 | 1.4 | | | | | | SP-SM | 10YR 3/1 (very dark gray) wet, cohesive poorly-graded fine sand with silt. Mild odor. |
| 51 | | | | | 0.0 | | | SP-SM | 10YR 2/1 (black) wet, cohesive poorly-graded fine sand with silt with laminated dark bands. Mild odor. Sample collected at 51' bgs. |
| 52 | 52-54 | 1.6 | | | | | | SP-SM | 10YR 3/2 (very dark grayish brown) wet, cohesive poorly-graded fine sand with silt and occasional rounded pebbles. Consistant color throughout recovery. Mild odor. |
| 53 | | | | | 4.9 | | | | |
| 54 | 54-56 | ND | | | | | | | Same as above. |
| 55 | | | | | 4.9 | | | SW-SM | 10YR 4/2 (dark grayish brown) wet, cohesive well-graded fine to medium sand with silt. No odor. |
| 56 | 56-58 | ND | | | | | | SW-SM | 10YR 4/2 (dark grayish brown) wet, cohesive well-graded fine to coarse sand with silt. Mild odor. Sample collected at 56' bgs. |
| 57 | | | | | 4.9 | | | SP-SM | 10YR 4/3 (brown) wet, cohesive poorly-graded fine sand with silt. No odor. |
| 58<br>59 | 58-60 | ND | | | -- | | | -- | No recovery from 58' to 60' bgs due to recovery sliding out of sampler. |
| 60<br>61 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface. |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-9 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# VISUAL CLASSIFICATION OF SOILS

EMR INCORPORATED

**EMR Project Name:** *NIROP Pilot-Scale 2005*
**EMR Project Number:** *5427*
**Note:**

**Drilling Information**

| | |
|---|---|
| Drilling Contractor: | Bergerson-Caswell |
| Drilling Method: | Hollow Stem Auger |
| Drillers Name: | Glen Holmen |
| Borehole Diameter: | 8-1/4 inch |
| Sampler Type: | Stainless Split Spoon |

**Event Information**

| | | | |
|---|---|---|---|
| Logged by: | CAD - EMR, Inc. | Boring #: | SB-10 |
| Boring Depth: | 60 feet | MW #: | |
| GW Encountered | 29.5 feet | Surface Elevation: | |
| Static GW Level: | | Start time/date: | 0936 3/22/05 |
| Location: | | End time/date: | 1204 3/22/05 |

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Groundwater | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 0-2 | 0.0 | | | | | | | No recovery 0'-4' bgs due to augering through frost. |
| 1 | | | | | -- | | | | |
| 2 | 2-4 | 0.0 | | | | | | | |
| 3 | | | | | -- | | | | |
| 4 | 4-6 | 1.4 | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded medium sand. No odor. |
| 5 | | | | | 0.0 | | | SP | 10YR 4/3 (brown) moist, loose poorly-graded medium sand. No odor. |
| 6 | 6-8 | 1.8 | | | | | | SP | 10YR 5/3 (brown) moist, loose poorly-graded medium sand. No odor. Homogenous. |
| 7 | | | | | 2.8 | | | | |
| 8 | 8-10 | 1.6 | | | | | | SW | 10YR 5/2 (grayish brown) moist grading to dry, loose, well-graded fine and medium sand. No odor. |
| 9 | | | | | 2.4 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine and medium sand. No odor. |
| 10 | 10-12 | 1.0 | | | | | | GW | 10YR 4/3 (brown) dry, loose well-graded gravel with fine and medium sand. No odor. |
| 11 | | | | | 0.0 | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand. No odor. |

Boring Number: SB-10 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 12-14 | 0.6 | | | | | | SW | 10YR 4/3 (brown) dry, loose well-graded medium and coarse sand with gravel. No odor |
| 13 | | | | | 4.8 | | | | |
| 14 | 14-16 | 1.4 | | | | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand. No odor. |
| | | | | | | | | SP | 10YR 5/2 (grayish brown) dry, loose poorly-graded fine sand. No odor. |
| 15 | | | | | 4.8 | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded medium and coarse sand. No odor. |
| 16 | 16-18 | 1.8 | | | | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine and medium sand with occasional pebbles. No odor. |
| 17 | | | | | 2.4 | | | SP | 10YR 5/2 (grayish brown) dry, loose poorly-graded fine sand. No odor. |
| 18 | 18-20 | 0.8 | | | | | | SP | 10YR 5/3 (brown) dry, loose poorly-graded fine sand with occasional pebbles. No odor. |
| 19 | | | | | 2.4 | | | SW | 10YR 5/3 (brown) dry, loose well-graded fine and medium sand with occasional pebbles. No odor. |
| 20 | 20-22 | 0.5 | | | | | | SW | 10YR 5/2 (grayish brown) dry, loose well-graded fine to coarse sand with occasional pebbles. No odor. Homogenous throughout sample recovery. |
| 21 | | | | | 2.4 | | | | |
| 22 | 22-24 | 1.2 | | | | | | SW | 10YR 4/2 (dark grayish brown) dry, loose fine to coarse well-graded sand with occasional pebbles. No odor. Homogenous throughout recovery. |
| 23 | | | | | 2.4 | | | | |
| 24 | 24-26 | 1.6 | | | | | | SP | 10YR 4/2 (dark grayish brown) dry, loose poorly-graded fine sand with occasional pebbles. No odor |
| 25 | | | | | 4.8 | | | SW | 10YR 4/2 (dark grayish brown) dry, loose well-graded fine to coarse sand with gravel. Rocks up to 3/4-inch diameter. No odor. |
| 26 | 26-28 | 1.2 | | | | | | | |
| 27 | | | | | 2.4 | | | SP | 10YR 5/2 (grayish brown) moist, loose poorly-graded fine sand. No odor. |
| 28 | 28-29 | | | | | | | SW | 10YR 3/3 (very dark grayish brown) moist grading to wet at 29.5' bgs, loose medium to coarse sand with gravel. Mild odor. |

