SEMIANNUAL SITE STATUS REPORT
(for the Months February and May 2004)

FOR FORMER UST SITE 957/970
AT DEPARTMENT OF DEFENSE HOUSING FACILITY
NOVATO, CALIFORNIA

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ACRONYMS AND ABBREVIATIONS

BTEX	benzene, toluene, ethylbenzene, and xylenes
btoc	below top of casing
cfm	cubic feet per minute
CSWRCB	California State Water Resources Control Board
DIPE	diisopropyl ether
DO	dissolved oxygen
DoDHF	Department of Defense Housing Facility
DTSC	Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
ETBE	ethyl tertiary butyl ether
GC/MS	gas chromatography/mass spectrometry
HAAF	Hamilton Army Airfield
HCl	hydrochloric acid
ID	identification
LUFT	Leaking Underground Fuel Tank
MNA	monitored natural attenuation
MTBE	methyl-*tert*-butyl ether
NA	not analyzed
N/A	not applicable
NEX	Naval Exchange
NFESC	Naval Facilities Engineering Service Center
NS	not sampled
ORP	oxygen reduction potential
PQL	practical quantitation limit
PWC	Public Works Center
QA	quality assurance
QA/QC	quality assurance/quality control
QC	quality control
RAO	remedial action objective
RBCA	Risk Based Corrective Action
RWQCB	Regional Water Quality Control Board, San Francisco Bay Area
SVE	soil vapor extraction
TAME	tertiary amyl methyl ether

TBA *tert* butyl alcohol
TBF *tert* butyl formate
TMB trimethylbenzene
TPH total petroleum hydrocarbons
TPH-G total petroleum hydrocarbons quantified as gasoline

UST underground storage tank

VOA volatile organic analysis
VOC volatile organic compound

Section 1.0: INTRODUCTION

This site status report describes activities performed under Task Order No. 0026 of the U.S. Naval Facilities Engineering Service Center (NFESC) Contract No. N47408-01-D-8207 and was prepared in compliance with Regional Water Quality Control Board, San Francisco Bay Area (RWQCB) Order No. 00-064, Task 9. In accordance with the Order, this report presents the results of quarterly groundwater and surface water monitoring conducted in February and May 2004. It also contains the results of the biosparging and performance well monitoring activities that have been conducted since December 2003.

The subject of this report is former Underground Storage Tank (UST) Site 957/970 at Department of Defense Housing Facility (DoDHF) Novato, which is located approximately 20 miles north of San Francisco in Marin County, CA. The Site comprises an area of approximately 13 acres of land (an approximate rectangle with dimensions approximately 1,100 ft by 500 ft) bounded on the south by Main Entrance Road, and on the north by a set of railroad tracks operated by the Golden Gate Bridge, Highway, and Transportation District. The eastern border of the Site runs north-south from the intersection of Main Entrance Road and C Street, and the western border of the Site runs north-south approximately 500 ft west of the intersection of Main Entrance Road and C Street (see Figure 1). The Site is approximately 9,412 feet west of San Pablo Bay and 4,831 feet south of Ignacio Reservoir (Pacheco Pond).

The Site is the location of a former Naval Exchange (NEX) gas station and a former Public Works Center (PWC) gas station. The NEX gas station was located at the northwest corner of Main Entrance Road and C Street, where Building 970 and associated pump islands were in use from the mid-1970s through the early 1990s. The NEX gas station was closed in the early 1990s, and subsequently the three (3) USTs that had supported the station (UST 970-1, UST 970-2, and UST 970-3, collectively referred to as UST 970) were removed. The PWC gas station was the location of UST 957; this UST and associated underground piping were removed in 1992.

Water and soil samples were collected from excavations during tank removal activities in the areas of former USTs 957 and 970. Analytical results from these samples indicated that gasoline was released to the environment from the USTs. Because the groundwater plumes underlying these areas have merged and are no longer distinguishable, the individual Site designations have been combined and the label “Former UST Site 957/970” has been adopted.

Starting in June 1998, an interim remedial action consisting of air sparging and soil vapor extraction (SVE) was implemented to reduce hydrocarbon mass in areas in which the highest hydrocarbon concentrations were observed in groundwater. Significant mass removal was achieved, and the air sparging and SVE systems were shut down in early October 1999 because of greatly diminished mass removal rates. In September 2002, a biosparging system was initiated at the site to mitigate elevated MTBE concentrations on Navy-owned property. This remediation system will be operated until the objectives defined in the *Final Remedial Design and Work Plan* (Battelle, 2002a) have been achieved or the system no longer cost-effectively removes MTBE. Groundwater monitoring to track the behavior of dissolved gasoline constituents continues to be conducted on a quarterly, semiannual, or annual basis as described in Section 5.1 of the *Annual Site Status Report (for the Year 2003)* (Battelle, 2004).

Section 2.0: SUMMARY OF SITE ACTIVITIES

This section includes a summary of Site activities performed from December 2003 through May 2003. Previous project and Site activities have been reported in Semiannual Site Status Reports and monthly reports.

2.1 Board Order Deliverable Items

In various correspondence from the RWQCB to the Navy (letters from Mr. James Ponton to Mr. Thomas Macchiarella dated December 18, 2001, March 20, 2002, and April 16, 2003), it is documented that the Navy has met the requirements of Cleanup and Abatement Order 00-064. Some of the tasks included in the Order require that the Navy continue performing some activities at the Site. The Navy will fulfill the continuing obligations that are included in the Order and that are summarized below:

- **Task 6:** Implement the RWQCB-approved remedial approach (biosparging with a SVE contingency, monitored natural attenuation, and institutional controls) recommended in the *Final Corrective Action Plan for Groundwater* (Battelle, 2002b).
- **Task 8:** Update the *Groundwater Monitoring Plan* (Battelle, 2000a) for the Site by presenting recommendations in the regular site status reports that will allow all data objectives to continue to be met in a cost-effective manner.
- **Task 9:** Monitor groundwater and surface water and report the results collected during those monitoring activities in semiannual site status reports.

The main project documentation prepared by the Navy are the semiannual site status reports, which are included under Task 9. In February 2004 the Navy submitted the *Annual Site Status Report (for the Year 2003) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California* (Battelle, 2004), in compliance with Task 9 of Order No. 00-064. The report presented the results of quarterly groundwater and surface water monitoring conducted in August and November 2003. It also contained the results of the biosparging and performance well monitoring activities that were conducted through November 2003, and summarized the bedrock well installation activities which occurred in November 2003. An annual evaluation of the groundwater and surface water monitoring program was included to ensure that monitoring objectives had been met in an efficient manner. Based on the evaluation of the monitoring program, recommendations to modify the sampling frequency and sampling network without compromising the objectives of the program were provided.

2.2 Field Activities

Field activities that were conducted at the Site between December 2003 and May 2004 included quarterly groundwater and surface water sampling and regular biosparging system operation and monitoring. Details regarding each of these field events are as follows:

- Performed quarterly groundwater and surface water sampling at the Site from February 11 through February 24 and from May 13 through May 24. The new bedrock wells (MW-2E-BR, MW-M2-BR, and MW-M8-BR) were sampled June 4, in accordance with the *Groundwater Monitoring Plan* (Battelle, 2000a). Groundwater sampling was conducted according to the protocol presented in Table 5 and Table 11 of the *Annual Site Status Report (for the Year 2003)* (Battelle, 2004). Results from groundwater and surface water sampling are described in further detail in Sections 3.0 and 4.0, respectively, and in appendices of this report.

- Biosparging activities such as system operation and performance monitoring were performed from December 2003 through May 2004. Biosparging activities are summarized in Section 5.0 of this report. Regular monitoring of subsurface conditions during biosparging was continued as outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a). Weekly visits were made to the site by the subcontractor (ERRG) to confirm that the system continued to operate properly and that safe conditions were being maintained.

Section 3.0: GROUNDWATER MONITORING

The first two quarterly groundwater-monitoring events for the year 2004 are summarized in this section. Groundwater monitoring for the first quarter was conducted from February 11 through February 24 and for the second quarter from May 13 through May 24 for the majority of the wells. Due to sample shipping problems, the three new bedrock wells (MW-2E-BR, MW-M2-BR, and MW-M8-BR) were resampled on June 4. All samples were collected in accordance with the *Groundwater Monitoring Plan* (Battelle, 2000a), the *Draft Health and Safety Plan* (Battelle, 1998), and the RWQCB letter of March 13, 2003. Fifty-seven groundwater samples (excluding duplicates and quality control samples) were collected during the February 2004 quarterly monitoring event, and 75 groundwater samples (excluding duplicates and quality control samples) were collected during the May 2004 quarterly monitoring event. This section presents the results from both of these sampling events.

Well inspections were performed during groundwater monitoring activities in accordance with the *Monitoring Well Protection Plan* (Battelle, 2000b). Significant damage or deterioration that could impact well function or protection was not observed. Corrective actions taken in the February and May 2004 sampling events were limited to general maintenance of wells (i.e., cleaning seals and identification [ID] tags, etc.). Observations are included on the well purge and maintenance log sheets provided in Appendix A.

3.1 Analytical Program

Sampling objectives for monitoring wells included in the monitoring well network are provided in Table 1 of this document. Sampling and analytical methods are summarized in Table 2 and laboratory practical quantitation limits (PQLs) for analytes based on clean matrices are listed in Table 3. Table 4 provides the number of quality control (QC) samples and Table 5 provides a summary of the monitoring analytical program for all of the wells. Table 5 contains the modifications that have been made to the sampling protocol since they were originally presented in Tables 2 and 4 of the *Groundwater Monitoring Plan* (Battelle, 2000a). All samples collected during the February and May 2004 quarterly monitoring events were analyzed for benzene, toluene, ethylbenzene, total xylenes (BTEX), and methyl-*tert*-butyl ether (MTBE) by EPA Method 8260B in accordance with the sampling protocol summarized in Table 5. A subset of thirty-three (33) wells located primarily in the area of the site impacted by BTEX constituents were analyzed for total petroleum hydrocarbons (TPH) quantified as gasoline (G) using U.S. Environmental Protection Agency (EPA) Method 8015B; MTBE degradation products *tert* butyl alcohol (TBA) and *tert* butyl formate (TBF) were analyzed in 22 wells during February and 29 wells during May. These wells include eight biosparging treatment wells and others located throughout the site. Fuel oxygenates ethyl *tert* butyl ether (ETBE), *tert* amyl methyl ether (TAME), and diisopropyl ether (DIPE) were monitored in 14 wells in February and 21 wells in May 2004. Details of the analytical sampling program can be found in Table 5. Dissolved oxygen (DO), pH, temperature, and oxygen reduction potential (ORP) are measured for each well during purging activities and is recorded on the well purge logs (Appendix A). Past studies indicate that aerobic biodegradation of MTBE occurs at the site; therefore, measurements of DO and chemical concentrations are the main criteria used to track the effects of monitored natural attenuation (MNA). Section 3.6.9 discusses the MNA mechanisms occurring north of the Navy property and Section 5.0 (Biosparging System Activities) discusses groundwater field parameters and MNA associated with the remedial activities occurring on site.

The lowest possible reporting limits for all analytes were achieved in all samples determined to be nondetect in the February 2004 and May 2004 sampling events.

3.2 Water-Level Measurements

Prior to sampling, a water-level measurement was taken from each monitoring well and tabulated in accordance with the *Groundwater Monitoring Plan* (Battelle, 2000a). Groundwater was measured as depth below top of casing (btoc). Groundwater-level elevation was determined by subtracting the depth of groundwater btoc from the surveyed elevation of a reference point marked at the top of casing. In all nested well pairs, depths to groundwater used for the potentiometric map were measured from the shallow well. Cumulative water-level measurements are tabulated and included as Appendix B, and potentiometric maps for the February and May 2004 sampling events are presented in Figure 2. Groundwater flow in February and May is generally to the north, and is similar to that reported for previous quarters. No discernable changes in groundwater flow direction are evident in the biosparging treatment area since the system was started in September 2002. Because of the spatial placement of wells, the potentiometric maps should be used to make general observations about groundwater flow and not to determine localized flow patterns.

3.3 Purging and Sampling

Prior to sampling, wells were purged to remove stagnant water in accordance with procedures outlined in the *Groundwater Monitoring Plan* (Battelle, 2000a). Purging was considered adequate when the required volume of water was removed and field parameter readings had stabilized, or when the well was determined to be a slow recharging well (the well had purged dry). Samples were collected immediately from wells in which the required volume was purged and field parameters had stabilized. After purging to dryness, slow recharging wells were sampled when a sufficient volume of groundwater was present in the well to meet sample volume requirements. The criteria used to stop purging each well were recorded on the purge log sheets provided in Appendix A.

Upon completion of purging, samples were collected in accordance with the *Groundwater Monitoring Plan* (Battelle, 2000a). Samples to be analyzed for all analytes except TBA were collected in sample vials which were prepreserved with hydrochloric acid by the analytical lab. TBA was collected in an upreserved container. Following collection, all samples were labeled and stored at approximately 4°C until they were shipped and received by a State of California-certified laboratory. Each well was secured upon completion of sampling according to the protective measures described in the *Monitoring Well Protection Plan* (Battelle, 2000b). All purge water and water used to decontaminate the equipment was contained in drums or polyethylene tanks prior to disposal.

3.4 Quality Assurance/Quality Control Summary

All groundwater samples were collected and preserved in accordance with the methods stated in the *Groundwater Monitoring Plan* (Battelle, 2000a) and analyzed within the prescribed analytical holding times. Laboratory QC summary reports are provided in Appendix C. The laboratory's quality assurance (QA) oversight involved the performance of a first-level screening of the data and an indication of any deviations from their precision, accuracy, reporting limit, or laboratory quality control (QC) criteria. A representative from the laboratory signed the data sheets, ensuring that the screening described above had been completed. Subsequently, Battelle completed data validation as described in the *Groundwater Monitoring Plan* (Battelle, 2000a).

Quality assurance/quality control (QA/QC) samples were collected in the field to ensure that meaningful and representative data sets were generated. Table 4 summarizes the frequency of QC sample collection. During the February 2004 and May 2004 quarterly monitoring event, six field duplicate samples were collected per event to ensure the consistency and integrity of sample collection methods.

All duplicate samples showed consistency in results. Summary tables of all the analytical results are included in Appendix D.

Dedicated sample tubing is used for each well rather than having dedicated tubing for wells with high and low historical concentrations. Equipment rinsate samples were collected to ensure that sampling devices did not contribute to analyte concentrations in the samples. Six rinsate samples were collected during the February 2004 quarterly monitoring event, and five rinsate samples were collected during the May 2004 event. No analytical results for rinsate samples were detected at levels above their respective PQLs.

3.5 Deviations from the Groundwater Monitoring Plan

Deviations from the sampling protocol outlined in the *Groundwater Monitoring Plan* (Battelle, 2000a) included the following:

February Monitoring Event

- Certain wells were not sampled during the February sampling event due to changes in the monitoring program (see Table 5). These wells are: MW-1A, MW-4A, MW-10A, MW-1B, 970-MW1, 970-MW2, 970-MW4, 970-MW5, NA-0, PZ-4, MW-M11, MW-M12, MW-4B, MW-5A, MW-6B, MW-M24, IT-MW-81S, MW-M20S, MW-M25S, MW-M25D, MW-M26S, MW-M27S, MW-M27D, IT-EW-91-1, and IT-2MW-2.
- The following wells purged dry before three well volumes were recovered; however, samples were collected from these wells and submitted for analyses: MW-M10, 970-MW3, MW-M15, PZ-10, PZ-1, MW-3B, IT-GMP-18, MW-M22, MW-M8, MW-M20D, MP-1D, MW-2D, MW-3D, NA-4, NA-7, 957-MW4, MW-M8-BR, MW-M2-BR.
- Well PZ-11 was not purged, just sampled due to slow recharge/low well volume.

May Monitoring Event

- One well (IT-EW-91-1) was not sampled during the May sampling event due to changes in the monitoring program (see Table 5).
- The following wells purged dry before three well volumes were recovered; however, samples were collected from these wells and submitted for analyses: MW-M12, IT-MW-81S, MW-M14S, MW-M22, MW-M8, PZ-1, MW-M8-BR, MW-2E-BR, MW-M2-BR, MW-2D, MW-M15, MW-M1, MW-M19, 970-MW3, MW-3B, MW-3D, MW-6A, NA-4, NA-7, 957-MW4, PG-MW5, MW-M10, MW-9A, MW-4A, MW-6B, MW-4B, and PZ-10.
- Samples were not collected from PZ-11 because this well was dry.
- Sampling of MW-5A was inadvertently omitted from the May 2004 sampling event.

3.6 Summary of Findings

This section provides a summary of findings for the February and May 2004 groundwater-sampling events. Copies of original laboratory data sheets are provided in Appendix C. Tabulated results of the cumulative groundwater analytical data are provided as Appendix D.

3.6.1 Maximum and Average Concentrations. Maximum concentrations of benzene and MTBE in groundwater were 160 µg/L and 17,000 µg/L, respectively, for the February 2004 quarterly monitoring event and 210 µg/L and 19,000 µg/L, respectively, for the May 2004 monitoring event (Table 6). Maximum MTBE concentrations in both February and May 2004 were detected at MW-3D, while maximum benzene concentrations in February and May 2004 were detected at NA-7. Average concentrations of benzene and MTBE in groundwater were 5 µg/L and 1,184 µg/L, respectively, for February 2004 and 5 µg/L and 1,413 µg/L, respectively, for May 2004. The historical maximum and average concentrations of gasoline constituents of concern for each historical monitoring event also are presented in Table 6. These concentrations are in line with the generally decreasing trends that have been observed over time during previous sampling.

The maximum concentrations of benzene in February 2004 and May 2004 (160 µg/L and 210 µg/L, respectively) are higher than those observed last year in February 2003 and May 2003 (65 µg/L and 150 µg/L, respectively), but less than the benzene concentration measured in November 2003 (230 µg/L). The maximum MTBE concentrations for the February 2004 and May 2004 sampling events (17,000 µg/L and 19,000 µg/L, respectively) are less than the concentrations detected in the February 2003 and May 2003 sampling events (25,000 µg/L and 24,000 µg/L, respectively).

The average concentrations of benzene during the February 2004 and May 2004 sampling events (5 µg/L for both sampling events) are consistent with those observed during February 2003 and May 2003 (5 µg/L and 6 µg/L, respectively) and all other preceding February and May sampling events (Table 6). Similarly, the average concentrations of MTBE during the August and November 2003 sampling events are less than the average concentrations observed during the February and May 2004 monitoring events, and less than previous February and May monitoring events. Average concentrations reported in Table 6 were calculated using one-half of the detection limit for nondetect results during each quarterly monitoring event. The comprehensive benzene and MTBE data indicates that maximum and average concentrations are decreasing. These decreasing maximum and average concentrations indicate a long-term decreasing concentration trend.

3.6.2 Bedrock Wells. A summary of the analytical data for all the bedrock wells is presented in this section and provided in Appendix D along with all other tabulated groundwater and surface water data. Results of laboratory analyses performed on the groundwater samples collected from the bedrock wells (MW-9A, MW-3D, MW-2E-BR, MW-M2-BR, and MW-M8-BR) during the February and May 2004 quarterly monitoring events are presented in Table 7. Each of the bedrock wells listed in Table 7 is grouped with another monitoring well that is screened nearby, in the shallow alluvium. One of the main objectives of the chemical analyses conducted on groundwater samples collected from the bedrock wells and nearby alluvial wells is to determine if there is a continuous aquifer at the Site rather than an alluvial aquifer and separate bedrock aquifer. Based on the data provided in Table 7, it is evident that the majority of chemical concentrations detected in the bedrock wells are of the same order of magnitude as the concentrations detected in the nearby alluvial wells. The only exception to this is MTBE detected in MW-M8-BR (7.3 µg/L and 1.9 µg/L) and MW-M8 (150 µg/L and 1,300 µg/L) during February and May 2004, respectively. The likely reason for this discrepancy is that the bedrock well near MW-M8 is installed much deeper than any of the other bedrock wells at the site. The screened interval at MW-M8-BR is from 49 ft to 59 ft bgs. The next deepest bedrock well at the site is MW-2E, which is screened from 33 ft to 43 ft bgs. MTBE detected in MW-M8-BR has a greater distance to diffuse from the alluvium to the deeper portions of the bedrock because this well is screened much deeper than the other bedrock wells at the site.

Geochemical parameters including calcium, magnesium, sodium, potassium, alkalinity (including carbonate and bicarbonate), sulfate, and chloride were analyzed for in groundwater samples collected from all the bedrock wells (except MW-9A) and nearby alluvial wells. The results from these analyses were compared graphically by plotting the results on a Piper diagram (also referred to as a trilinear diagram) and by comparing the Stiff diagrams. Both of these graphical analyses are commonly used to compare the geochemical character of groundwater collected from different sources. Figure 3 through Figure 6 present the results of samples collected during February and May 2004 sampling events. Using the Piper diagram, the percentage composition of anions, cations, and total ions can be displayed on a graph. The major cations are plotted on one diagram while the major anions are plotted on another diagram. A third, diamond-shaped field located between the two trilinear diagrams represents the composition of water with respect to both cations and anions (Fetter, 1988). Groundwater of similar compositions will plot in the same general area of the graph as shown on Figures 3 through 6.

A second graphical means of comparing groundwater geochemistry is the Stiff diagram. Using the Stiff diagram, the cations and anions are plotted on opposite sides of a vertical line and when data points are connected they form a polygonal shape. These shapes, generated for each groundwater sample, are then compared to the shapes from other samples. This comparison can be made on Figure 3 through Figure 6. These patterns provide a means by which the chemistry of different water samples can be easily compared (Fetter, 1988). While the bedrock well pattern does not exactly match the pattern generated for the alluvial well, the similarity between them provides good evidence that these waters are likely from the same source but different hydrochemical facies. In general, the results of these evaluations indicate that the water in both the bedrock and alluvium are of similar composition. These data, combined with the similar MTBE concentrations in alluvial and bedrock wells, indicate that it is very likely that groundwater beneath the site exists as one hydrologic unit rather than an alluvial aquifer and a separate bedrock aquifer. Quarterly monitoring will continue at the bedrock well and alluvial well locations so comparisons can be made of the analytical results from groundwater samples.

3.6.3 Nested Well Pairs. Five nested well pairs were installed within the alluvial aquifer on former HAAF property to determine if a variation of MTBE concentrations exists between the upper and lower levels of the aquifer. Historical analytical results from the well pairs do not provide evidence of MTBE stratification (see Table 8). During the February 2004 sampling event, the deep wells, MW-M14D, MW-M20D, and MW-M26D, plus the shallow well, MW-M14S, were sampled due to changes in monitoring requirements (Table 5). Concentrations observed in MW-M14D, MW-M14S, and MW-M26D in February 2004 were slightly higher than those reported for November 2003, while concentrations in MW-M20D are less than those reported in November 2003 (Table 8). For the May 2004 sampling event, deep wells, MW-M14D, MW-M20D, MW-M25D, MW-M26D, and MW-M27D, plus the shallow well, MW-M14S, were sampled due to changes in monitoring requirements (Table 5). An MTBE concentration less than the detection limit (<0.5 μg/L) was observed in MW-M25D. MTBE concentrations in the deep wells sampled during May 2004 were less than those reported in February 2004; concentrations in wells MW-M14S and MW-M14D were greater than those reported in May 2003 (Table 8).

3.6.4 Water-Level Measurements Over Time. The groundwater-level measurements collected during the February and May 2004 sampling events indicated that the groundwater elevation was generally consistent with historical observations. Appendix B contains the cumulative water level measurements for all Site wells. Figure 7 shows water levels over time at selected wells along the centerline of the Site, covering the length of the MTBE plume. Seasonal fluctuations in groundwater elevations are evident over time (Figure 7), with water levels highest in February and much lower in August and November. The general groundwater flow direction to the north has been relatively constant over the last two quarterly monitoring events (Figure 2).

3.6.5 Concentration Versus Time Trends. Graphical representations of selected data inputs for decision criteria (as defined in Table 3 of the *Groundwater Monitoring Plan* [Battelle, 2000a]) and revised in Table 1 of the *Annual Site Status Report (for the Year 2003)* (Battelle, 2004) are presented in Figures 7 through 22 for both the February and May 2004 monitoring events.

Concentration versus time graphs are provided for transect wells located in Area A (Figures 8, 9, and 10), Area B (Figures 11, 12, and 13), and Area D (Figures 14, 15, and 16). Figures 8, 9, and 10 show benzene, MTBE, and TPH-G concentrations, respectively, for transect wells located in Area A (near former UST 970). The figures illustrate general decreasing concentrations of all analytes over time. Seasonal fluctuations are evident throughout the 2001, 2002, and 2003 sampling events in MW-6A for benzene where concentrations start increasing in August, peaking in November, and then decrease in February and May (Figure 8). Benzene concentrations in wells MW-7A, MW-5A, 970-MW1, and MW-1A continued to decrease or remain consistent throughout 2004. For MTBE (Figure 9), concentrations in MW-7A continue to show cyclic increasing concentrations in February, as it has since 2001, whereas concentrations of MTBE in the other transect wells have remained consistent over the 2004 sampling events as well as consistent with the 2003 and 2002 sampling events. TPH-G concentrations are also affected by seasonal fluctuations in wells MW-1A, MW-6A, and MW-7A, but overall, concentrations decrease or remain consistent during 2004.

Generally decreasing benzene, MTBE, and TPH-G concentrations continue to be observed in Area B transect wells (Figures 11, 12, and 13). Area D (near former UST 957) transect wells, as shown in Figures 14, 15, and 16, continue to show historically fluctuating benzene, MTBE, and TPH-G concentrations, but an overall decreasing trend is evident for all three analytes. Area D benzene concentrations (Figure 14) have remained relatively constant in wells 957-MW3 and 957-MW4. The benzene concentrations in MP-1D have exhibited decreasing concentrations throughout 2003 and during the first two quarters of 2004. However, the benzene concentrations in MW-1D continue to fluctuate in the first quarter sampling events as shown for 2001, 2002, 2003, and 2004. MTBE concentrations in Area D (Figure 15) continue to fluctuate among sampling events; however, MTBE concentrations have generally decreased since November 1999. Area D TPH-G concentrations (Figure 16) have remained constant at nondetect levels in monitoring wells 957-MW3 and 957-MW4 since May 2002. Concentrations in MP-1D and MW-1D are generally stable and have decreased in concentration since the May 2003 sampling event. The overall decreasing trend in Area A and the lack of a consistently increasing trend in Area D indicate that a continual source to groundwater does not exist based on the decision criteria established in Table 3 of the *Groundwater Monitoring Plan* (Battelle, 2000a).

Figures 17 and 18 plot benzene and MTBE concentrations, respectively, in plume perimeter wells over time. Figure 17 illustrates that benzene has not been detected above the reporting limit in any perimeter wells, indicating that a stable benzene plume exists. The MTBE plume perimeter wells included in Figure 18 show relatively stable MTBE concentrations with the exception of IT-GMP-17, IT-PZ-5, and MW-M13. The MTBE concentrations in IT-GMP-17 continue to exhibit an increasing trend. Because MTBE has been detected at IT-GMP-17 and IT-GMP-18, monitoring well IT-MW-81 serves as the plume perimeter monitoring well in the northeast portion of the plume. Concentrations of MTBE continue to remain below detection limits in IT-MW-81. MTBE concentrations in IT-PZ-5 dropped to below detection limits in August 2003, but were detected at low levels (<10 μg/L) in the three quarters since. MTBE concentrations at MW-M13 have been increasing since November 2001. Stable MTBE concentrations in other wells included on Figure 18 indicate that little to no plume migration is occurring in areas other than IT-GMP-18, IT-PZ-5, and MW-M13. The MTBE concentration in MW-M2 exhibited a noticeable decrease in February 2003 from the November 2002 sampling event and stayed below detection limits throughout 2003 and during the first two quarters of 2004.

Figures 19 through 22 show benzene and MTBE concentrations along their respective plume center during February and May for the 1999 through 2004 monitoring events. The benzene concentrations in February and May 2004 (Figures 19 and 20, respectively) are generally lower than those reported in February and May 2003, with the exception of concentrations at monitoring well NA-7, which are slightly higher in 2004 than in 2003. Concentrations at most wells are lower than those reported in February and May 2002, 2001, 2000, and 1999. These results indicate that no significant rebound of benzene concentrations has occurred since interim remedial action (in situ air sparging/SVE) activities were concluded in October 1999. Figures 21A and 22A show that MTBE concentrations detected during February and May 2004 are consistently similar to or lower than those detected during the months of February and May in previous years. The well ID in parentheses after selected wells indicates a well that has been abandoned. Although the replacement wells are not in the exact locations of the abandoned wells, they are presented here as such for comparison purposes.

Because of the large scale required to show maximum MTBE concentrations in Figures 21A and 22A, MTBE fluctuations in the northeastern portion of the plume are not evident. For this reason, downgradient monitoring wells IT-MW-92-38, IT-PZ-9, IT-GMP-17, and IT-GMP-18 were plotted separately in Figures 21B and 22B for the February and May 2004 sampling events, respectively. Unlike other portions of the plume, IT-PZ-9, IT-GMP-17, and IT-GMP-18 have consistently demonstrated increasing concentrations over time. MTBE concentrations in IT-MW-92-38 decreased in February 2004 (52 μg/L) but increased in May 2004 (1,400 μg/L). The most likely reason for increases in MTBE concentrations in the northeastern portion of the plume are associated with the hydrogeology in the area, and was discussed in detail in Attachment 1 of the *Annual Site Status Report (for the Year 2001)* (Battelle, 2002c).

3.6.6 Other Oxygenates. TBA (an MTBE degradation product) and TBF were monitored in 22 wells during February 2004 and 29 wells during May 2004. Of the wells that were sampled, eight were biosparging performance goal wells (results discussed in Section 5.0). In the majority of wells that were sampled, TBA was detected but showed no sign of accumulation. Generally, wells where TBA was detected also have low-level detections of TBF. Fuel oxygenates ETBE, TAME, and DIPE were monitored in 14 wells in February and 21 wells in May 2004. One or more of the fuel oxygenates was detected at low levels during February 2004 in six wells, and at eight wells in May 2004. The monitoring wells where these oxygenates were detected are mostly located in the regions of highest MTBE concentration. All analytical results for TBA and oxygenate monitoring is provided in Appendix D.

3.6.7 Mass Estimates. Table 9 provides dissolved MTBE and benzene mass estimates calculated for each quarterly monitoring event since May 1998 for benzene and November 1998 for MTBE. The data are presented by year so that seasonal variations over time can be observed. Note that although the mass estimate calculations are made consistently every quarter, changes in MTBE mass occur when the monitoring well network is modified (i.e., well abandonment, replacement, or additional installation) because dissolved mass is estimated from the wells being monitored. Because some wells that were historically sampled and included in the mass estimates were not sampled in the February 2004 event as a result of the revised monitoring requirements (refer to Table 11 of the *Annual Site Status Report (for the Year 2003)* [Battelle, 2004], mass estimates were not calculated. Mass estimates were, however, calculated in the May 2004 sampling event as all wells were sampled according to the revised monitoring requirements. The dissolved mass estimate of 0.02 kg for benzene in May 2004 was less than the estimated mass of 0.03 kg for November 2003, and also less than mass estimates for previous May sampling events (Table 9). The MTBE mass estimate for May 2004 decreased from the November 2003 sampling event and the previous May 2003 sampling event. Although a general decreasing trend in mass has been observed at the site, some variations (i.e., increases) have been observed periodically due to seasonal variations. In addition, variation in mass estimates can be attributed to the use of the computer software program, Earthvision^{TM}, which is used to estimate mass. The methodology used by the software program to estimate mass is significantly affected by the volume of water present in the saturated zone; therefore, MTBE mass estimates may be artificially inflated at times because water elevations are higher in areas of greater concentration, rather than concentration differences that actually exist within the wells.

3.6.8 Plume Status. Benzene and MTBE plume contour maps for May 2004 are presented in Figures 23 and 24, respectively. Plume contour maps for the February 2004 sampling event are not provided because not all of the wells were sampled during this quarter, as they were in May 2004. Recall that the sampling of the monitoring network is reduced in the February and August sampling events per RWQCB-approved changes presented in Table 13 of the *Annual Site Status Report (for the Year 2001)*. Concentrations of benzene in wells sampled in both February and May 2004 were similar (refer to Appendix D), indicating that the overall shape and downgradient extent of the benzene plumes are similar for both monitoring events.

Concentrations of MTBE in wells sampled in both February and May 2004 were similar (refer to Appendix D), indicating that the overall shape and downgradient extent of the MTBE plumes are similar for both monitoring events. The overall shape and downgradient extent of the MTBE plume for May 2004 (Figure 24) is similar to the last sampling event in which all wells were sampled (i.e., the November 2003 sampling event).

Other observations made with respect to particular wells for sampling performed in February and May 2004 were as follows:

- MTBE concentrations in monitoring well MW-3B, located near the Northbay Children's Center complex, remained below the reporting limit of <0.5 μg/L. These data are consistent with the long-term trend of nondetect MTBE concentrations in this well. The MTBE concentration in the other monitoring well located near the Northbay Children's Center, 970-MW3, was above the detection limit of 0.5 μg/L, but has decreased since November 2003. Throughout 2004, the MTBE concentrations in 970-MW3 were 1.2 μg/L in February, and 0.46 J μg/L in May, both of which are below the Basin Plan Water Quality Objective of 13 μg/L, as well as the nuisance level of 5.0 μg/L. Future data from well 970-MW3 will be carefully monitored.

- The MTBE concentration in IT-GMP-17 continued to increase to 650 μg/L in February 2004, and 840 μg/L in May 2004. These concentrations are higher than concentrations for the previous year for February and May in IT-GMP-17. Concentrations at monitoring well IT-GMP-18 have also increased at the plume's leading edge. For the past 14 quarters, concentrations were below the reporting limit of <0.5 μg/L; however, the concentrations in IT-GMP-18 were 0.79 μg/L in February 2004, and 1.45 μg/L in May 2004. For IT-PZ-9, the MTBE concentration has remained relatively consistent over the four quarterly events in 2003; however, concentrations are slightly higher than those detected in 2003. The northeastern portion of the MTBE plume will continue to be closely monitored.

- MTBE was detected in MW-M13 at a concentration of 37 μg/L in February 2004 and 44 μg/L in May 2004. This well serves as an MTBE perimeter well and data indicate concentrations of MTBE are increasing over time at this location. The concentrations in MW-M13 are increasing slowly as compared to those in the northeastern edge of the plume because there seems to be a greater tendency for groundwater to flow around Ammo Hill to the east.

3.6.9 Evaluation of Monitored Natural Attenuation of the MTBE Plume on Former HAAF Property. MNA (also referred to as intrinsic remediation) relies on naturally occurring processes such as biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization to reduce concentrations in groundwater. Because a biosparging system has been installed to contain and treat the MTBE plume on currently Navy-owned property (i.e., property south of the railroad tracks), the focus of the MNA evaluation is on various subareas of the MTBE plume that are not directly affected by the biosparging system. The subareas that were evaluated for MNA are shown on Figure 24 and include:

- The area near the former UST 970,
- Hamilton Meadows Area (i.e., the area just north of State Access Road),
- The western edge of the plume, and
- The northeast leading edge.

Parametric and nonparametric regression analyses were conducted to quantify trends in MTBE concentration for subareas, as well as individual wells within subareas. Table 10 identifies the wells by subarea. The analyses were conducted using MTBE data through February 2004 for the Hamilton Meadows Area, the Western Edge, and the Leading Edge. Sparging was conducted in the Former UST 970 subarea in October 1999 to remove MTBE from the source area of the plume. Because remedial activities were completed in October 1999, it is assumed that this subarea has experienced natural attenuation since that date. To determine the extent of natural attenuation upon completion of sparging, the trend analyses for the Former UST 970 subarea were conducted using data from fourth quarter 1999 through February 2004.

The parametric regression method used for evaluating trends at individual wells is a method proposed by Buscheck and Alcantar (1995), which is based on a regression of the logarithms of contaminant concentration versus time at each well. As a result, separate trend estimates are obtained for each well. A parametric multiple-location method by Naber, et al. (1997) was used to evaluate the subareas of the plume. This method involves fitting a regression model to the logarithms of MTBE concentrations for a collection of wells using a common slope for all wells but different intercepts, which represent different “initial values” for each of the sampling locations. As a result, there is a single estimate for the “average” trend within the subarea while allowing for differences in MTBE concentration magnitude among the wells. Both parametric regression methods were extended to account for seasonal fluctuations by one of two methods: incorporating Fourier terms to represent the seasonal fluctuations or using separate intercepts for each seasonal event for each well.

The nonparametric method for assessing trends at individual wells consisted of the Mann-Kendall procedure (Mann, 1945; Kendall, 1938) to test whether there was a statistically significant trend in MTBE concentrations at a well, while the Sen procedure (Sen, 1968) provided an estimate of the trend (regression slope). Estimating the trend involved obtaining estimates of the trend by looking at the standardized (by time) difference in MTBE concentrations for each pair of observations at a well and taking the median of those estimates. The nonparametric analysis for multiple-location trends (i.e., by subareas) was developed by von Belle and Hughes (1984). Their method allocates the variability within the observed rankings among season, well, and trend and provides tests for statistically significant trends either with or without seasonal fluctuations. To obtain a nonparametric estimate of the “average” slope within each subarea, a modification of Sen’s procedure was used to estimate the trend. All of the individual trend estimates for each well (based on each pair of observations) in the subarea are combined, and the median of those estimates is used to provide an estimate of the "average" trend.

Table 10 summarizes the results of the analyses by subarea and by individual wells. The subarea results appear on the left-hand side of the table while the individual well results appear on the right-hand side of the table. It should be noted that the von Belle-Hughes nonparametric analysis could not be completed due to large discrepancies in sample sizes among wells within each zone. However, Sen-like trend estimates were obtained. Estimates of annual rates of reduction can be derived from the slope and Sen estimates by using the following equation:

$$\left(1 - e^{\text{slope}}\right) \text{x } 100 = \text{Annual concentration trend}$$

The subarea analyses indicated that MTBE concentrations have been decreasing over time in the Former UST 970, Hamilton Meadows, and the Western Edge areas. MTBE concentrations have been increasing over time in the Leading Edge area. Note that in general, the parametric and nonparametric estimates of the trends agree. However, discrepancies exist in the Western Edge subarea and the Leading Edge subarea, where the nonparametric estimates are closer to zero. These discrepancies result from a heavy influence by nondetect observations in the nonparametric estimates. Annual reduction rates for all of the subareas are provided on Table 11.

The individual-well results were examined to determine the degree of variability within each of the subareas. For the Former UST 970 subarea, most wells showed a statistically significant (p-value <0.05) decrease in MTBE concentrations over time, leading to the conclusion that MTBE concentrations in this subarea are decreasing. In the Hamilton Meadows subarea, which shows a statistically significant "average" decrease in MTBE concentrations, there are wells that exhibit decreasing MTBE concentrations as well as wells that exhibit increasing MTBE concentrations. The two largest increasing trends are seen at wells with relatively few observations (3 and 5), so that the overall subarea trend is not affected much by those wells. For the Leading Edge subarea, the majority of the wells exhibit increasing MTBE concentration trends. In the Western Edge subarea, the MTBE concentration trend varies among the wells, although few have statistically significant trends (p-value < 0.05). Parametric regressions can not be performed when many of the wells are nondetect; therefore there are some wells in the Western Edge Subarea for which the parametric analysis has no estimate or p-value. In all of these cases, the nonparametric regression showed that there was no trend in the MTBE concentrations over time.