Boring Number: SB-10 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 29 | 29-30 | | | water | 2.4 | | | SW | 10YR 3/3 (very dark grayish brown) moist grading to wet at 29.5' bgs, loose medium to coarse sand with gravel. Mild odor. |
| 30<br>31 | 30-32 | 1.0 | | | 4.8 | | | GW | 10YR 4/3 (brown) wet, loose well-graded gravel with coarse sand. No odor. Very minor silt component. |
| 32<br>33 | 32-34 | 0.4 | | | 2.4 | | | SW-SM | 10YR 3/3 (dark brown) wet, loose well-graded fine to coarse sand with silt. No odor. |
| 34 | 34-36 | 0.6 | | | | | | ML | 10YR 3/4 (dark yellowish brown) wet, cohesive silt with fine sand. No odor. |
| 35 | | | | | 4.8 | | | SM | 10YR 3/4 (dark yellowish brown) wet, cohesive silty fine sand. No odor. Some staining to 10YR 3/2 (very dark grayish brown) at 35.5' bgs. |
| 36<br>37 | 36-38 | 1.0 | | | 2.4 | | | SM | 10YR 3/2 (very dark grayish brown) wet, cohesive silty fine sand with stained bands of 10YR 3/1 (very dark gray) throughout recovery. |
| 38<br>39 | 38-40 | 1.9 | | | 2.4 | | | SP-SM | 10YR 4/2 (dark grayish brown) wet, mildly cohesive fine sand with very minor silt component. No odor. Homogenous throughout sample recovery. |
| 40<br>41 | 40-42 | 1.2 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Homogenous throughout sample recovery. |
| 42<br>43 | 42-44 | 1.6 | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Homogenous throughout sample recovery. |
| 44 | 44-46 | 1.8 | | | | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Homogenous throughout sample recovery. |
| 45 | | | | | 2.4 | | | SP | 10YR 2/1 (black) wet, loose poorly-graded fine sand. Moderate odor, no sheen. |

Boring Number: SB-10 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 46 | 46-48 | 1.8 | | | | | | SP | 10YR 2/1 (black) wet, loose poorly-graded fine sand. Strong odor. No sheen. Homogenous through sample recovery. Sample collected at 46' bgs. |
| 47 | | | | | 2.4 | | | | |
| 48 | 48-50 | 1.6 | | | | | | SP | 10YR 2/1 (black) wet, loose poorly-graded fine sand. Moderate odor, no sheen. Same as above. |
| 49 | | | | | 4.8 | | | | |
| 50 | 50-52 | 1.6 | | | | | | | Same as above. |
| 51 | | | | | 2.4 | | | SP | 10YR 4/2 (dark grayish brown) wet, loose poorly-graded fine sand. No odor. Sample collected at 51' bgs. |
| 52 | 52-54 | 1.5 | | | | | | SP | 10YR 3/2 (very dark grayish brown) wet, loose poorly-graded fine sand. No odor. |
| 53 | | | | | 2.4 | | | SP | 10YR 3/3 (dark brown) wet, loose poorly-graded fine sand. No odor. |
| 54 | 54-56 | 1.8 | | | | | | SM | 10YR 4/3 (brown) wet, cohesive poorly-graded fine silty sand. No odor. |
| 55 | | | | | 2.4 | | | | |
| 56 | 56-58 | ND | | | | | | SW | 10YR 4/3 (brown) wet, cohesive well-graded fine to medium sand. No odor. Sample collected at 56' bgs. |
| 57 | | | | | 2.4 | | | | |
| 58 | 58-60 | ND | | | | | | SW | 10YR 4/3 (brown) wet, cohesive well-graded fine to medium sand. Occasional pebbles. No odor. |
| 59 | | | | | 4.8 | | | SW | 10YR 4/3 (brown) wet, cohesive well-graded fine to medium sand. No odor. |
| 60 | 60-62 | | | | | | | | End of boring at 60 feet below ground surface |
| 61 | | | | | | | | | |
| 62 | 62-63 | | | | | | | | |