Section 4.0: SURFACE WATER MONITORING

The following subsections discuss surface water sampling that was conducted at five locations in and around Pacheco Creek in February and May 2004. The February and May 2004 quarterly monitoring events represent the sixteenth and seventeenth quarterly surface water monitoring events.

4.1 Analytical Program

All surface water samples were analyzed for BTEX and MTBE by EPA Method 8260B (gas chromatography/mass spectrometry [GC/MS]). The decision criteria and objectives for sampling locations were presented in Table 4 of the *Groundwater Monitoring Plan* (Battelle, 2000a) and are presented as revised in Table 12. Analytical methods and relevant sampling information are summarized in Table 2. Laboratory PQLs for analytes based on clean matrices are listed in Table 3.

4.2 Sampling

Samples were collected in accordance with the procedures described in the *Groundwater Monitoring Plan* (Battelle, 2000a). The locations where surface water samples were collected during this quarterly monitoring event are shown on Figure 25. These locations include one sample collected upstream of the Site, two samples within the area of dissolved MTBE in underlying groundwater, and two downstream samples (one at the edge and one approximately 1,500 ft downstream of the edge of the extent of dissolved MTBE in underlying groundwater). Figure 26 shows the locations selected and sampled to determine whether a source of MTBE exists in water originating from an individual culvert that enters the creek in this area.

During surface water sample collection, the depth to surface water was measured and recorded at one upstream and one downstream location (see Appendix C). Surface water samples were collected directly into preacidified volatile organic analysis (VOA) vials. Immediately following sample collection, VOA vials were maintained at 4°C until shipment and receipt by the analytical laboratory. Copies of the laboratory analytical reports and sampling log sheets (in addition to all pertinent surface water sampling information) are provided in Appendix C.

4.3 Deviations from the Monitoring Plan

PC-SW-CE is the only individual culvert location that is to be sampled (Figure 26). Written approval to discontinue sampling the other three locations (PC-SW-C1, PC-SW-C2, PC-SW-CW) was received from the RWQCB on July 24, 2002. This change is reflected in Table 12. Depth of surface water and flow measurements will be continued at these three locations, as requested by the RWQCB.

An additional surface water sampling location identified as PC-SW-5 (Figure 25) was added to the sampling protocol in the February 2001 monitoring event. The objective of this sampling location was to determine the surface water/groundwater interaction in this area of the Site. The location was selected next to existing monitoring well IT-2MW-1, so that surface water and groundwater concentrations of MTBE can be compared (Figure 27).

4.4 Summary of Findings

This section provides a summary of findings for the February and May 2004 surface water sampling events. Tabulated results of the cumulative surface water analytical data are provided in

Appendix D along with the cumulative groundwater analytical data. Copies of original laboratory data sheets from the February and May 2004 surface water monitoring events are provided in Appendix C.

4.4.1 Surface Water Results. Figures 25 and 26 provide a comprehensive list of MTBE concentrations detected in Pacheco Creek at all sampling locations during each quarterly monitoring event. A cumulative summary of the surface water sampling results for gasoline constituents of concern at regularly sampled locations is provided in Table 13. Concentrations of MTBE were again below detection limits in PC-SW-1 for both the February and May 2004 sampling events. Figure 25 shows that MTBE was present upstream of the Site at location PC-SW-1 in Pacheco Creek in the November 2003 sampling event, but was not present in any previous quarterly sampling events (also see Table 13). The detection of MTBE at the upstream surface water sampling location was most likely a result of construction activities occurring in the area south of the Site, rather than associated with conditions at the Site. Quarterly sampling will continue at the upstream location to determine if there is an observable trend in MTBE concentrations.

The MTBE concentration detected at PC-SW-2, located immediately downstream of several culvert outfalls, was 3.1 μg/L in February 2004, but decreased to below detection limits in May 2004. For the February and May 2004 sampling events, MTBE concentrations at PC-SW-5 were detected at concentrations of 2 μg/L and 16 μg/L. MTBE concentrations at PC-SW-3 decreased in February and May 2004 to 1.7 μg/L and <0.50 μg/L, respectively, since November 2003 when the MTBE concentration was measured at 8.9 μg/L. Potential sources of MTBE at PC-SW-3 and PC-SW-5 include the storm sewer outlet (PC-SW-CE) that has been shown to contain the highest concentrations of MTBE prior to discharge to Pacheco Creek, or the MTBE plume originating from Navy property. The MTBE concentrations at PC-SW-4 in February and May 2004 were 2 μg/L and 1.7 μg/L, respectively. The MTBE concentrations detected in the current sampling event are well below the MTBE interim water quality objective of 66,000 μg/L recommended by RWQCB (1998) for the protection of freshwater organisms.

Surface water sampling performed during this quarterly event in the area of the North Hamilton Parkway Bridge (see Figure 26) was conducted to determine whether MTBE concentrations detected in the surface water could be associated with individual culvert outfalls entering Pacheco Creek. MTBE has only been detected at one culvert outfall (PC-SW-CE). The concentrations of MTBE from PC-SW-CE for the February and May 2004 sampling events were 150 μg/L and 0.21J μg/L, respectively.

In order to assess the surface water-groundwater interaction near PC-SW-5, comparisons of MTBE concentrations at PC-SW-5 and in IT-2MW-1 were made (Figure 27). Figure 27 illustrates MTBE concentrations measured in Pacheco Creek at PC-SW-5 and in the nearby monitoring well, IT-2MW-1, over 13 quarters of monitoring data. A comparison of MTBE concentrations in surface water and the nearby monitoring well does not provide clear evidence of surface water-groundwater interaction. Concentrations of MTBE in surface water and groundwater have varied over the quarters and have been at times significantly different from each other. The groundwater-surface water interaction is likely limited by the concrete lining of Pacheco Creek and the MTBE concentrations in surface water are more likely affected by the effluent from the eastern culvert outlet (PC-SW-CE), rather than groundwater conditions. The competency of the concrete lining of Pacheco Creek is not easily observable because of the presence of excessive vegetation (e.g., cattails) and the turbid nature of the water. However, an assessment of the lining will try to be obtained during future sampling events as is reasonably feasible.

Based on historical surface water sampling activities, the flowrates observed in Pacheco Creek are very low and in most cases, the creek flowrate will not register on the digital water velocity flowmeter. It has been observed that the flow is generally higher during February sampling events, especially following rain events.

Section 5.0: BIOSPARGING SYSTEM ACTIVITIES

Routine operation and monitoring of the biosparging system was performed from December 2003 through May 2004 as described in the *Final Remedial Design and Work Plan* (Battelle, 2002a). Activities included collecting field measurements, soil-gas samples, and groundwater samples. A description of these activities conducted from December 2003 through May 2004 is provided in this section. Previous biosparging activities were summarized in technical monthly reports that were forwarded to the RWQCB and other interested parties on October 3, November 6, and December 10, 2002, the *Semiannual Site Status Report* (for the Months February and May 2003) submitted on August 11, 2003 (Battelle, 2003b), and the *Annual Site Status Report* (for the Year 2003) submitted on February 27, 2004 (Battelle, 2004).

5.1 System Operation

The biosparging system operated normally from December 2003 to May 2004. Field measurements consisting of system operational parameters and groundwater field parameters were collected on a monthly basis in accordance with the *Final Remedial Design and Work Plan* (Battelle, 2002a). Appendix E contains the observations on the well purge and maintenance logs for the performance well sampling events. Appendix F contains the laboratory QC summary reports and analytical data for groundwater samples, and field data collected from the performance wells and soil-gas monitoring probes are provided in Appendix G.

5.1.1 System Operational Parameters. System operational parameters that were measured included sparging flowrates and injection pressures for each sparging well. In general, the sparging flowrates ranged from 2 to 6 cubic feet per minute (cfm), which is the design specification range of the biosparging system outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a). The flowrates remained fairly steady from December 2003 through May 2004; however, if flowrates were found to have increased above 6 cfm, they were adjusted down to below 6 cfm.

System operation was changed to a “pulsing” mode at the end of September 2003 to try and increase the treatment efficiency. Airflow to the individual biosparging injection wells is controlled at five separate control panels, or banks located around the Site. The “pulsing” mode of operation means approximately three of five banks are operating within the design range injection rates (i.e., 2-6 cfm) for two weeks while two of the banks are shutdown. Following two weeks of operation, airflow is rotated to three different banks of injection wells. The rotation of banks continues on a two-week schedule unless the Navy identifies another schedule that might better optimize system operation. The objective of the “pulsed” operation is to introduce air in a manner that differs from previous operations, such that subsurface mixing is promoted and additional MTBE is degraded.

During April 2004, a biosparging optimization plan was implemented in an attempt to improve system operations and cause more efficient MTBE mass removal. In this optimization plan, four groups of individual sparging wells were operated at different frequencies. Table 14 shows the groupings of wells and associated sparging frequencies. All wells were operated at flowrates as close to 6 cfm as possible (it is not possible to reach 6 cfm in several injection wells, which are located in less permeable, clayey soils).

5.1.2 Groundwater Field Parameters. Groundwater field parameters consisted of groundwater elevation and DO measurements in 18 monitoring wells located within the biosparging treatment area (see Appendix G). Most groundwater elevations increased slightly from December 2003 to May 2004 as a result of the wet season that occurs during the winter months. Overall, the biosparging system has not affected groundwater elevations in such a way that would change the groundwater flow direction within the biosparging treatment area.

The data provided in Appendix G indicate that DO levels in performance monitoring wells located near the biosparging treatment area (PG-MW1 through -MW5 and MW-M3) have been fairly consistent or decreasing slightly since December 2003. It should be noted that the DO meter was shipped to the manufacturer for routine maintenance immediately following the May 2004 sampling event. During the course of this maintenance, the DO sensor was found to be defective and was replaced. It is suspected that the DO sensor may have been dysfunctional from March to May 2004. Slight increases in DO levels are evident in most wells within the biosparging treatment area since the system was started in September 2002. Note that DO measurements during November 2002 were collected using a different probe and should not be considered when evaluating overall trends in DO concentrations. In December 2002, the Navy began collecting DO measurements using the same meter and procedure that is followed during quarterly groundwater monitoring events.

5.2 Soil-Gas Sampling Results

Soil-gas samples were collected according to the schedule in the *Final Remedial Design and Work Plan* (Battelle, 2002a). Table 15 presents the identification labels for each type of soil-gas monitoring probe. Figure 28 contains a site map showing the location of each soil-gas monitoring probe.

5.2.1 Laboratory Analytical Soil-Gas Measurements. Laboratory samples of soil-gas were collected from seven (7) shallow soil-gas monitoring probes, three (3) deep soil-gas monitoring probes, eight (8) system monitoring soil-gas probes, and two (2) RWQCB-requested quarterly soil-gas monitoring probes according to the schedule presented in Table 16. The sampling procedure followed for collecting soil-gas samples for laboratory analysis was consistent with that used to collect soil-gas samples for the *Final Revised Risk Assessment* (Battelle, 2001a). Duplicate samples were collected for QA/QC purposes from the entire group of soil-gas samples at a rate of 10% during each sampling event. All laboratory samples were analyzed for BTEX, MTBE, 1,2,4-trimethylbenzene (TMB), 1,3,5-TMB, isopropylbenzene, *n*-propylbenzene, and *sec*-butylbenzene.

Laboratory samples of soil-gas were collected from the seven (7) shallow soil-gas monitoring probes consistent with the sampling schedule outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a) and on the dates presented in Table 16. The laboratory results indicate that threshold levels as presented in Table 5 of the *Final Remedial Design and Work Plan* (Battelle, 2002a) were exceeded in two (2) shallow soil-gas monitoring probes (SG-21-3 and SG-24-3) during the December 2003 through May 2004 sampling events. The risk associated with each exceedance was determined using the Department of Toxic Substances Control (DTSC) risk models, which were consistent with the 30-year residential scenario considered in the *Final Revised Risk Assessment* (Battelle, 2001a). For each exceedance, the total cancer risk did not exceed 1E-06 and the noncancer hazard index did not exceed 1.0. Laboratory results for the shallow soil-gas monitoring probes are provided in Appendix G.

Gasoline constituent concentrations at all of the shallow soil-gas sampling locations have been stable to decreasing at low-level or nondetect concentrations between December 2003 and May 2004. Concentrations seem to have stabilized more than they were during the early stages of system operation. The MTBE concentration at SG-21-3, which has been a monitoring point of concern in the past, has decreased significantly over the past six months. MTBE was detected at 2,026 $\mu g/m^3$ at SG-21-3 in December 2003. Concentrations increased to 2,123 $\mu g/m^3$ in February 2004, and then decreased to about 1,600 $\mu g/m^3$ in March and April 2004. However, in May 2004 the MTBE concentration at SG-21-3 dropped to 131 $\mu g/m^3$ (with a duplicate at 148 $\mu g/m^3$). Some minor variations in concentrations would be expected even without biosparging operations because the soil-gas analyses are highly sensitive, and can detect concentrations on the order of 1 $\mu g/m^3$. In addition, seasonal fluctuations such as decreased rainfall during the summer months certainly have an effect on conditions in shallow soil-gas. The important point is that the Navy has conducted monthly sampling in accordance with the *Final Remedial Design and Work Plan* (Battelle, 2002a), and the results of that sampling indicate that the area is safe for residents, as well as students and faculty at the Northbay Children's Center and Novato Charter School. The Navy will continue with the aggressive monthly shallow soil-gas sampling and confirm that there is no unacceptable risk to these nearby receptors during any period of biosparging system operation.

Laboratory samples of soil-gas were collected from the three (3) deep soil-gas monitoring probes consistent with the sampling schedule outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a) and on the dates presented in Table 16. Laboratory results for the three (3) deep soil-gas monitoring probes are summarized in Appendix G. The results indicate that nearly all of the gasoline constituents have decreased and remain well below baseline levels after system startup.

Laboratory samples of soil-gas were collected from the four (4) multilevel system monitoring soil-gas probes consistent with the sampling schedule outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a) and on the dates presented in Table 16. The laboratory results for the system monitoring soil-gas probes show that essentially all of gasoline constituent concentrations have remained below baseline levels since system startup (see Appendix G). These data indicate that significant hydrocarbons are not being added to the vadose zone within the treatment area through volatilization from the saturated zone.

Laboratory samples of soil-gas were collected from the two (2) RWQCB-requested quarterly monitoring probes in December 2003 and March 2004 consistent with the sampling schedule outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a). Laboratory results from the quarterly soil-gas monitoring probes are provided in Appendix G. The laboratory results indicate all gasoline constituent concentrations except benzene, 1,2,4-TMB, and 1,3,5-TMB at SG-19-3 were at or below their respective baseline levels. The measured concentrations in the RWQCB-requested quarterly monitoring probes do not constitute an unacceptable risk based on the DTSC risk models.

5.2.2 Field Soil-Gas Measurements. Soil-gas field parameters, consisting of measurements for volatile organic compounds (VOCs), oxygen, and carbon dioxide, were collected for shallow monitoring, deep monitoring, and system monitoring purposes. These data were collected to track changes in subsurface conditions caused by biosparging system operation and as indicators of biodegradation. Field measurements were made at the soil-gas monitoring probes to correspond with the collection of soil-gas samples for laboratory analysis. In instances where the sampling schedule did not require soil-gas samples to be collected for laboratory analysis, field measurements were collected from those soil-gas probes to monitor the oxygen, carbon dioxide, and VOC levels. The results of the soil-gas field measurements are presented in Appendix G.

The results indicate that oxygen and carbon dioxide levels remained relatively steady from December 2003 through May 2004 in the shallow and deep soil-gas monitoring probes. VOC concentrations remained low and steady in all of the shallow and deep soil-gas monitoring probes (see Appendix G; note the difference in scale among the graphs for VOC concentrations). These trends are consistent with the expected behavior of subsurface conditions during biosparging operation.

Field measurements were made at the four (4) multilevel system monitoring soil-gas probes consistent with the monthly schedule as outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a). The results of the soil-gas field measurements for the four (4) multilevel monitoring probes and for the RWQCB-requested quarterly points SG-19-3 and SG-25-3 are presented in Appendix G. In general, oxygen levels appear to have reached steady state at approximately 21% following the initial increasing trend seen soon after system startup. Carbon dioxide levels have remained low at the system monitoring probes. VOC concentrations remained low and steady in all of the multilevel system monitoring soil-gas probes from December 2003 to May 2004 (see Appendix G; note the difference in scale among the graphs for VOC concentrations). These trends are consistent with the expected behavior of subsurface conditions during biosparging operation.

5.3 Performance Goal Groundwater Sampling Results

Laboratory samples of groundwater were collected from eight (8) performance goal monitoring wells on a monthly basis from December 2003 to May 2004. These groundwater sampling events were conducted approximately 15 through 21 months after system startup and are consistent with the monthly sampling schedule outlined in the *Final Remedial Design and Work Plan* (Battelle, 2002a). One (1) duplicate sample was collected during each sampling event for QA/QC purposes. The laboratory samples were analyzed for BTEX, MTBE, and MTBE degradation products including TBA, TBF, and acetone. Baseline groundwater samples were collected in the eight (8) performance goal monitoring wells on June 23-24, 2002, for laboratory analysis. A complete listing of laboratory results is provided in Appendix F. Table 17 lists the laboratory results for MTBE concentrations in performance goal monitoring wells before and during biosparging system operation. Figure 29 is a site map showing the locations of performance goal monitoring wells PG-MW1 through PG-MW5, MW-M3, MW-M9, and MW-M10.

The laboratory results indicate that MTBE concentrations have decreased in all performance wells since the baseline sampling event. From December 2003 to May 2004, concentrations of MTBE decreased in four (4) wells and increased in four (4) wells. The maximum overall MTBE concentration decrease since system startup was at PG-MW2 from 20,000 μg/L to 360 μg/L, which constitutes a 98% decrease.

Figure 30 shows a plot of the actual versus expected trends in the average MTBE concentration of the performance goal monitoring wells. An average MTBE concentration of 2,551 μg/L existed in the performance goal monitoring wells in May 2004. The average MTBE concentration in the performance goal monitoring wells prior to initiating the biosparging system was 12,951 μg/L. The reduction observed over 21 months of system operation constitutes an 80% decrease in the average MTBE concentration across all performance goal monitoring wells. One of the main performance goals of the biosparging system is to reduce the average MTBE concentration in the performance goal monitoring wells by 95% to 99%, although the following paragraphs discuss specific reasons that this performance goal might not be applicable. Figure 30 shows that concentrations have not decreased as rapidly as expected. It seems that the biosparging system may be reaching asymptotic conditions. During the six-month period between December 2003 and May 2004, concentrations have decreased by about 6% in the biosparging performance wells.

It is important to note that the actual average MTBE concentration in performance goal monitoring wells (12,951 μg/L) was well below 30,000 μg/L, which was the assumed average concentration in the *Final Corrective Action Plan* (Battelle, 2002b) and *Final Remedial Design and Work Plan* (Battelle, 2002a). Because the actual average concentration was much lower than the assumed concentration, it can be expected that the trend of concentration decreases is not as rapid. Another noteworthy point is that some of the performance goal monitoring wells (e.g., PG-MW1 and PG-MW5) were installed in tighter soils, outside the target treatment area defined by a preferential flowpath that has been observed at the site. The treatment efficiency of the biosparging system cannot be completely represented by sampling all of the performance goal monitoring wells because some of the wells are installed in diffusion-limited soils, outside the target treatment area.

In addition to monthly sampling of the performance goal monitoring wells, the quarterly groundwater monitoring program has commenced in the area of the biosparging system. A visual interpretation of the biosparging treatment effectiveness can be deduced from the MTBE plume contour maps that are shown in Figure 31. The hot-spot of MTBE (concentrations >10,000 μg/L) located on currently-owned Navy property is shown to exist before the biosparging system was started, and following two months of system operation. During the February 2003 sampling events the MTBE hot-spot is shown to have disappeared, indicating that the biosparging is operating as expected. During the May 2004 sampling event, the MTBE hot-spot reappears, but appears to be much smaller than it was in May 2003. The Navy anticipated that the hot-spot would begin to collapse on itself after the biosparging system was initiated.

BTEX in the performance goal monitoring wells remained below the detection limit. In May 2004, acetone was detected at MW-M3 for the first time in 10 months, and at PG-MW5 for the first time since biosparging operation commenced. Over the past six months of system operation, TBA concentrations ranging between 9 μg/L and 650 μg/L were detected in the six (6) performance goal monitoring wells exhibiting the highest MTBE concentrations; however, the detections do not indicate TBA accumulation because the concentrations seem to be stable to decreasing. Concentrations of TBA during May 2004 ranged from 9 μg/L to 170 μg/L. TBF was detected in two performance goal monitoring wells (MW-M3 and PG-MW2), but at very low concentrations, which also indicates it is not accumulating.

5.4 Summary of Biosparging System Operation Results

Based on the data collected since system startup, the biosparging system is operating as expected. Biodegradation that is likely occurring within the saturated zone and deeper portions of the vadose zone is sufficiently controlling gasoline constituents in the subsurface. MTBE concentrations in groundwater are decreasing with some production (yet no significant accumulation) of degradation byproducts over the past 21 months of system operation. Significant decreases in MTBE concentrations exist in all performance monitoring wells. The laboratory results and field measurements of gasoline constituents in soil gas indicate that significant hydrocarbons are not being added to the shallow vadose zone within the treatment area or along pathways to nearby receptors.

MTBE concentrations within the biosparging treatment area are significantly reduced from levels that existed prior to system startup. The remedial action objectives (RAOs) of the Final CAP (Battelle, 2002b) that are applicable to the biosparging system (i.e., "stabilize and contain the MTBE groundwater plume on Navy property and reduce the time to achieve final cleanup levels [MCLs] for all gasoline constituents") have been met. Data collected from the performance goal monitoring wells from December 2003 through May 2004 indicate that concentrations decreased by only 6%, which indicates asymptotic conditions may exist. The Navy met with representatives from the RWQCB and DTSC on July 15, 2004 to discuss the performance of the biosparging system and determine whether it is time to shift to the next phase of the remedial alternative — monitoring for rebound within the treatment area followed by MNA. The Navy will continue to work with the RWQCB and DTSC to determine when it is time to shift remedial activities to monitoring for: 1) rebound within the biosparging treatment and 2) natural attenuation mechanisms.

Section 6.0: CONCLUSIONS AND RECOMMENDATIONS

This section presents conclusions drawn from the results of the February and May 2003 groundwater and surface water monitoring activities and recommendations based on the evaluation of the data.

6.1 Conclusions for Groundwater Monitoring

The overall shape and downgradient extent of the benzene and MTBE plumes is similar to the previous reported sampling event in November 2003. Pertinent observations of the results collected during February and May 2004 are as follows:

- Concentrations of MTBE in wells sampled in both February and May 2004 were similar, indicating that the overall shape and downgradient extent of the MTBE plumes are similar for both monitoring events. The overall shape and downgradient extent of the MTBE plume for May 2004 is similar to the last sampling event in which all wells were sampled (i.e., the November 2003 sampling event).

- The estimated benzene mass for May 2004 (0.02 kg) decreased slightly since the November 2003 sampling event (0.03 kg) and is lower than the benzene mass estimates from May sampling events in the previous three years.

- The estimated MTBE mass for May 2004 (116 kg) was less than the November 2003 and May 2003 sampling event (126 kg), and also is less than the MTBE mass estimates from May sampling events in the previous five years. Note that the estimated dissolved mass of MTBE in May 1999 was 277 kg.

- MTBE concentration in monitoring well MW-3B, located near the Northbay Children's Center complex, remained below the reporting limit of <0.5 µg/L. The MTBE concentration in the other monitoring well located near the Northbay Children's Center, 970-MW3, was above the detection limit of 0.5 µg/L, but has decreased since November 2003. Throughout 2004, the MTBE concentrations in 970-MW3 were 1.2 µg/L in February, and 0.46 J µg/L in May; both of which are below the Basin Plan Water Quality Objective of 13 µg/L, as well as the nuisance level of 5.0 µg/L.

- The MTBE concentration in MW-M2, located on the eastern perimeter of the plume, decreased significantly from the November 2002 event (370 µg/L) to below the detection limit in February 2003 and remained below the detection limit in May, August, and November 2003.

- The MTBE concentration in IT-GMP-17 continued to increase to 650 µg/L in February 2004, and 840 µg/L in May 2004. These concentrations are higher than concentrations for the previous year for February and May in IT-GMP-17. This well serves as an MTBE perimeter well. An increasing concentration trend is evident in this well. Future monitoring will continue to track the condition of the well.

- Concentrations at monitoring well IT-GMP-18 have also increased at the plume's leading edge. For the past 14 quarters, concentrations were below the reporting limit of <0.5

µg/L; however, the concentrations in IT-GMP-18 were 0.79 µg/L in February 2004, and 1.45 µg/L in May 2004. For IT-PZ-9, the MTBE concentration has remained relatively consistent over the four quarterly events in 2003; however concentrations are slightly higher than those detected in 2003. The northeastern portion of the MTBE plume will continue to be closely monitored.

- MTBE concentrations for February 2004 in bedrock wells MW-9A and MW-3D were reported at 94 µg/L and 17,000 µg/L, respectively. For May 2004, MTBE concentrations in bedrock wells MW-9A and MW-3D were reported at 270 µg/L and 19,000 µg/L, respectively. The MTBE concentrations in MW-9A and MW-3D have decreased in 2004 compared to sampling events in 2003. MTBE concentrations in the new bedrock wells that were installed in November 2003 ranged from <0.5 µg/L to 9.9 µg/L. Concentrations in two of the bedrock wells (MW-2E-BR and MW-M2-BR) are fairly consistent with their associated alluvial monitoring wells. Concentrations of MTBE in MW-M8-BR, however, are significantly less than concentrations in the associated alluvial well, MW-M8, which is likely a result of this bedrock well location being installed much deeper than the others at the site.

- All surface water sampling results are well below the interim water quality objective of 66,000 µg/L recommended in 1998 by the RWQCB for the protection of freshwater organisms.

- The MTBE concentration in the culvert sample (PC-SW-CE) was detected at 150 µg/L in February 2004, but decreased to below detection limits in May 2004. It also appears that MTBE was detected at low concentrations in PC-SW-2, PC-SW-3, PC-SW-4, and PC-SW-5 in February 2004. Concentrations of MTBE at all of these locations except PC-SW-5 decreased in May 2004.

6.2 Conclusions for Biosparging Activities

The biosparging system operated normally from December 2003 to May 2004. Results indicate that biodegradation is likely occurring within the saturated zone and deeper portions of the vadose zone, which suggests gasoline constituents in the subsurface are being sufficiently controlled. Pertinent observations of the results obtained between December 2003 and May 2004 are as follows:

- Soil-gas laboratory results for the seven (7) shallow monitoring probes indicate that threshold levels as presented in Table 5 of the *Final Remedial Design and Work Plan* (Battelle, 2002c) were exceeded in two (2) shallow soil-gas monitoring probes (SG-21-3 and SG-24-3). The risk criteria of 1E-06 for carcinogenic risk and 1.0 for noncarcinogenic hazard were not exceeded.

- Laboratory results of soil gas collected from the three (3) deep soil-gas monitoring probes indicate that nearly all of the gasoline constituents have decreased and remained well below baseline levels after system startup.

- Laboratory results of soil gas collected from the four (4) multilevel system monitoring soil-gas probes indicate that significant hydrocarbons are not being added to the vadose zone within the treatment area through volatilization from the saturated zone.

- Laboratory results of soil gas collected from the two (2) RWQCB-requested quarterly monitoring probes indicate all gasoline constituent concentrations except benzene, 1,2,4-TMB, and 1,3,5-TMB at SG-19-3 were at or below their respective baseline levels. The measured concentrations in the RWQCB-requested quarterly monitoring probes do not constitute an unacceptable risk based on the DTSC risk models.

- Laboratory results of groundwater collected from the eight (8) performance goal monitoring wells indicate that MTBE concentrations have decreased in all performance wells since the baseline sampling event. The most notable change has occurred in PG-MW2. The MTBE concentration was 20,000 μg/L in June 2002 and 360 μg/L in May 2004; a decrease of 98% since system startup.

6.3 Recommendations

The May 2004 monitoring event constitutes the 25th quarterly groundwater sampling event performed at the Site over the past six years. During this time, a large amount of analytical data has been collected to better understand the behavior of the dissolved gasoline constituent plumes.

Recommendations presented in the *Annual Site Status Report* (for the Year 2003) (Battelle, 2004) were approved by the RWQCB verbally on May 11, 2004; therefore, those recommendations were implemented during the May 2004 quarterly sampling event. Tables 1, 5, and 10 of this report reflect changes to the monitoring program based on implementation of the recommendations approved by the RWQCB. Additional recommendations will be presented in the next *Annual Site Status Report*, which will be distributed at the end of January 2005.

The biosparging system has clearly been effective at significantly reducing MTBE concentrations within the treatment area and on Navy property. Based on recent data collected over the past six months that indicate asymptotic conditions may exist within the treatment area, the Navy will confer with the RWQCB about when it is time to shift to the next phase of the remedial alternative (i.e., monitoring for rebound followed by MNA).

Section 7.0: FUTURE PLANNED ACTIVITIES

This section describes future activities to be performed in association with Former UST Site 957/970 during the two quarters of June through November 2004. An annual site status report will be distributed in January 2005 to report on activities over the next two quarters, in accordance with Task 9 of the RWQCB Order No. 00-064. Section 7.1 identifies activities to be performed in the field, and Section 7.2 includes all other activities not specifically associated with the above items.

7.1 Fieldwork

- Continue to perform quarterly groundwater and surface water sampling in August and November 2004 in accordance with the *Groundwater Water Monitoring Plan* (Battelle, 2000a). Sampling will be conducted according to the protocol presented in Tables 5 and 10 for groundwater and surface water, respectively.
- Perform routine operations and monitoring of the biosparging system as described in the *Final Remedial Design and Work Plan* (Battelle, 2002c). Some additional adjustments to system operation will likely be made to promote more cost-effective treatment efficiency in the near future.

7.2 Other Activities

- Continue to address regulatory and public concerns regarding biosparging system operation and property transfer issues.
- Determine, with RWQCB oversight, when biosparging operations should transition to monitoring for rebound of MTBE concentrations.

Section 8.0: REFERENCES

Battelle. 1998. *Draft Health and Safety Plan for Soil and Groundwater Remediation for the Former UST 957/970 Site at Department of Defense Housing Facility Novato, California: Revision 2.0.* Prepared for Naval Facilities Engineering Command, Engineering Field Activity West, San Bruno, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. March 18.

Battelle. 2000a. *Groundwater Monitoring Plan for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California: Revision 4.0 – Final.* Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. September 13.

Battelle. 2000b. *Monitoring Well Protection Plan for Former UST Site 957/970 at Department of Defense Housing Facility Novato, CA: Revision 1.0 – Final*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. October 2.

Battelle. 2001. *Final Revised Risk Assessment for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. June 8.

Battelle. 2002a. *Final Remedial Design and Work Plan for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California.* Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. December 27.

Battelle. 2002b. *Final Corrective Action Plan for Groundwater for Former Underground Storage Tank Site 957/970, Department of Defense Housing Facility, Novato, CA.* Prepared fro Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. March 1.

Battelle. 2002c. *Annual Site Status Report (for the Year 2001) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. January 25.

Battelle. 2003a. *Annual Site Status Report (for the Year 2002) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. January 31.

Battelle. 2003b. *Semiannual Site Status Report (for the Months February and May 2003) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California.* Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. April 11.

Battelle. 2004. *Annual Site Status Report (for the Year 2003) for Former UST Site 957/970 at Department of Defense Housing Facility Novato, California*. Prepared for Naval Facilities Engineering Command, Southwest Division, San Diego, CA; and Naval Facilities Engineering Service Center, Port Hueneme, CA. February 27.

Buscheck, T.E. and C.M. Alcantar. 1995. "Regression Techniques and Analytical Solutions to Demonstrate Intrinsic Bioremediation," In *Intrinsic Bioremediation*, R.E. Hinchee, J.T. Wilson, and D.C. Downey, (eds.), pp. 109-116. Battelle Press, Columbus, OH.

California State Water Resources Control Board. 1989. *Leaking Underground Fuel Tank Field Manual: Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure.* Issued by the Leaking Underground Fuel Tank Task Force. October.

CSWRCB, see California State Water Resources Control Board.

Fetter, C.W. 1988. Applied Hydrogeology. 2nd Edition. Pp. 355-358.

Regional Water Quality Control Board, San Francisco Bay Area. 1998. "Recommended Interim Water Quality Objectives (or Aquatic Life Criteria) for Methyl Tertiary-Butyl Ether (MTBE)." Memo from Stephan Morse, Chief Toxics Cleanup Division, to Toxics Cleanup Division Staff and Interested Parties. Oakland, CA. October 1.

RWQCB, see Regional Water Quality Control Board.

Kendall, M.G. 1938. "A new Measure of Rank Correlation," *Biometrika* **30**: 81-93.

Mann, H.B. 1945. "Nonparametric Tests Against Trend," *Econometrica* **13**: 245-259.

Naber, S.J., Buxton, B., McMillan-Darby, N., and Soares, A. 1997. "Statistical Methods for Assessing the Effectiveness of Intrinsic Remediation." In *Proccedings of the Fourth International In Situ and On-Site Bioremediation Symposium: Volume 5*. B.C. Alleman and A. Leeson (eds.). pp. 349-354. Battelle Press, Columbus, Ohio.

Sen, P.K. 1968. "Estimates of the Regression Coefficient Based on Kendall's Tau," *J. American Statistical Association*, **63**: 1379-1389.

von Belle, G. and J.P. Hughes. 1984. "Nonparametric Tests for Trend in Water Quality," *Water Resources Research* **20**(1): 127-136.

FIGURES

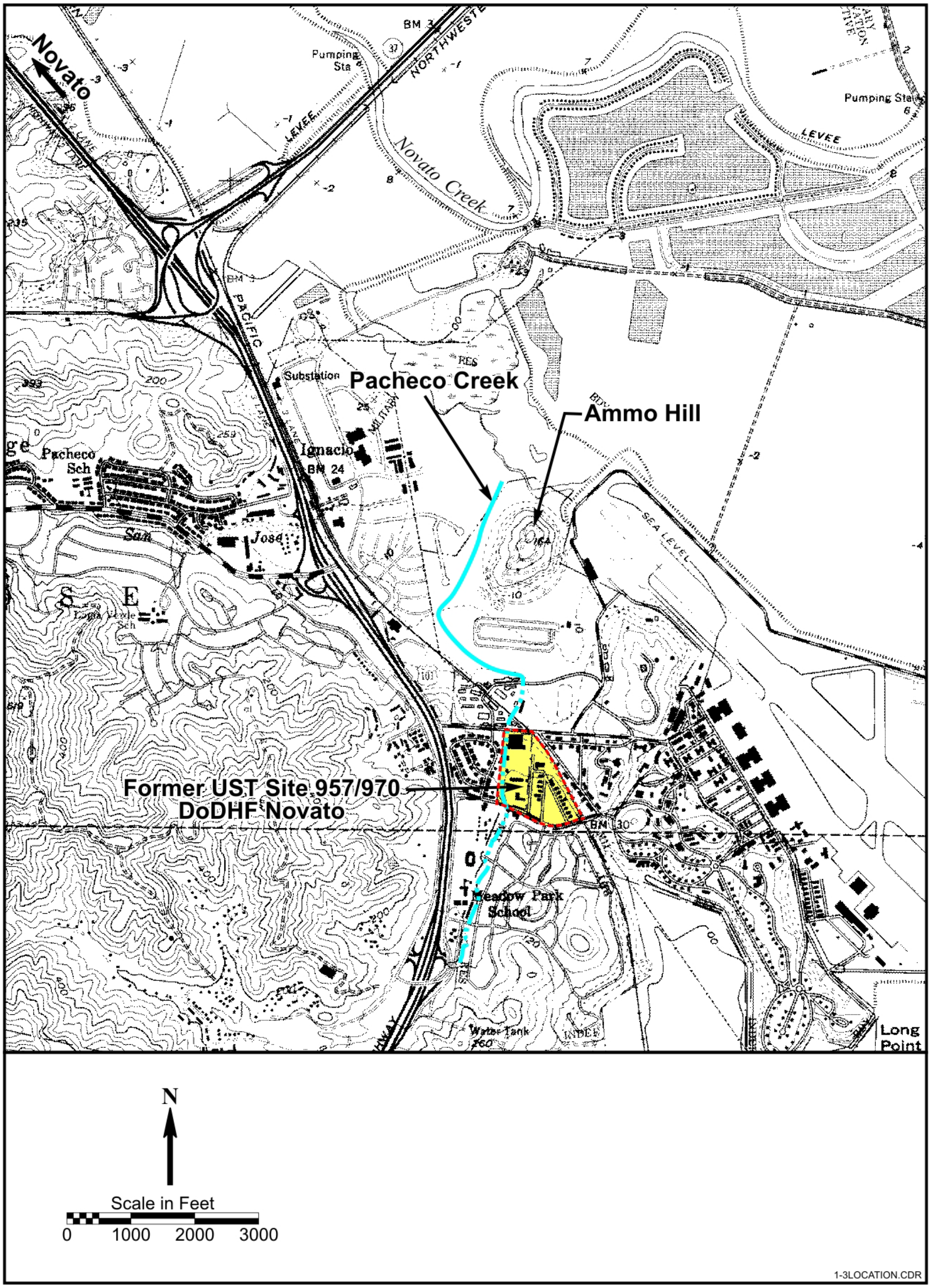
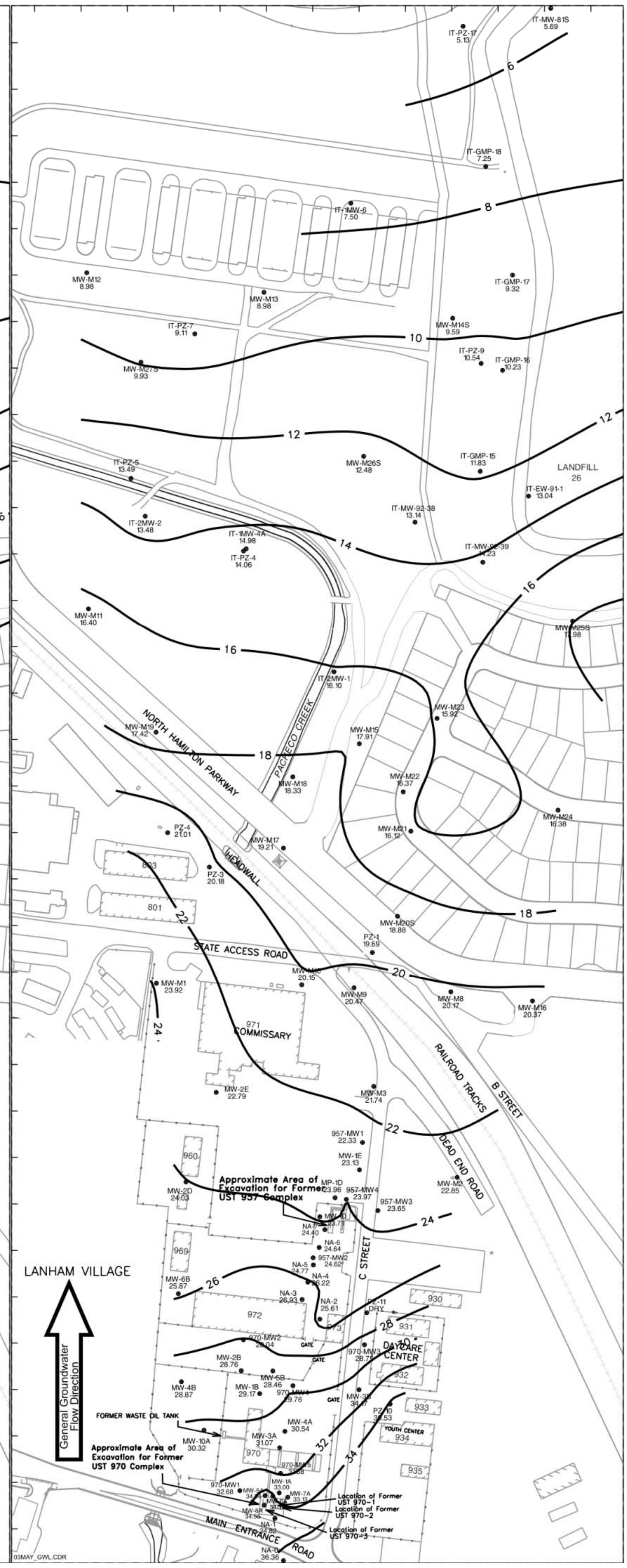