Boring Number: SB-10 Project : NIROP Pilot-Scale 2005 Project #: 5427

| Depth (ft) | Sample Interval | Sample Recovery | Evacuation Rate | Ground water | PID/FID Readings | GC Reading | Graphic Log | USCS Classification | Soil Classification/ Description |
|---|---|---|---|---|---|---|---|---|---|
| 63 | 63-64 | | | | | | | | |
| 64 | 64-66 | | | | | | | | |
| 65 | | | | | | | | | |
| 66 | 66-68 | | | | | | | | |
| 67 | | | | | | | | | |
| 68 | 68-70 | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | 70-72 | | | | | | | | |
| 71 | | | | | | | | | |
| 72 | 72-74 | | | | | | | | |
| 73 | | | | | | | | | |
| 74 | 74-76 | | | | | | | | |
| 75 | | | | | | | | | |
| 76 | 76-78 | | | | | | | | |
| 77 | | | | | | | | | |
| 78 | 78-80 | | | | | | | | |
| 79 | | | | | | | | | |

# APPENDIX C

# RESPONSE TO COMMENTS MATRICES

# RESPONSE TO WRITTEN COMMENTS ON THE TECHNICAL MEMORANDUM DATED NOVEMBER 2005 VEGETABLE OIL INJECTION PILOT TEST NAVAL INDUSTRIAL ORDNANCE PLANT FRIDLEY, MINNESOTA

| Item | Section | Page | Comments | Responses |
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| General Response to Comments: | | | | |
| Minnesota Pollution Control Agency Comments<br>Note: MPCA states in their letter dated November 30th 2005 that it is unnecessary for the Navy to respond to comments provided in the subject letter. However, for completeness the comments provided by the MPCA are included in this response to comments document. | | | | |
| 1. | General | NA | The technical memorandum contains conclusions and recommendations that the MPCA may or may not agree with. | None necessary. |
| 2. | General | NA | Revisions to the pilot test, including the new monitoring well network, have resulted in much more quantifiable and definitive assessments about the pilot study area and the magnitude of the impacts of vegetable oil injection. | None necessary. |
| 3. | General | NA | The technical memorandum shows that the vegetable oil injection has resulted in the distribution of organic carbon within the impacted aquifer that has delivered a carbon source to a well-defined area of the aquifer down gradient of the injection area. | None necessary. |
| 4. | General | NA | Within the area of carbon distribution, there have been reductions in TCE levels that have been shown. in part, to be a result of reductive dechlorination due to the vegetable oil injection. | None necessary. |
| 5. | General | NA | The pilot test data quality objectives for the reduction of TCE levels continue to be met. | None necessary. |
| 6. | General | NA | The production of VC from vegetable oil injection has not been observed to be an issue in the pilot test area. | None necessary. |
| 7. | General | NA | After the pilot test report has been reviewed by the USEPA and MPCA, the NIROP partnering team will meet to discuss the conclusions and recommendations of the report and the potential applicability of the vegetable oil injection technology to the Anoka County Riverside Regional Park | None necessary. |

| Item | Section | Page | Comments | Responses |
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| | | | groundwater contamination problem. | |
| 8. | General | NA | Upon completion of the USGS capture evaluation report, the results of the capture evaluation as well as the results of the final pilot test will need to be taken into account when making remedy decisions for the parks groundwater contamination problem. | None necessary. |
| 9. | General | NA | Any discussion in the technical memorandum beyond the objectives of the pilot test as cited in the Quality Assurance Project Plan should be considered the subject of subsequent meetings by the NIROP partnering team. | None necessary. |
| 10. | General | NA | The NIROP contaminant plume in the park is currently exceeding MPCA surface water quality standards for this stretch of the Mississippi River. Meeting the MPCA water quality standards for the site contaminants of concern in the park compliance wells prior to plume discharge to the Mississippi River remains a remediation goal for NIROP and the primary reason that the NIROP partnering team is evaluating the vegetable oil technology in the park. | None necessary. |
| 11 | General | NA | Eventually the NIROP partnering team needs to discuss the potential application of the vegetable oil injection technology (and other appropriate remedies) to source area beneath the main NIROP building. | None necessary. |
| United States Environmental Protection Agency Comments | | | | |
| 1 | General Comment: Generally, the recommendations provided in the last section of the Tech Memo appear vague. The second paragraph on Page 21 recommends "organic substrate addition in general and vegetable oil injection specifically be considered as a future remedial option at the site." However, the Tech Memo goes on to identify permeable reactive barriers or injectable zero valent [sic] iron as possible remedial technologies. In addition, the Tech Memo indicates "it is unlikely that any remedial technology will be successful in significantly accelerating the time it will take to clean up the site." These recommendations appear to be contradictory.<br><br>The Final Vegetable Oil Pilot Test Report should include detailed discussions of specific recommendations. These recommendations should be | | | |

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| | developed only after addressing the concerns identified in the following Specific Comments regarding the analysis of potential applicability of the vegetable oil injection technology at the NIROP site and the impact of the diffusion of contaminants out of the fine grained sediments identified on site.<br><br>General Response: The conclusions section in the technical memorandum will be revised and clarified such that recommendations regarding the future use to organic substrate addition at Anoka County Park are clear and well supported by the data collected to date. | | | |
| Specific EPA Comments | | | | |
| 1 | Site Hydrology | 13 | The Tech Memo states that "hydraulic conductivity measurements conducted in wells PES-MW-3, PES-MW-8, and PES-MW-9 indicate that a zone of low hydraulic conductivity is present down gradient of the immediate injection area." The geometric mean for the hydraulic conductivity values measured in these wells was reported to be 0.010 cm/sec. Such values of hydraulic conductivity represent relatively permeable materials. It does not appear appropriate to characterize the area surrounding these wells as "a zone of low hydraulic conductivity." Although unclear, the discussion appears to suggest that this is an area of reduced hydraulic conductivity relative to other nearby areas. Revise this statement to provide a more detailed discussion of the areas being compared and the nature of the comparison. | The site hydrogeology section of the tech memo compares calculated hydraulic conductivities from three areas over time. The three areas are the injection area, the area surrounding wells PES-MW-3, PES-MW-8, and PES-MW-9, and the area around the contingency wells. The geometric mean of hydraulic conductivities calculated in the injection area and in the area surrounding the contingency wells was approximately 0.062 cm/sec and 0.069 cm/sec while the geometric mean of hydraulic conductivities in the area of PES-MW-3, PES-MW-8, and PES-MW-9 was 0.010 cm/sec. Thus, the calculated hydraulic conductivity in area surrounding wells PES-MW-3, PES-MW-8, and PES-MW-9 is low in relation to the injection area and the contingency well area as stated in the tech memo.<br><br>The third sentence in the 5th paragraph of the hydrogeology section will be revised to read as follows: "Hydraulic conductivity measurements conducted in wells PES-MW-3, PES-MW-8, and PES-MW-9 indicate that a zone of low hydraulic conductivity, relative to the injection area and the area around the contingency wells, is present in the vicinity of these well locations." |
| 2 | VOCs in Ground | 15 | The Tech Memo utilizes the data presented in Tables 11A and 11B to support a conclusion that 'TCE concentrations within the pilot test area decreased much more rapidly than | Concur, the comparison of TCE reduction rates within the pilot test area to reduction rates observed outside of the pilot test area will be removed. |

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| | water | | TCE concentrations outside of the pilot test area as indicated by the average slope within the pilot test area." However, Table 11A, which presents data outside of the pilot test area, includes data from monitoring wells located outside of the core area of the plume that likely do not represent the portions of the plume directly impacted by the recent upgrades in the groundwater extraction system (i.e., monitoring wells 17-S, 19-S, 27-S, 41-S, 43-S, and 44-S). If the data from the low concentration portions of the core areas of the plume (e.g., concentrations lower than 790 ugh TCE) are excluded from this assessment, the reductions in TCE concentrations outside the pilot test area appear similar to those within the pilot test area. In fact, the average percent reduction in TCE concentrations appears to be higher than in the pilot test area.<br><br>The analysis of the data from within the pilot test area clearly indicates that injection of vegetable oil has resulted in significant reductions in chlorinated solvent concentrations in groundwater. Figure 8 clearly illustrates these decreases. Because of underlying background trends in contaminant concentrations, the comparison of reductions in contaminant concentrations within and outside of the pilot test area does not appear useful in demonstrating the effectiveness of the injection of vegetable oil in reducing contaminant concentrations in groundwater. It is recommended that analysis of data from within the pilot test area be used primarily for this purpose. | |
| 3 | Summa ry | 18 | The Tech *Memo* concludes that "any remedial strategies implemented in this (study) area should be targeted to the finer grained units present between approximately 30 and 40 feet bgs where the majority of the contaminant mass | The reviewer is correct. The referenced conclusion does assume that the referenced remedial option will be designed primarily to remove contaminant mass. |

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| | | | resides." However, this conclusion presumes that the object of any remedial strategy is to remove maximum amounts of contaminants from the subsurface. However, as indicated in the recommendations presented in the Tech Memo, other remedial objectives have been evaluated, including the objective of reducing the potential impact to receptors and therefore reducing the environmental risk associated with contaminants remaining in the subsurface or migrating via groundwater from up gradient areas. These other remedial objectives may not necessarily target the removal of contaminant mass from the finer grained units. The Final Vegetable Oil Pilot Test Report should fully acknowledge these other potential remedial strategies. | Concur, The conclusions section will be revised to discuss different remedial goals (e.g., contaminant mass removal verses reduction of contaminant mass flux toward the river, etc.) and the viability of organic substrate addition to meet each goal based upon the results of the pilot test. |
| 4 | Recommendations | 21 | The Tech Memo states that "vegetable oil has also been shown to be effective at stripping contaminant mass from the soil matrix through its surfactant properties and immobilizing contaminant mass through its preferential partitioning properties." The Tech Memo does not appear to directly discuss these properties of vegetable oil or discuss how the data reported in the Tech Memo support such a conclusion. Consequently, the basis for this statement is not clear. In addition, it is not clear if this statement is intended to indicate that the injection of vegetable oil might provide a means of addressing the contaminant mass shown to be concentrated in the fine grained deposits in the study area. Any such statements included in the Final Vegetable Oil Pilot Test Report should be fully supported and their implications for the remediation of subsurface contaminant mass at the NIROP facility should be clarified. | The basis for these conclusions are drawn from Section 4.4.3 of the draft NIROP pilot test report (Parsons, 2004) and will be properly referenced in the technical memorandum.<br><br>This discussion is presented in order to support the conclusion that vegetable oil injection may be an effective means to sequester and immobilize contaminant mass and therefore meet the remedial goal of reducing contaminant flux to receptors. The conclusion that vegetable oil also effectively strips contaminant mass from the soil matrix could also indicate that vegetable oil injection might be an effective means of accelerating the removal of contaminant mass from the fine grained units. However, the effectiveness of vegetable oil to strip contaminant mass from the fine grained units would be limited by the degree of contact between the impacted soils and the vegetable oil. Thus, it would be very difficult to strip a significant amount of the contaminant mass that is sorbed to the fine grained units because it would be difficult to bring vegetable oil into direct contact with a significant percentage |