Figure 1. Site Location Map

February 2004



May 2004

N

0 300 600

SCALE IN FEET

Explanation

⊕ Monitoring Well Location

MW-4B ID

29.03 Water Table Elevation (ft amsl)

*Data not used in contouring

DESIGNED BY RL	Battelle
DRAWN BY LC	**Figure 2. Potentiometric Maps**
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA
	PROJECT G486026-21 · FILE WATER_04COMPARISON.CDR · DATE 07/04

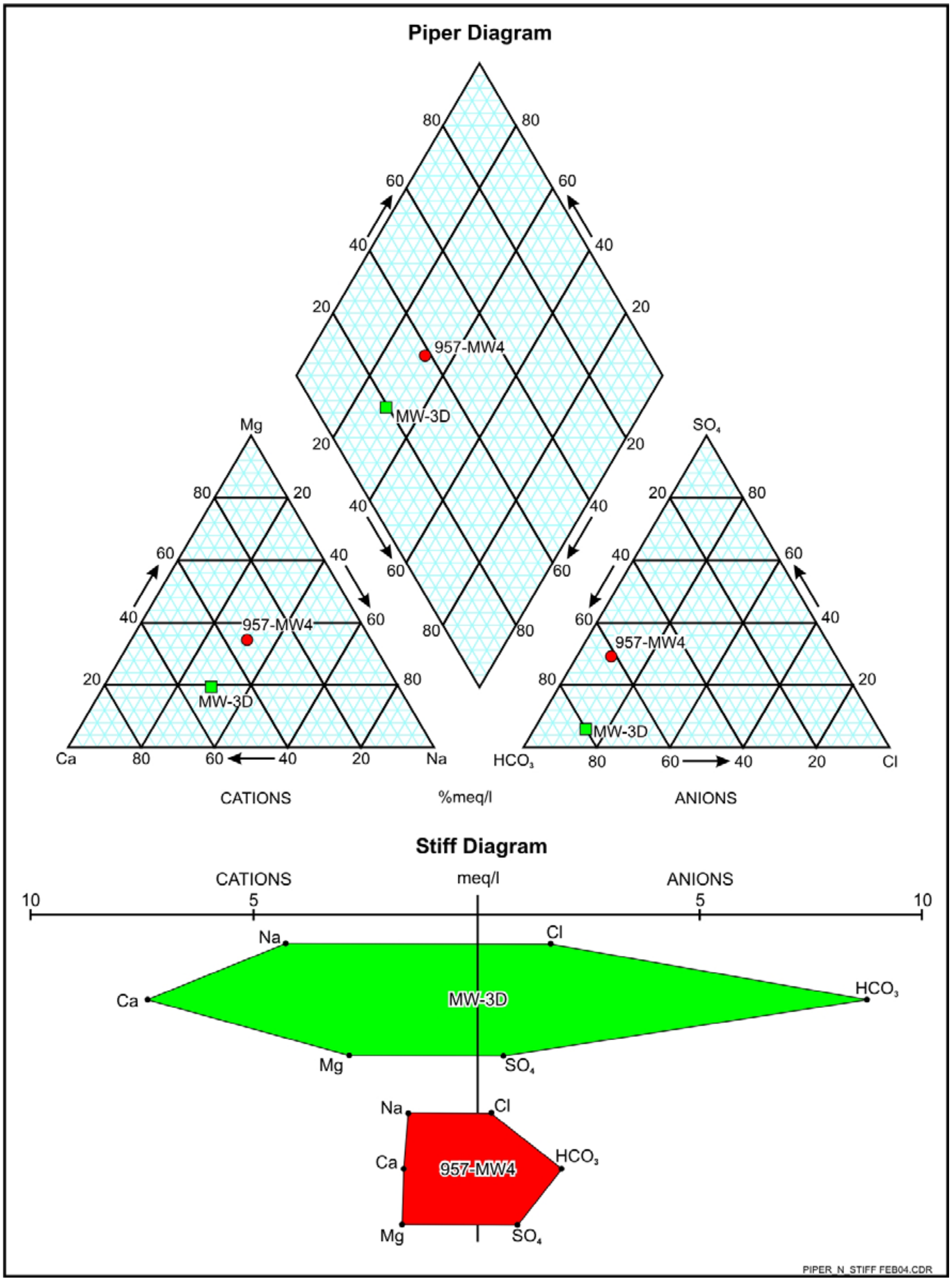


Figure 3a. Piper and Stiff Diagrams for Wells MW-3D and 957-MW4 (February 2004)

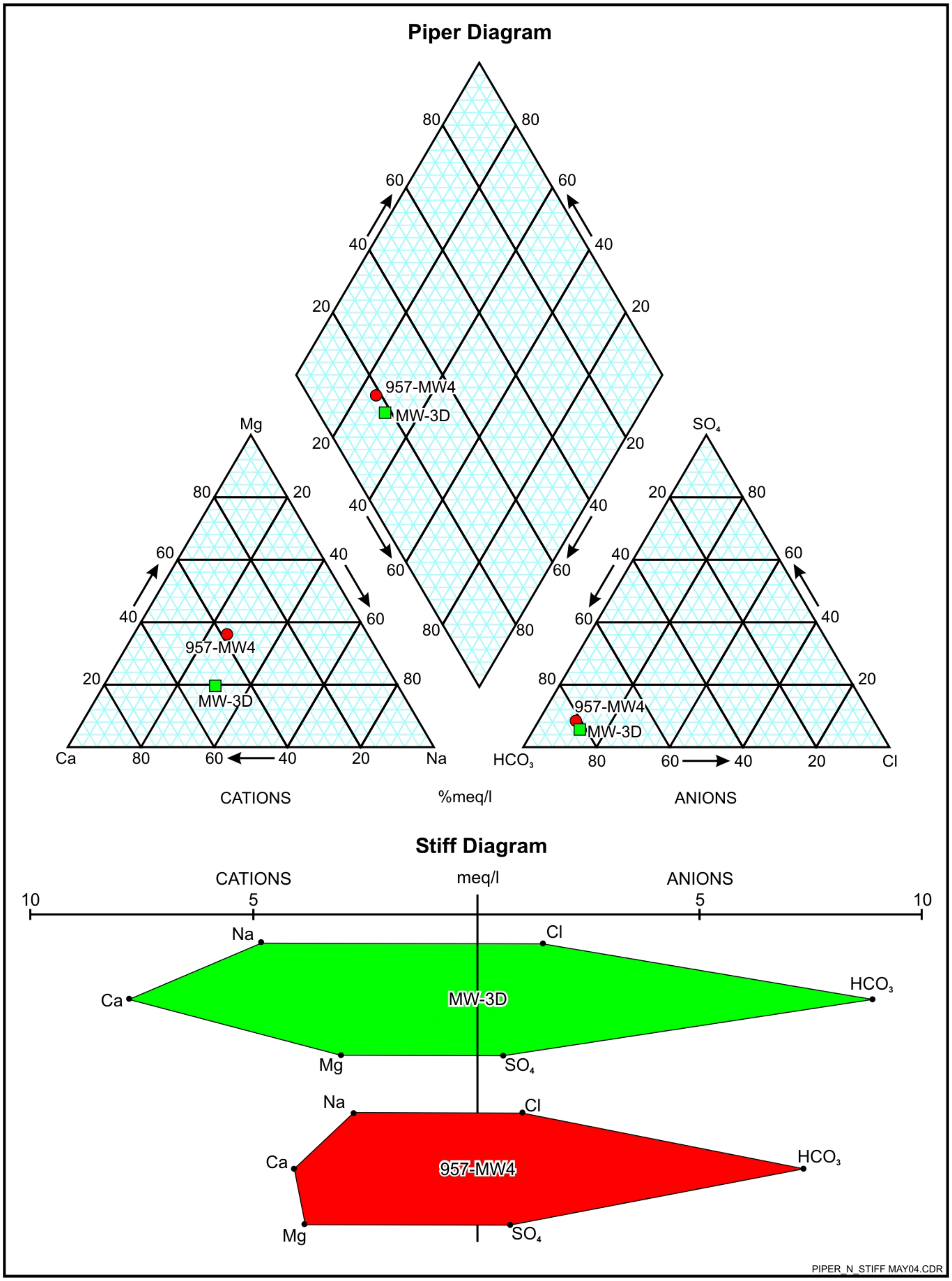


Figure 3b. Piper and Stiff Diagrams for Wells MW-3D and 957-MW4 (May 2004)

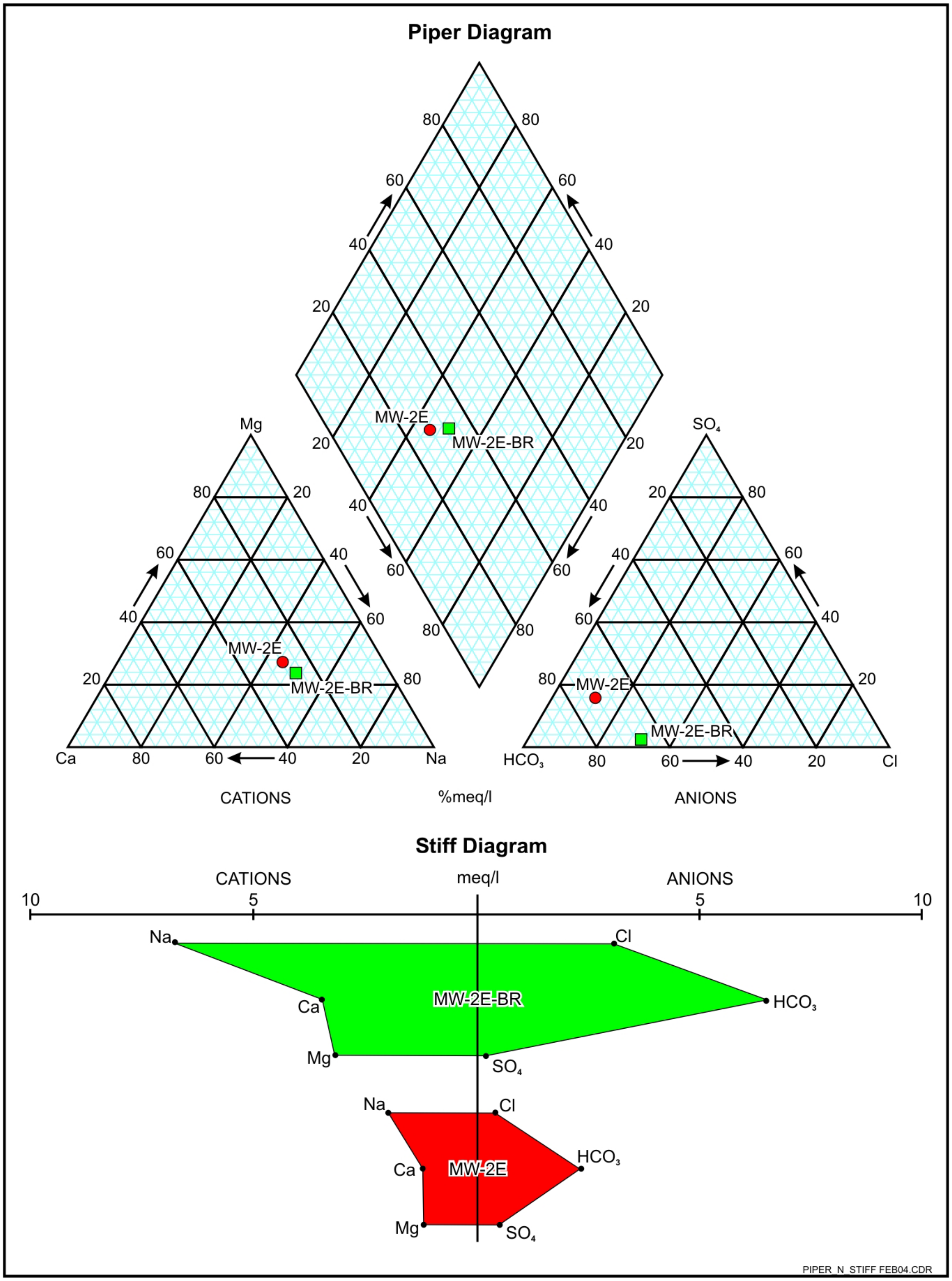


Figure 4a. Piper and Stiff Diagrams for Wells MW-2E-BR and MW-2E (February 2004)

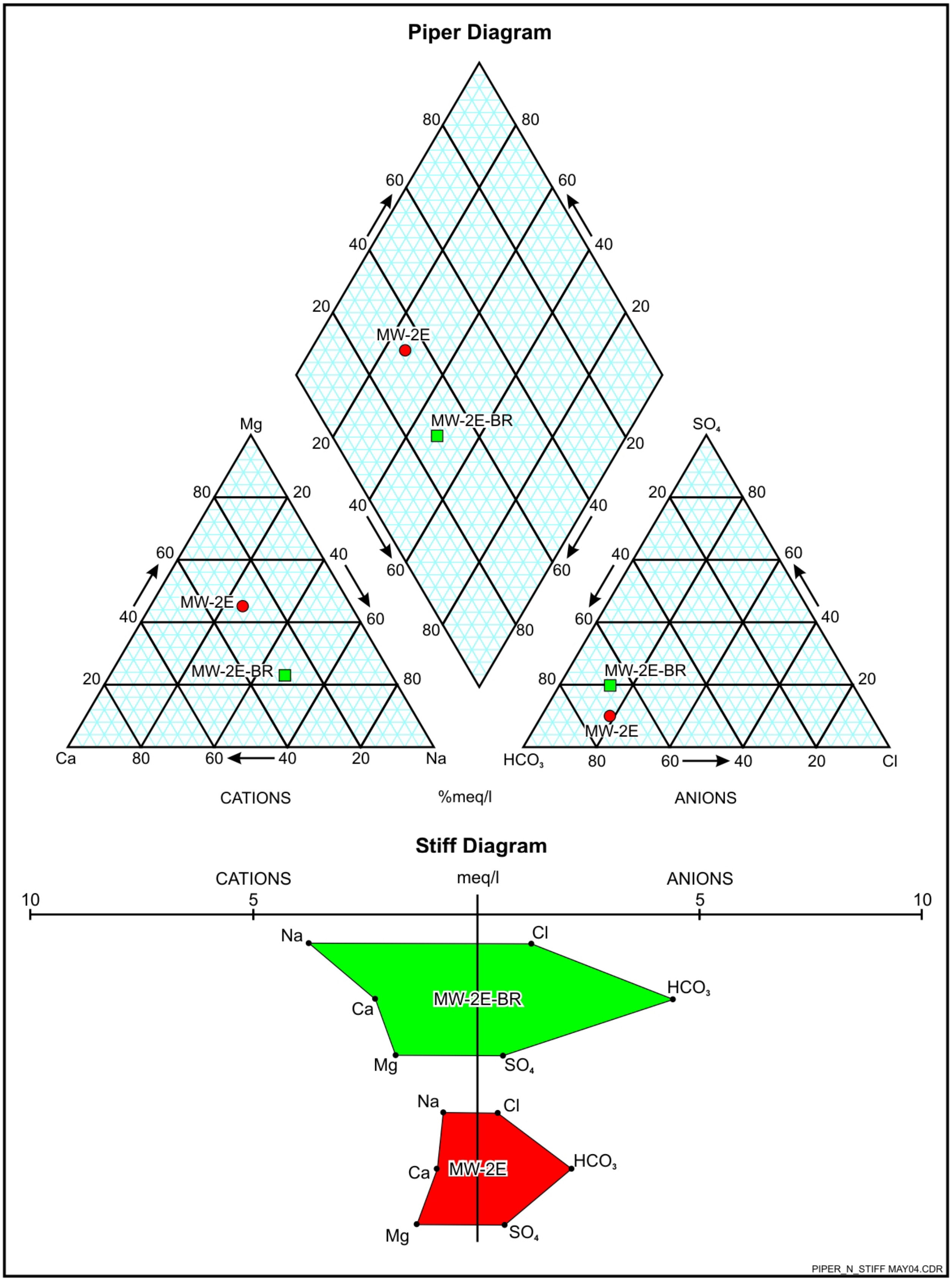


Figure 4b. Piper and Stiff Diagrams for Wells MW-2E-BR and MW-2E (May 2004)

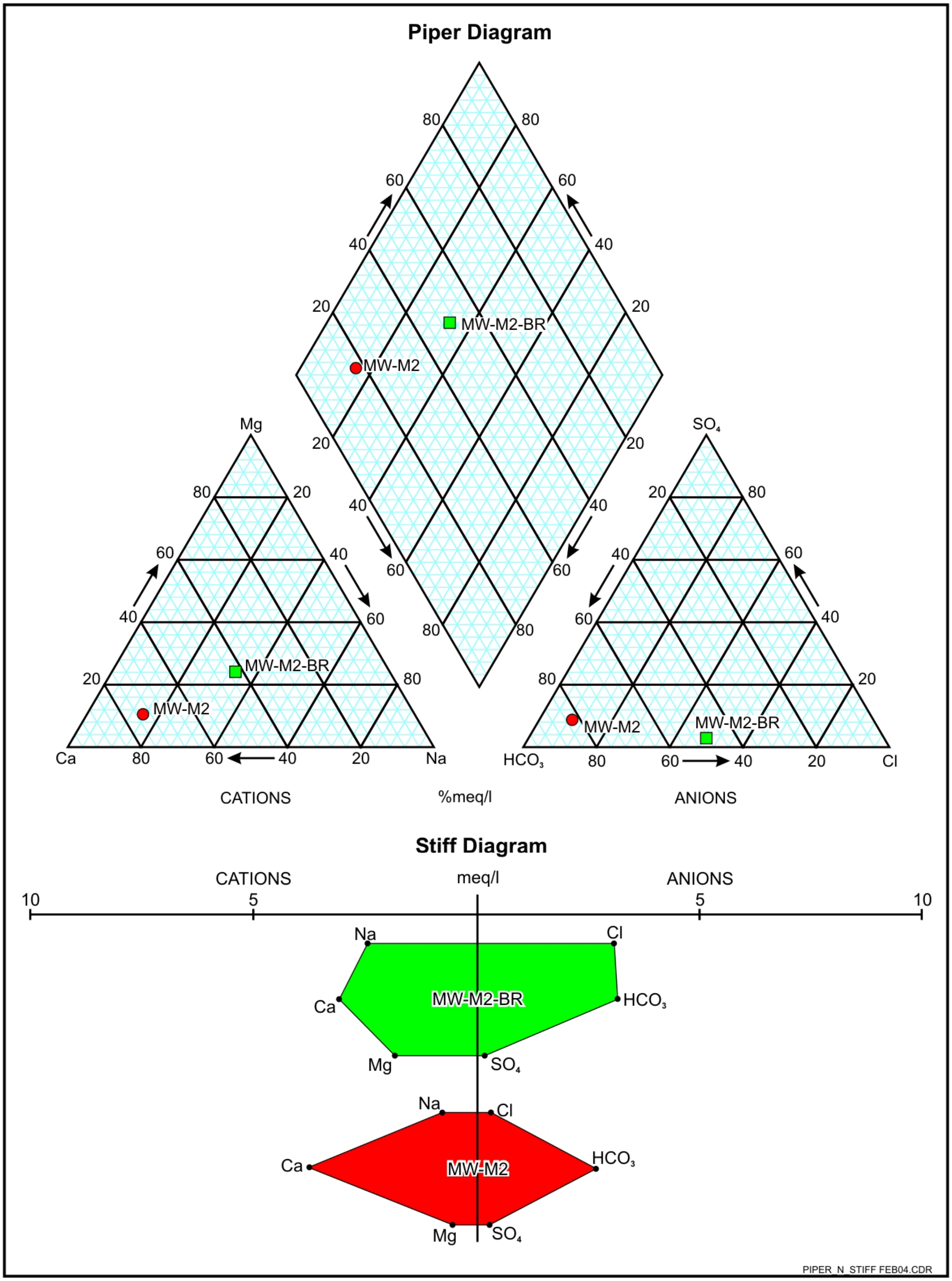


Figure 5a. Piper and Stiff Diagrams for Wells MW-M2-BR and MW-M2 (February 2004)