| Item | Section | Page | Comments | Responses |
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| | | | | of the fine grained sediments. |
| 5 | Recommendations | 22 | The Tech Memo states that "the rate at which contaminant mass diffuses out of the finer grained units could be increased slightly by removing the contaminant mass from the more transmissive units and thereby increasing the steepness of the contaminant concentration gradient." This statement is supported by citing the example of TCE concentrations measured in soil from the silt unit and underlying sand unit at Soil Boring SB-4. The significant differences in soil concentrations of TCE at this location are used to demonstrate that the soil data collected during the study "indicate that the contaminant concentration gradients from the finer grained units to the coarser grained units are already relatively steep." Based on this analysis, the Tech Memo concludes that "it is unlikely that any remedial technology will be successful in significantly accelerating the time it will take to clear up the site because contaminant mass will continue to diffuse out of the fine grained units for some time to come."<br><br>However, it is important to note. that TCE diffuses out of the finer grained materials into the coarser grained materials according to the contaminant concentration gradient in groundwater and not in soils. As the data collected during this study have clearly indicated, the finer grained materials contain significantly greater amounts of organic carbon than coarser grained materials found on site. Since the degree of adsorption of TCE is largely controlled by the organic carbon content of subsurface materials, a much greater amount of TCE will adsorb onto the finer grained soils than the coarser grained soils for an | The reviewer is correct that contaminant gradients are typically calculated using groundwater data. However, in this case groundwater data from the silt unit is not available. Samples were collected using a groundwater profiler during the Spring 2005 field event as part of the MIP survey activities. However, the soil stratigraphy data collected by the MIP system is not representative of soil conditions as reflected by boring logs collected during soil boring and well installation activities. As a result the soil stratigraphy within each profiler sampling interval can not be accurately determined.<br><br>The comparison of soil VOC data from the silt unit and the sand unit allows us to draw the qualitative conclusion that more contaminant mass is present in the silt unit than in the sand unit. The reviewer is correct that comparison of soil data does not however allow us to draw conclusions regarding the VOC concentration gradient from the silt unit to the sand unit because soil data represents both dissolved phase contaminant mass (pore water) and sorbed contaminant mass. The following statement: "However, the soil data collected during the Spring of 2005 indicates that the contaminant concentration gradient from the finer grained units to the coarser grained units is already relatively steep" will be removed from the conclusions section.<br><br>Regardless, the observation that the contaminant mass diffusion rates out of the fine grained units could be improved slightly by removing contaminant mass from the coarse grained units (thus increasing the concentration gradient from the silt to the sand) is correct. The observation: "However, it is unlikely that any remedial technology will be successful in significantly accelerating the time it will take to clean up the |

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| | | | equivalent dissolved concentration of TCE. Consequently, it is not clear that the differences in soil concentrations of TCE observed between fine and coarse grained materials actually indicate significant gradients in the dissolved TCE concentrations in groundwater between the fine and coarse grained materials. Thus, it is not clear that TCE concentration gradients between the fine and coarse grained materials could not be significantly improved through the application of vegetable oil injection in Anoka County Park.<br><br>There appears to be little basis provided in the Tech Memo for the above cited statement regarding the potential for increasing the rate of diffusion out of the fine grained materials through the injection of vegetable oil. Greater analysis of the factors that control diffusion out of the fined grained deposits found on site is required before such a statement can be fully evaluated. | site because contaminant mass will continue to diffuse out of the fine grained units for some time to come" is also correct as supported by the following calculations following Freeze and Cherry 1979 and using a modification of Ficks Law.<br><br>Ficks Law States that a concentration at time T and position x can be calculated assuming linear diffusion using the following parameters:<br>C(x,t) is the concentration at point x<br>Co is the initial concentration<br>D* is the diffusion coefficient<br>x is the diffusion distance<br>Through the following formula:<br><br>C(x,t) =Co erfc{x/2*sqrt(D*t)}<br><br>The calculation assumes that there is no advection, no dispersion, no retardation, no decay, and that diffusion is in one direction and so the calculation provides only an estimate of diffusion time. The calculation also assumes that the concentration at point x is zero so that the concentration gradient is maximized. However, the results are useful in that they provide a semi-quantitative estimate of diffusion time.<br><br>Assuming x = 1 foot, Co is 710 ppb (TCE concentration in the silt unit), D is 1e-4 $cm^2$/sec (Evans, 1995) and C(x,t) is 5 ppb (the TCE USEPA MCL) the diffusion time as iteratively calculated is approximately 400 to 700 years. If one were to consider retardation as well than the diffusion time would be longer. These calculations indicate that even in the case where the concentration gradient is maximized (i.e., contaminant mass is removed from the sand unit at point x as fast as it diffuses out of the silt unit) the time it will take to |