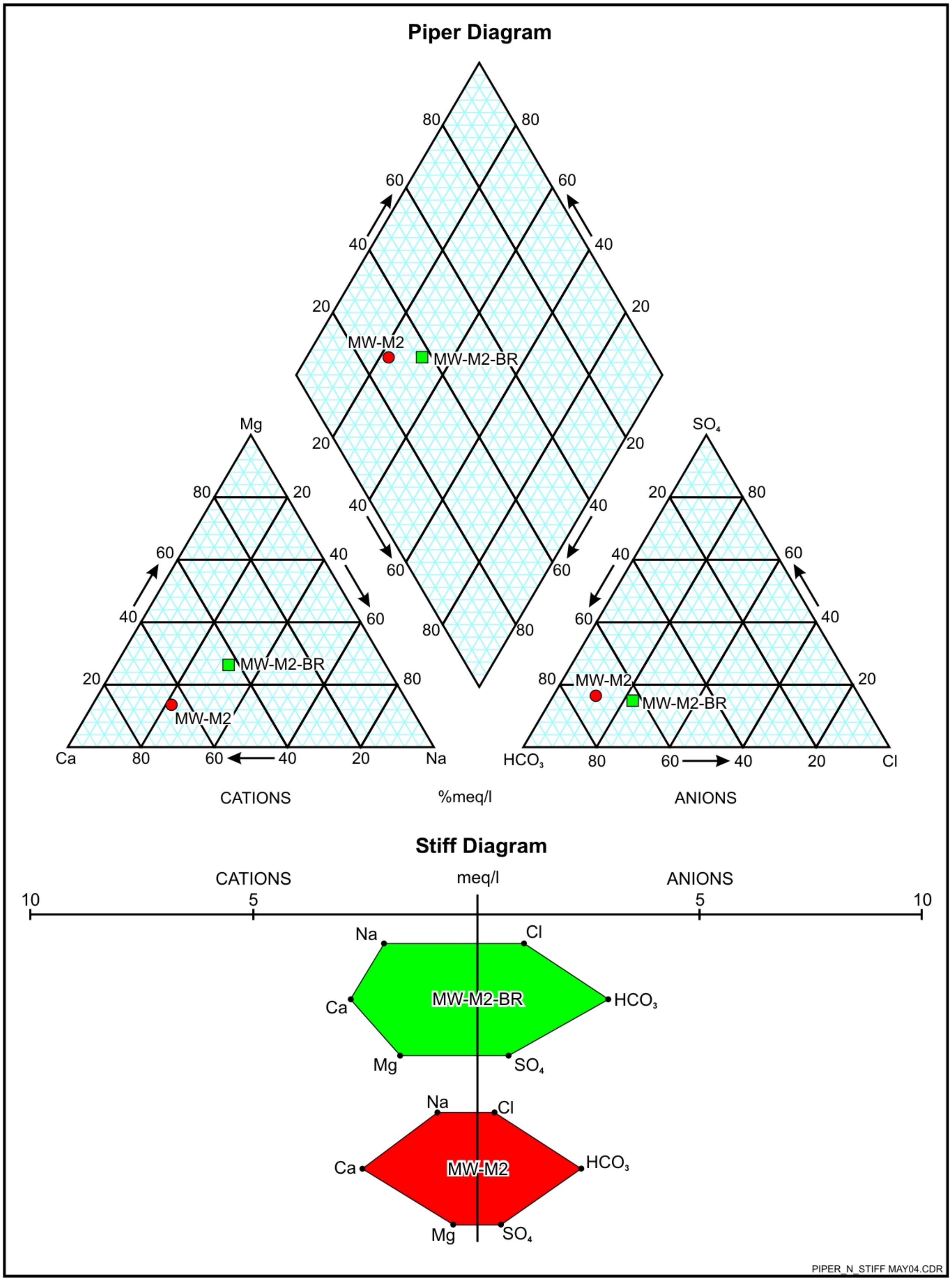


Figure 5b. Piper and Stiff Diagrams for Wells MW-M2-BR and MW-M2 (May 2004)

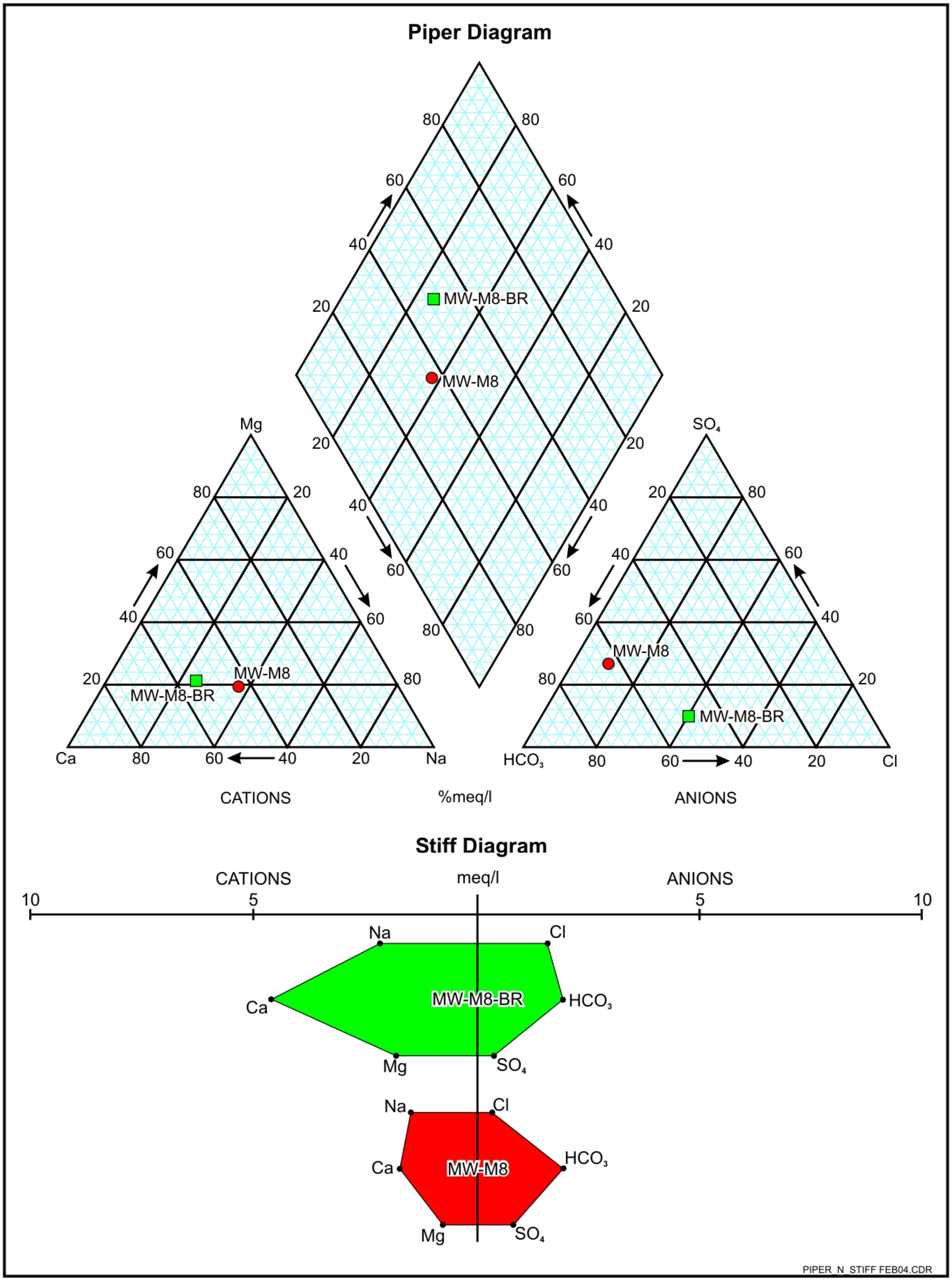


Figure 6a. Piper and Stiff Diagrams for Wells MW-M8-BR and MW-M8 (February 2004)

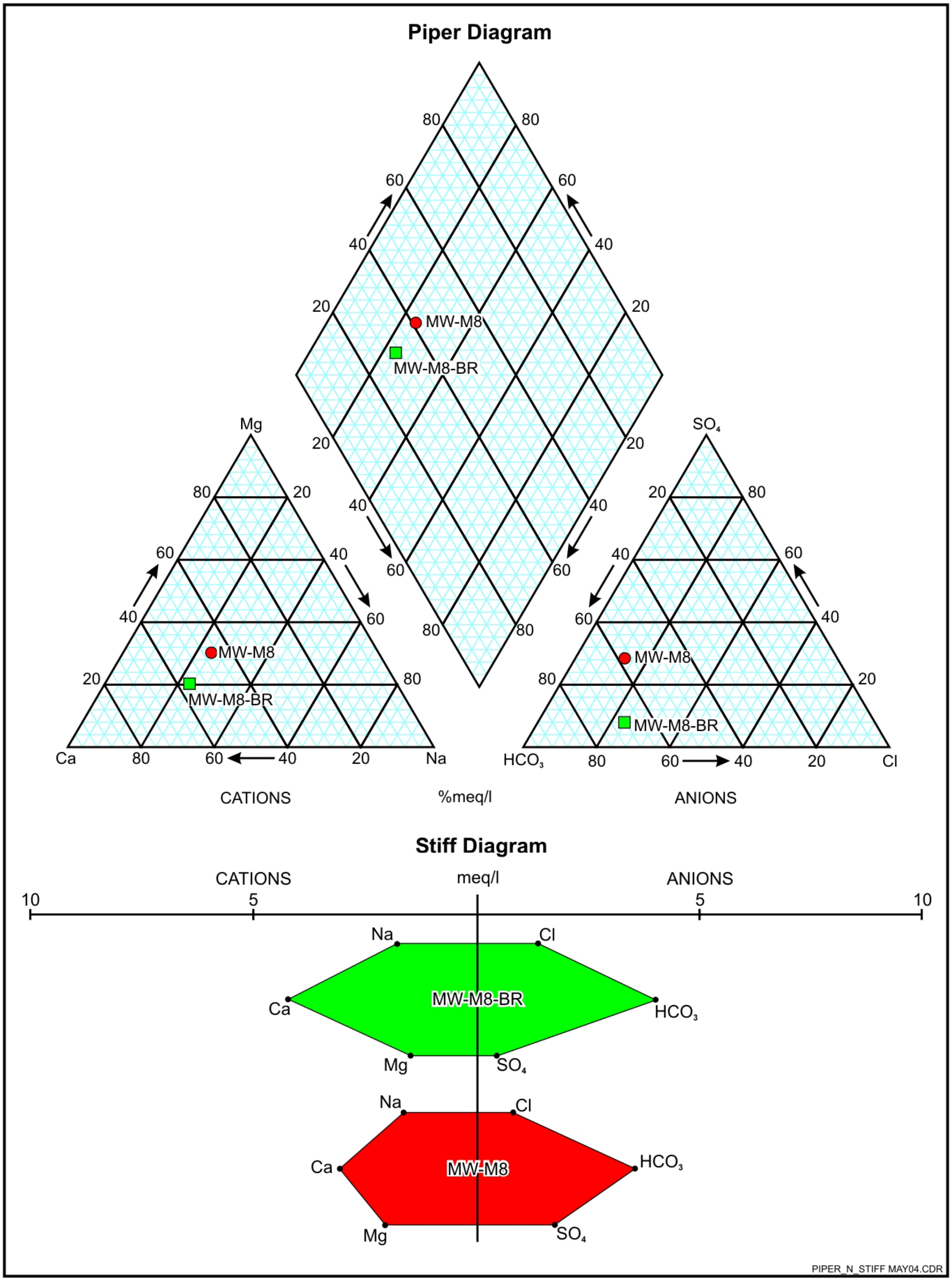


Figure 6b. Piper and Stiff Diagrams for Wells MW-M8-BR and MW-M8 (May 2004)

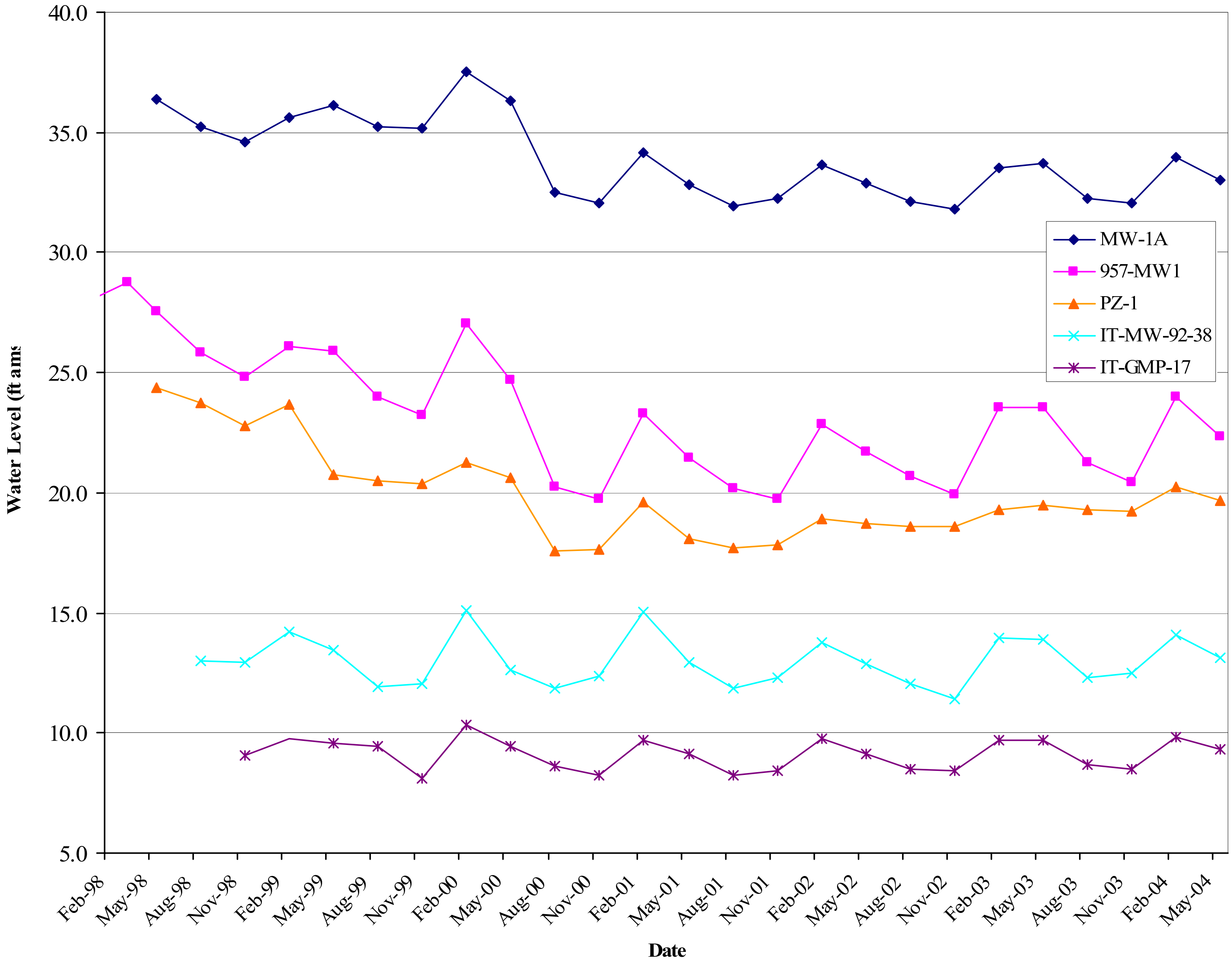


Figure 7. Water Levels Over Time at Wells Along the Plume Centerline

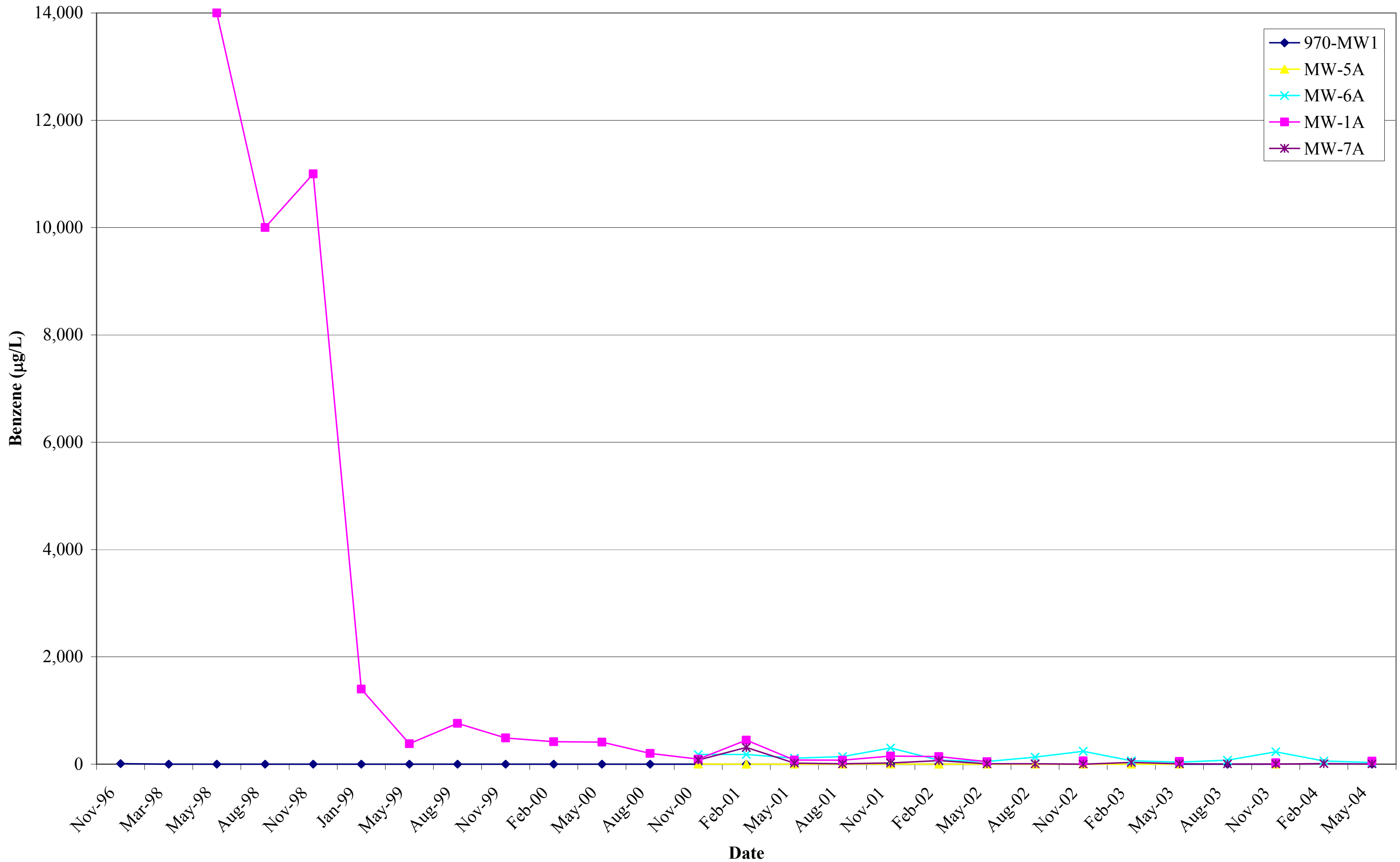


Figure 8. Area A (970 Source Area) Transect Wells Benzene Time Series Graph

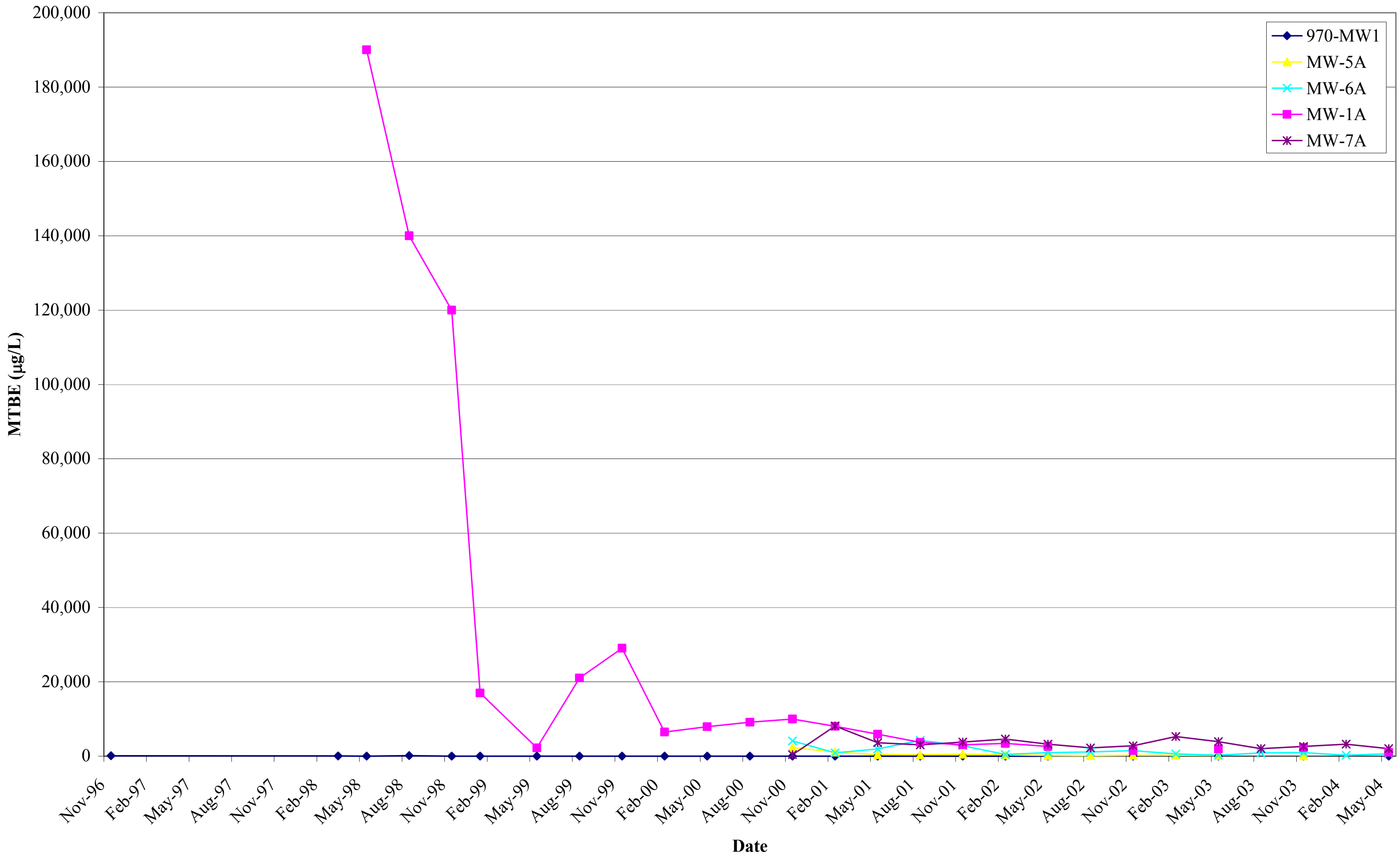


Figure 9. Area A (970 Source Area) Transect Wells MTBE Time Series Graph

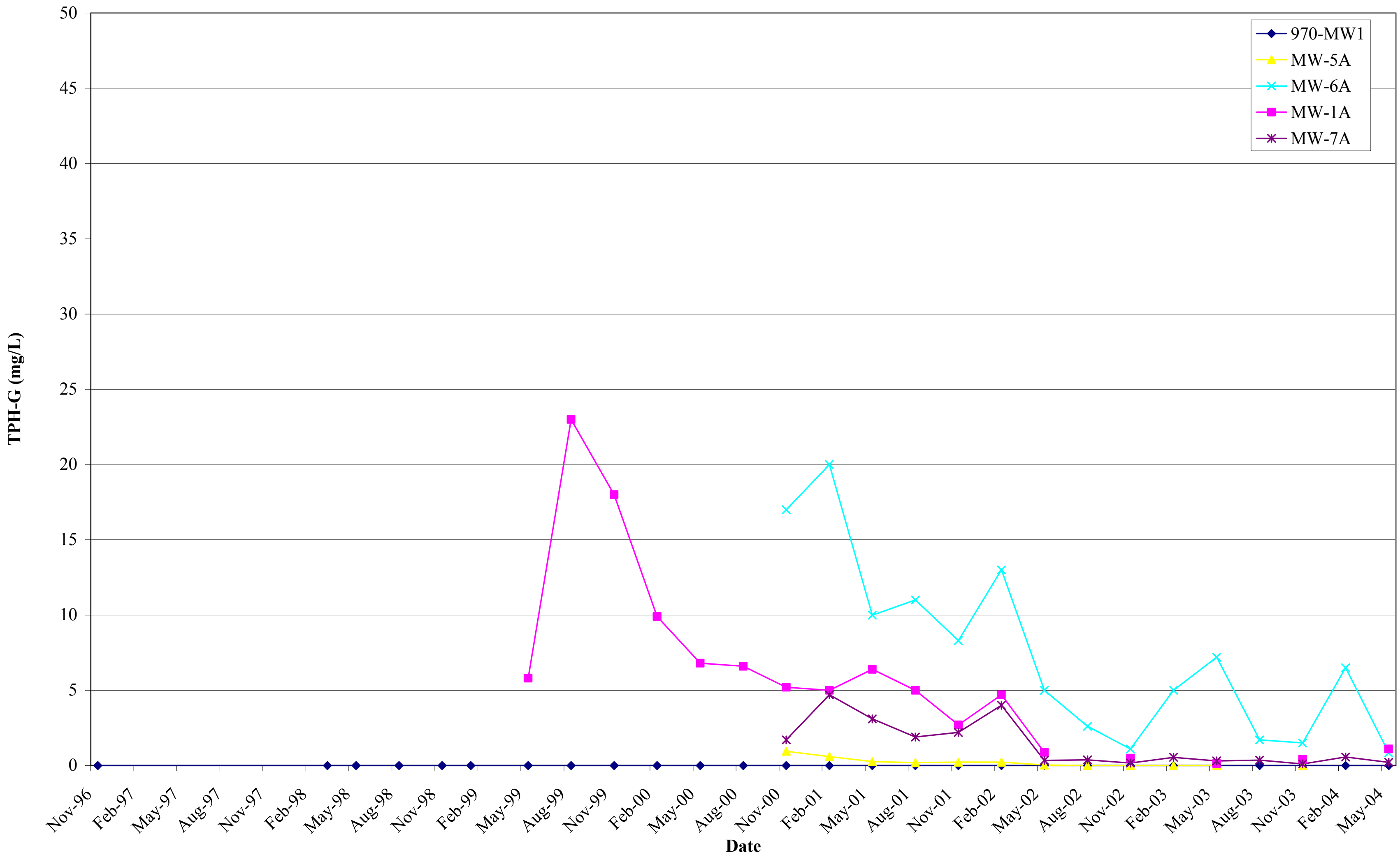


Figure 10. Area A (970 Source Area) Transect Wells TPH-G Time Series Graph

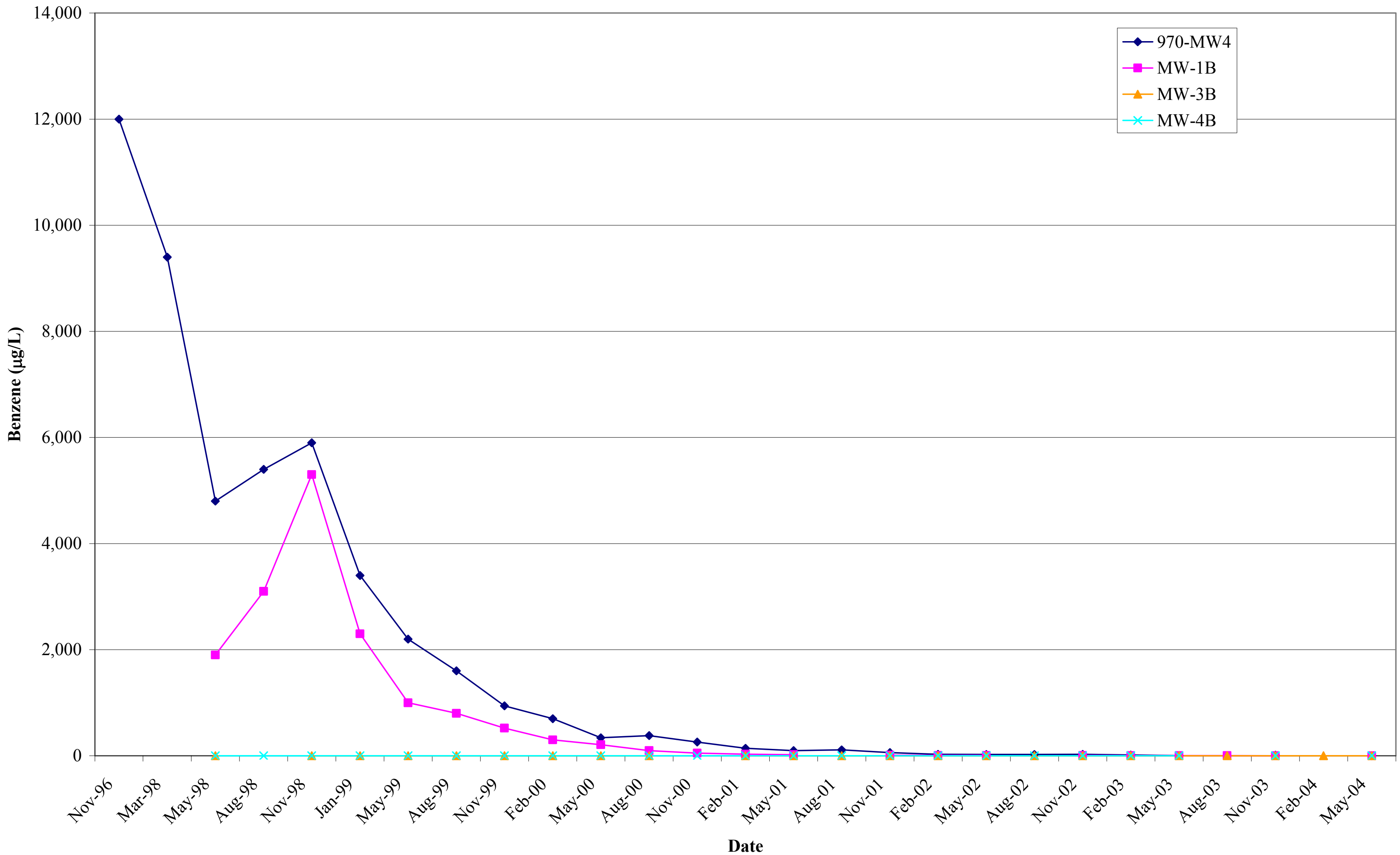


Figure 11. Area B Transect Wells Benzene Time Series Graph

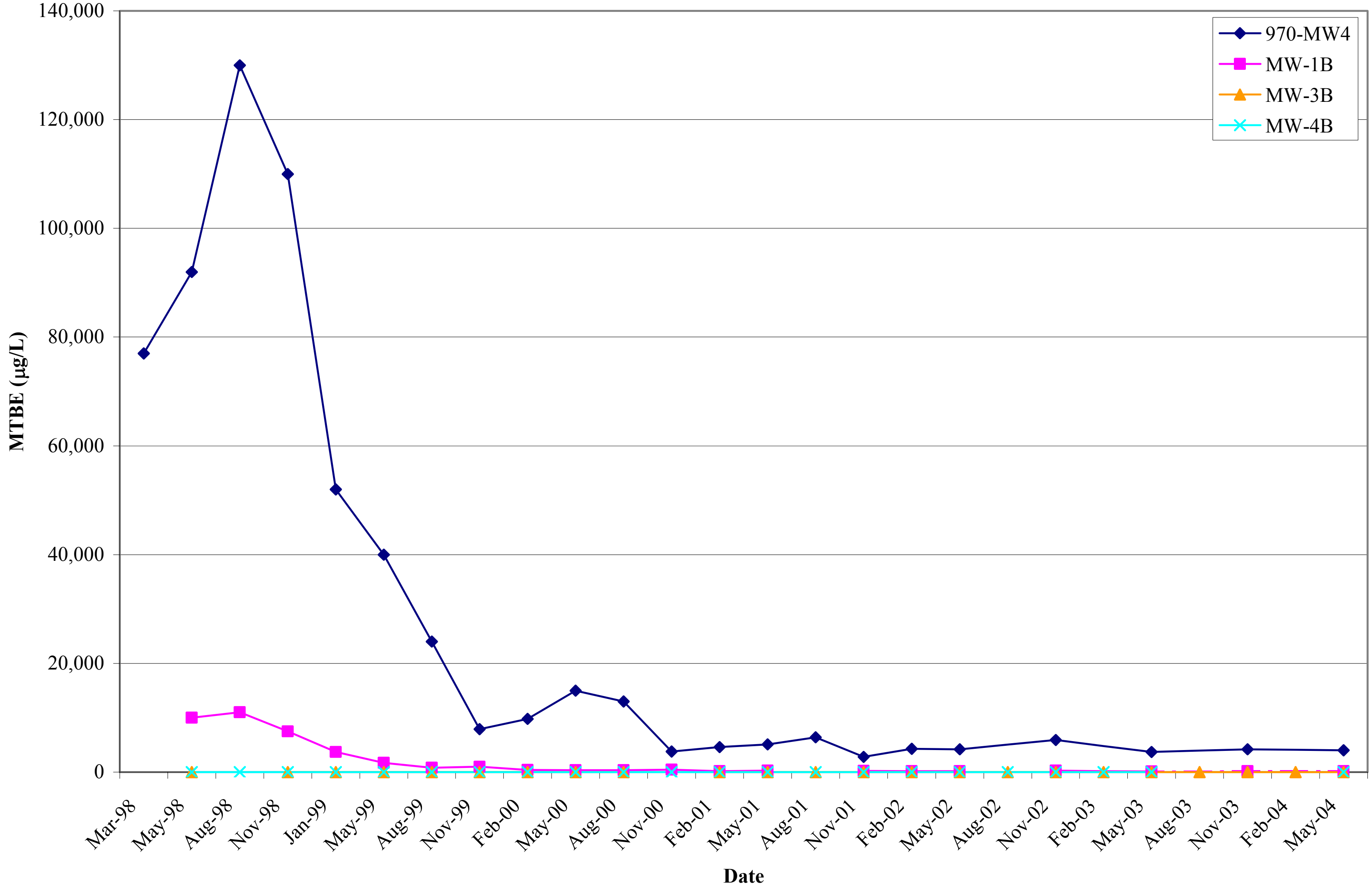


Figure 12. Area B Transect Wells MTBE Time Series Graph