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| | | | | diffuse out the contaminant mass in the silt unit is on the order of hundreds of years. Thus, the application of a remedial option will not accelerate site cleanup time significantly (regardless of how effective the option is).<br><br>The observation that the cleanup time for this site will be defined by diffusion based mechanics (i.e., the rate at which contaminant mass diffuses out of the silt units) leads to the conclusion that the primary remedial goal at this site should not be to simply remove/destroy contaminant mass but to protect receptors as stated in the conclusions section of the October 2005 technical memorandum.<br><br>These calculations and discussion will be incorporated into the technical memorandum. |
| 6 | Recommendations | 22 | As indicated above in Specific Comment No. *5*, the Tech Memo indicates that soil sampling results have shown that the majority of the contaminant mass observed in soils is retained in the finer grained materials. The Tech Memo also appropriately indicates that this contaminant mass may provide an ongoing source of groundwater contamination. However, it is not clear that such slow diffusion of contaminants out of fine grained deposits into the relatively fast moving groundwater in the more permeable strata in the study area could result in the contaminant concentrations currently observed in groundwater in the study area. Preliminary analysis of contaminant concentrations in groundwater in coarse grained materials underlying highly contaminated finer grained sediments was provided during the October 5, 2005 Technical Meeting on the Tech Memo. This analysis appeared to indicate that the diffusion of contaminants out of the fine | Concur, it is unlikely that back diffusion of contaminant mass from the fine grained units alone could account for VOC concentrations measured in the more permeable units.<br><br>The diffusion rate calculations presented above will be incorporated into the technical memorandum. Unfortunately analysis beyond the semi-quantative calculations presented above would require a significant effort involving an attempt to estimate the volume of silt and sand beneath the park, an estimate of contaminant mass in each unit, and an improved estimate of back diffusion rates and resultant mass released by back diffusion per unit time. The compilation of all of these estimates would produce theoretical masses in the silt and sand units and the relative contributions of each. This analysis is beyond Parsons current scope, budget, and schedule. |

**RESPONSE TO WRITTEN COMMENTS ON**
**THE TECHNICAL MEMORANDUM DATED NOVEMBER 2005**
**VEGETABLE OIL INJECTION PILOT TEST**
**NAVAL INDUSTRIAL ORDNANCE PLANT FRIDLEY, MINNESOTA**
**(Continued)**

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| | | | grained materials into the more permeable strata did not necessarily result in significantly elevated contaminated concentrations in groundwater. The Final Vegetable Oil Pilot Test Report should provide full analysis of the available data to help determine the relative impact of the diffusion of contaminants out of fine grained on the quality of groundwater migrating away from the study area. | |

# RESPONSE TO WRITTEN COMMENTS ON THE TECHNICAL MEMORANDUM DATED MARCH 2006 VEGETABLE OIL INJECTION PILOT TEST NAVAL INDUSTRIAL ORDNANCE PLANT FRIDLEY, MINNESOTA

| Item | Section | Page | Comments | Responses |
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| Minnesota Pollution Control Agency Comments | | | | |
| 1. | 5 | NA | It is MPCA staff's understanding that the conclusions and recommendations of the Report will be the subject of a forthcoming NIROP partnering and/or technical subcommittee meeting and that at this meeting, the future direction of the application of this technology for the NIROP site will be determined. The MPCA staff recommends that this meeting be scheduled as soon as possible. | The Navy concurs with this recommendation and will schedule the referenced NIROP partnering meeting to discuss the future of this technology at the NIROP site. |
| 2. | 5 | NA | The MPCA staff requests that the Navy explain how and when Mr. Hal Davis final United States Geological Survey capture evaluation report will be factored into the Report, including final conclusions and recommendations for the application of this technology at the NIROP site. | Future analytical data collected from the vegetable oil pilot test monitoring well network as well as conclusions and recommendations for future work drawn from future data and from studies that have not been published yet (e.g., the Final Capture Report) will be presented in the Annual Monitoring Report. |
| 3. | 5 | NA | The MPCA staff requests that the Navy identify any findings contained in the report entitled "2005 Annual Monitoring Report Naval Industrial Ordnance Plant Fridley, Minnesota" dated April 2006, that impact the conclusions and recommendations of the Report and identify how any such findings will be incorporated in the report. | The 2005 AMR finding that TCE concentrations continued to decrease between September 2004 and November 2005 at the majority of wells installed in Anoka County Park will be referenced to support conclusions presented in the conclusion section of the technical memorandum and the revised conclusions section of the 2004 report.<br><br>The finding that current extraction system "appears to be adequate to provide containment of most of the contamination migrating from the NIROP source areas, especially at shallow and intermediate depths" will be incorporated by reference to support conclusions presented in the conclusion section of the technical memorandum and the revised conclusions section of the 2004 report. |
| 4. | Tech Memo VOCs | 11, paragraph 2 | This paragraph discusses contaminant mass. The last sentence states that "...the fine grained silt/clay units contain more contaminant mass than the more transmissive sand units and will likely serve as secondary sources of | The referenced statement in the text ("...the fine grained silt/clay units contain more contaminant mass than the more transmissive sand units and will likely serve as secondary |

**Response to Written Comments on**
**the Technical Memorandum Dated March 2006**
**Vegetable Oil Injection Pilot Test**
**Naval Industrial Ordnance Plant Fridley, Minnesota**
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| | in Soil Section | | contaminant mass for some time" The MPCA staff requests that the Navy explain whether or not this contaminant mass accounts for the TCE mass transported in groundwater. Was the mass of TCE in the groundwater estimated in the calculation cited in this section? | sources of contaminant mass for some time") is partially inaccurate. VOC concentrations are higher in the fine grained units than in the coarser grained units, indicating that the fine units may contain more VOC mass than the coarse units. However, this is not necessarily the case because the total VOC mass in each unit is dependant on the VOC concentrations as well as the total volume of each unit. If the volume of the fine grained units is considerably smaller than the volume of the coarse grained units than the total VOC mass present in the fine grained unit may be smaller. The text will be revised to clarify this distinction.<br><br>It is currently unknown whether the VOC concentrations in the coarse grained units are present entirely as a result of back diffusion from the fine grained units. The total volume of the fine and coarse grained units would have to be accurately known to make this determination with any confidence. However, it is the authors opinion that it is unlikely that all of the VOC mass present in the coarse grained unit (s) is solely due to back diffusion. It seems more likely that the VOC mass present in the coarser grained units is sourced from back diffusion (from the fine grained units) and from contaminant mass being transported from upgradient areas. |
| 5. | Tech Memo Site Hydro Section | 14, paragraph 4. | This paragraph discusses viscosity. If the vegetable oil is completely hydrophobic, then it "lowers the relative permeability of the aquifer matrix" as stated. However, if it decreases the viscosity of the interstitial groundwater, then it inherently lowers the hydraulic conductivity as the dynamic viscosity is proportional to the intrinsic permeability if the porous media. The MPCA staff requests that the Navy identify whether or not the phase of the vegetable oil has been established in the aquifer matrix. | Vegetable oil is completely hydrophobic and as a result does not form a water-oil-mixture. Thus, the viscosity of the interstitial groundwater remains unchanged. Instead the vegetable oil LNAPL decreases soil hydraulic conductivity by physically constricting or blocking soil pore throats with vegetable oil ganglia. Vegetable oil will be present as LNAPL blobs and stringers, as a coating on soil particles, and sorbed on the subsurface soil matrix. The phase of the vegetable oil present in the NIROP subsurface soils has not been directly |

**Response to Written Comments on**
**the Technical Memorandum Dated March 2006**
**Vegetable Oil Injection Pilot Test**
**Naval Industrial Ordnance Plant Fridley, Minnesota**
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| | | | | determined (through for example microscope analysis). |
| 6. | Tech Memo. VOCs in ground water section. | 16, paragraph 4 | This paragraph states that "VC [vinyl chloride] has not (sic) [been] detected at concentrations above the MDL [method detection limit] in any of the contingency wells....or the new downgradient monitoring well cluster PES-MW-12A/B, during the course of the pilot test."<br><br>The concentration of TCE in PES-MW-12A increased from 80 to 350 micrograms per liter (µg/L) from April to November 2005. Over the same time period, the concentration of TCE at PES-MW-12B went from 330 to 290 µg/L. The latter is essentially stable. If TCE is not trending downward at these wells, the MPCA staff requests that the Navy explain how the Navy knows that the pilot remedy has effected groundwater at the new downgradient monitoring well cluster PES-MW-12A/B at all. The MPCA staff requests that the Navy continue to monitor for declines in TCE concentration and vinyl chloride at this well cluster. | The editorial comment (addition of the word "been") will be incorporated.<br><br>There is no evidence to indicate that either PES-MW-12A or PES-MW-12B have been directly impacted by the injected vegetable oil. MW-12A and B are listed as unimpacted monitoring wells on Table 6 of the March 2006 technical memorandum and are shown as being unimpacted on Figures 9 and 10 (depictions of elevated TOC in groundwater). In addition, TOC in soil data collected from the screen interval of PES-MW-12B is used as an example of unimpacted, naturally occurring TOC in soil (Page 8, paragraph 4 of the March 2006 technical memorandum).<br><br>The Navy concurs with MPCA's recommendation to continue to monitor monitoring well PES-MW-12A as this well is installed downgradient of the injection area and the well screen was installed in the same vertical interval than contains the injected vegetable oil. The March 2006 technical memorandum recommended that this well location continue to be sampled as part of the long term monitoring program for the vegetable oil pilot project.<br><br>The Navy disagrees with the recommendation to collect samples from PES-MW-12B annually because there is no evidence of vegoil impact at this well location or in the "B" installation depth at any of the newly installed well clusters. A recommendation to collect a groundwater sample from PES-MW-12B during the sampling round conducted immediately prior to a 5-year ROD review will be added per response to comment EPA-2. |
| United States Environmental Protection Agency Comments | | | | |

**Response to Written Comments on**
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**Vegetable Oil Injection Pilot Test**
**Naval Industrial Ordnance Plant Fridley, Minnesota**
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| 1 | General Comment: *(Responders note: The following text has been excerpted from the USEPA letter dated April 14th 2006)*<br><br>Several EPA comments on the previous Tech Memo (dated August 2005, revised October 2005) requested that changes be made in the Final Vegetable Oil Pilot Test Report. The Navy has addressed those comments by revising the Tech Memo and Sections 5 and 6 of the Report for a Field Application to Enhanced In-Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota, dated March 2004 (Vegetable Oil Pilot Test Report). The revisions appear to be appropriate. However, the revisions made to Sections 5 and 6 of the Vegetable Oil Pilot Test Report create inconsistencies with the remainder of that document. For example, the recommendations in the executive summary of the Vegetable Oil Pilot Test Report (including a recommendation for full-scale application of vegetable oil injection) are not consistent with the conclusions and recommendations in the revised version of Section 5.<br><br>In addition, the Navy previously responded to two sets of comments generated by EPA and Minnesota Pollution Control Agency (MPCA) (responses received August 6, 2004 and October 4, 2004). In these responses the Navy agreed to make numerous revisions in the Final Vegetable Oil Pilot Test Report. While the Tech Memo addresses some of the comments, numerous other comments relating to other sections of the Vegetable Oil Pilot Test Report have not been addressed. There is no comprehensive document that presents and evaluates the data collected during and since implementation of the pilot test. It is recommended that a Final Vegetable Oil Test Report should be produced. This Final Report should incorporate all previously agreed-upon revisions and all data and additional evaluations performed since the pilot test.<br><br>General Response: The Navy feels that the combination of the draft 2004 report and the final technical memorandum adequately presents all of the data collected during the course of the pilot test and the conclusions and recommendations that were drawn from this data set. Therefore, the Navy will revise the final technical memorandum, update section 5 of the draft report, and release both as the final deliverable for this project. Future monitoring results collected from the vegetable oil pilot test monitoring well network will be presented in the Annual Monitoring Report. | | | |
| Specific EPA Comments | | | | |
| 1 | VOCs in soil | 11 | A discussion of the diffusion of trichloroethene (TCE) out of low permeability units has been included in the March 2006 version of the Tech Memo. An analytical solution to Fick's Second Law of Diffusion is used to estimate the time required for TCE to diffuse out of low permeability deposits in Anoka County Park (ACP). The analytical solution is derived based on imposing a constant concentration boundary condition at x equals zero and a zero concentration at infinity. The initial condition assumes that no contaminant is initially present in the | The Fick's second law analysis was intended to provide a semi-quantitative estimate of the time required for the low-permeability silts and clays to be "flushed" free of contaminants by diffusion. Fick's second law is more accurately used to describe diffusion across a low-permeability layer with a constant, high-concentration source on one side. Parsons made the assumption that the rate of diffusion out of the low-permeability unit would be the same as the rate of diffusion into the unit. Therefore, the starting boundary conditions for the calculation were zero |

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| | | | solution domain. The analytical solution predicts the concentration profile throughout the solution domain in time in response to the diffusion of the contaminant from the constant source at x equals 0.<br><br>It does not appear that this equation provides a useful analysis of the diffusion time out of the low permeability sediments in ACP. The Tech Memo states that "the calculation assumes that the concentration at point x is 0 so that the concentration gradient is maximized." However, this solution does not allow the concentration at x equals one foot, where the high permeability sediments are postulated to begin, to remain at zero or at some arbitrarily low contaminant concentration reflecting the dilution of diffusing contaminant into the high permeability deposits. If the analytical solution is run to develop a concentration profile from x equals 0 to x equals two feet (well into the high permeability deposits) for a series of times, it can be seen that the concentration profile extends well into the high permeability deposits. These computations will also show that the concentration gradient at the interface between the low and high permeability deposit (X = 1 ft.) steadily decreases with time. Thus, concentration gradients are clearly not maximized. Rather, this solution significantly underestimates the gradients at the interface between the low and high permeability deposits.<br><br>The text indicates that using the analytical solution, the diffusion time is computed to be approximately 400 to 700 years. It is not clear how these times have been obtained or what exactly is meant by the "diffusion time." However, computations using the analytical solution indicate that the | concentration within the silty clay and 2,100 ug/L at the edge of the silty clay. Parsons calculated the time for the concentration at a distance of one foot (into the silty clay) to reach the approximate boundary concentration (i.e. the present-day concentration in the silty-clay) and than reversed the results per our first assumption. For several reasons, including those cited by both Parsons and EPA, we believe that this was a conservative approach.<br><br>Parsons intent in including this discussion was to illustrate how slow diffusion based mechanics are. Parsons agrees with the EPA that the audience of this technical memorandum understands this point. Therefore, Parsons agrees with the EPA that this discussion is not necessary and will remove the Fick's second law presentation as suggested. The following text will be substitute in its place: "The removal of TCE mass from the silty clay units beneath the NIROP site will be an extremely slow process because removal rate will be limited by the rate of diffusion, which is typically several orders of magnitude slower than advective-dispersive processes. Thus, the application of a remedial option in the more permeable unit(s) will not accelerate site cleanup time significantly because the time to achieve MCLs on this site is dependant on the rate at which contaminant mass diffuses out of the fine grained units, not on the rate at which the remedial option of choice destroys contaminant mass." |