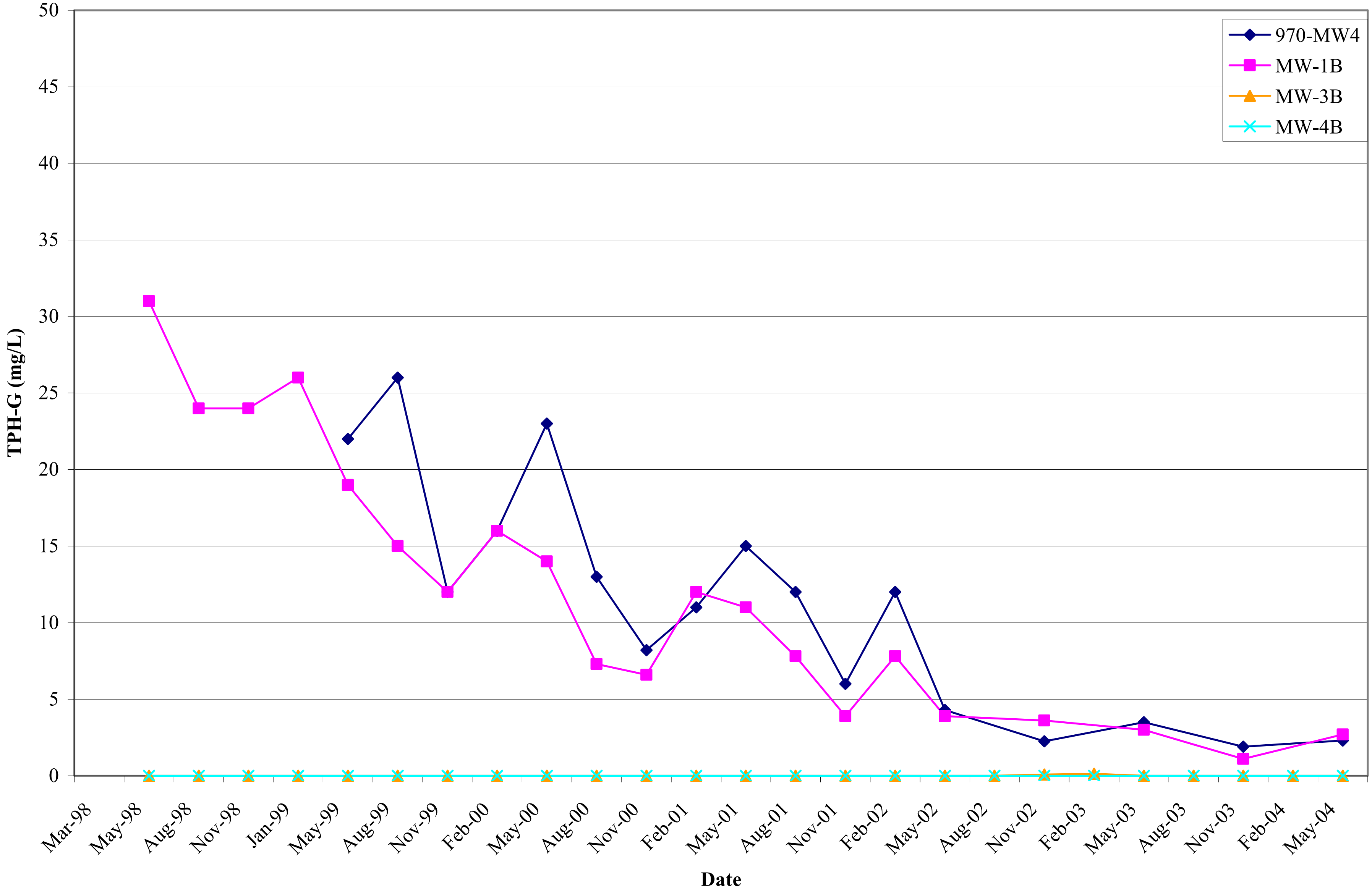


Figure 13. Area B Transect Wells TPH-G Time Series Graph

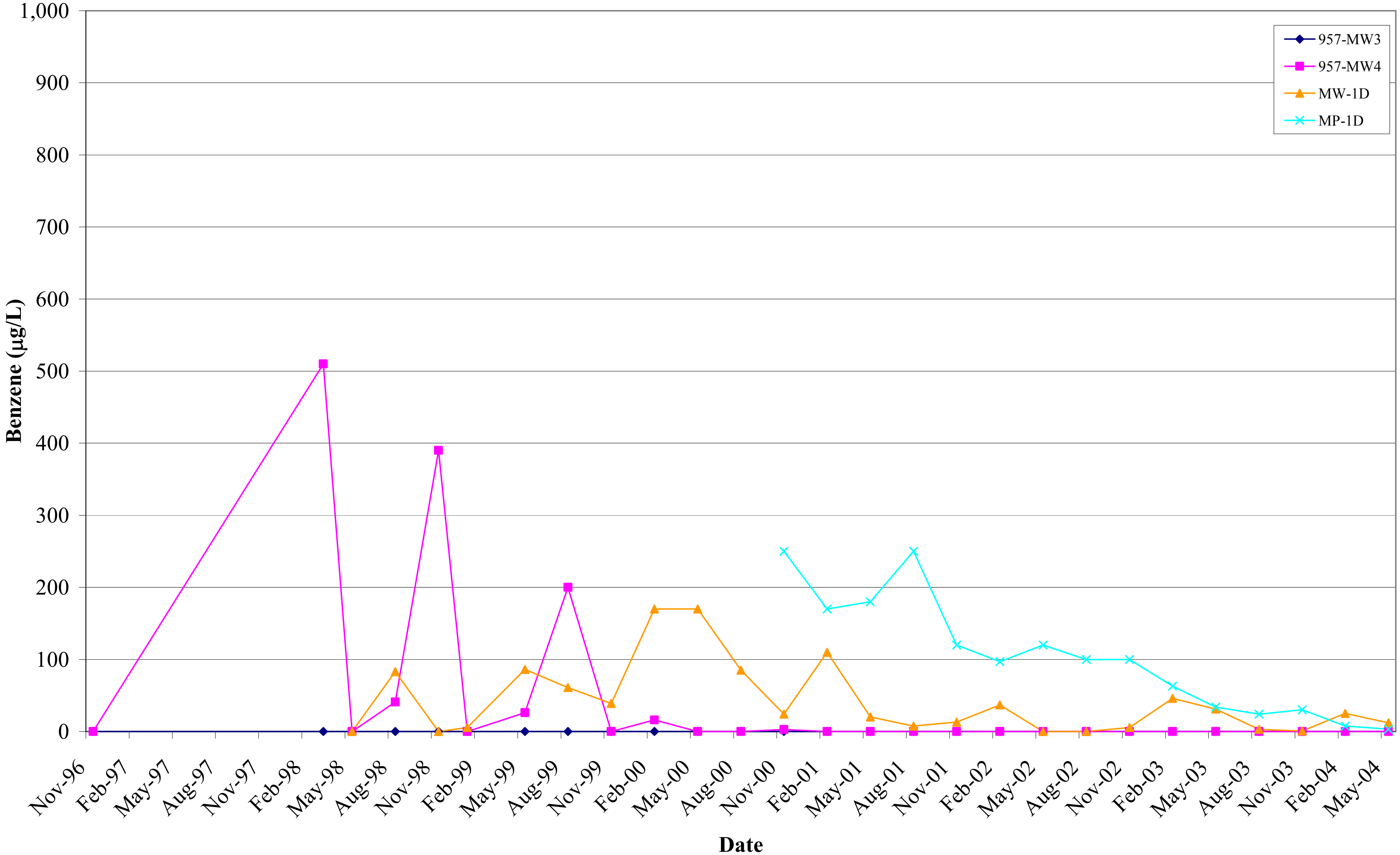


Figure 14. Area D (957 Source Area) Transect Wells Benzene Time Series Graph

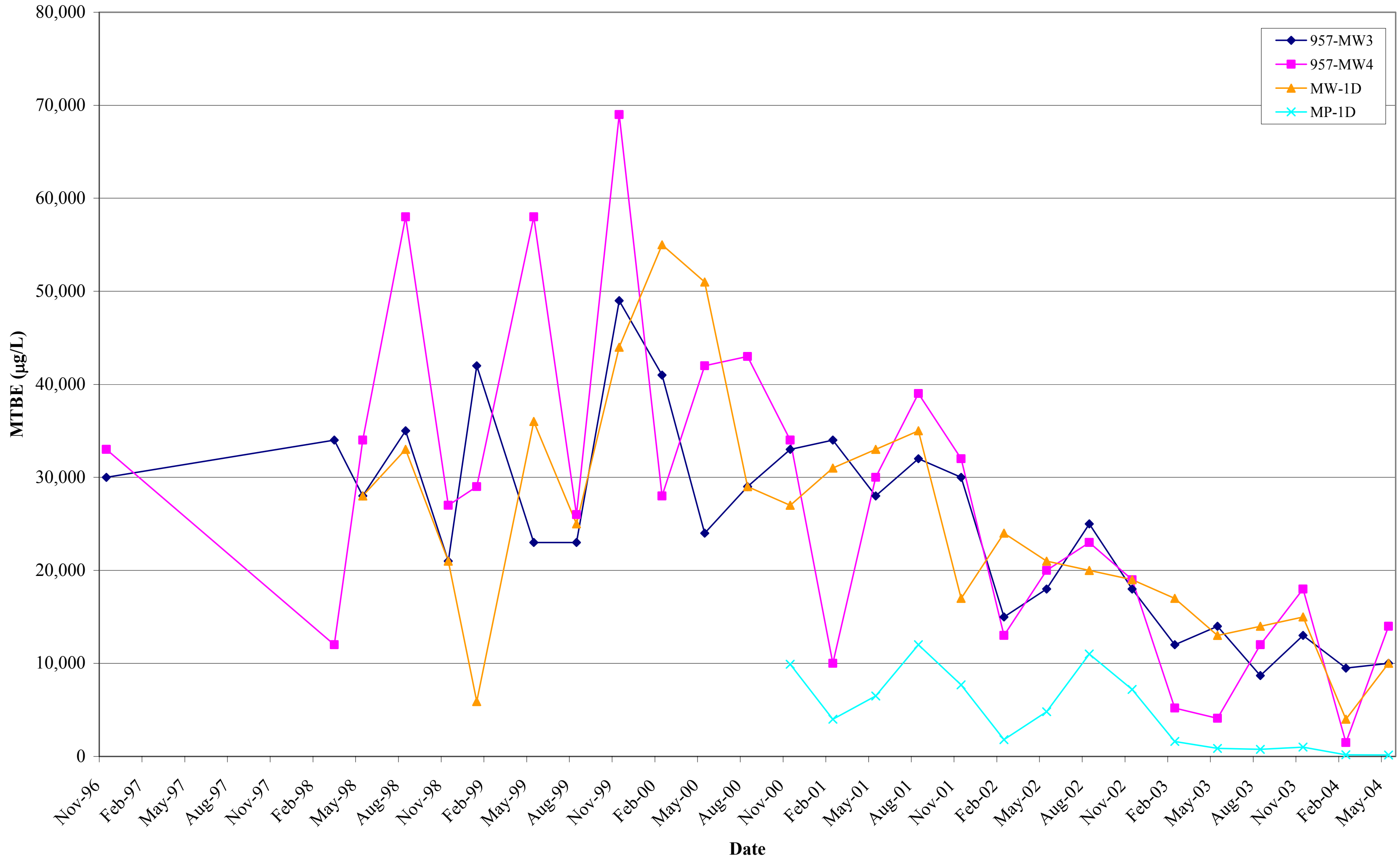


Figure 15. Area D (957 Source Area) Transect Wells MTBE Time Series Graph

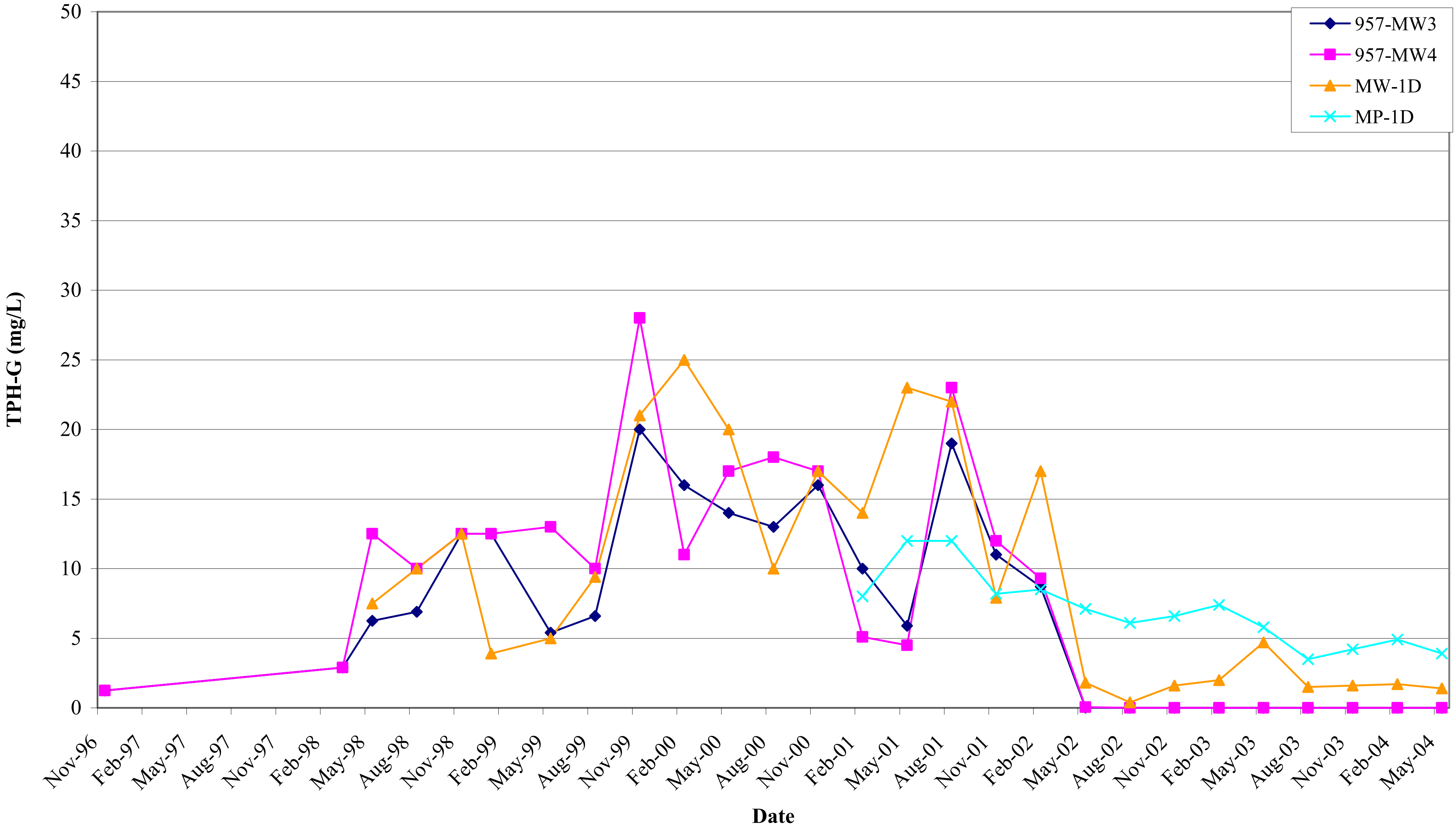


Figure 16. Area D (957 Source Area) Transect Wells TPH-G Time Series Graph

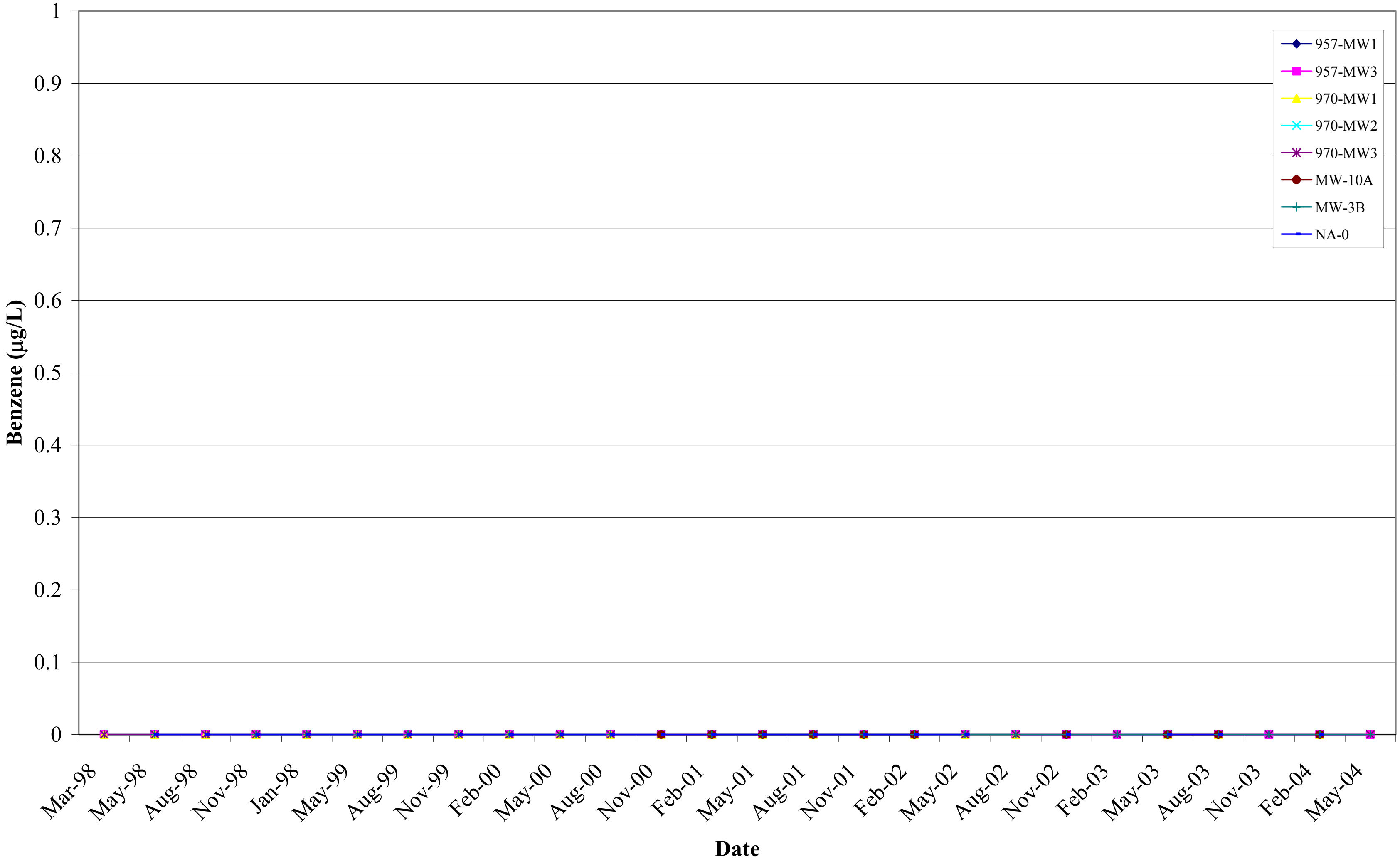


Figure 17. Plume Perimeter Wells Benzene Time Series Graph

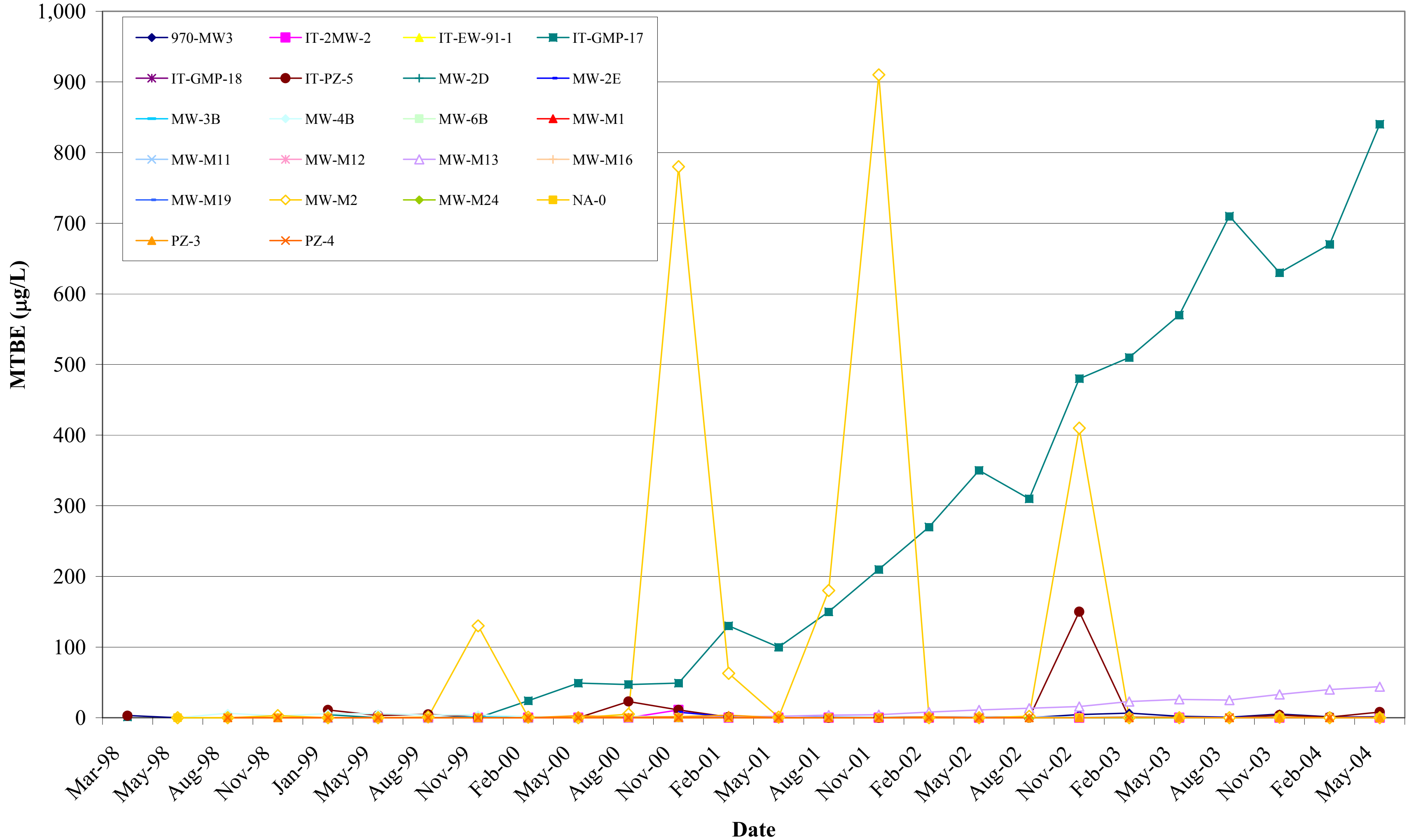


Figure 18. Plume Perimeter Wells MTBE Time Series Graph

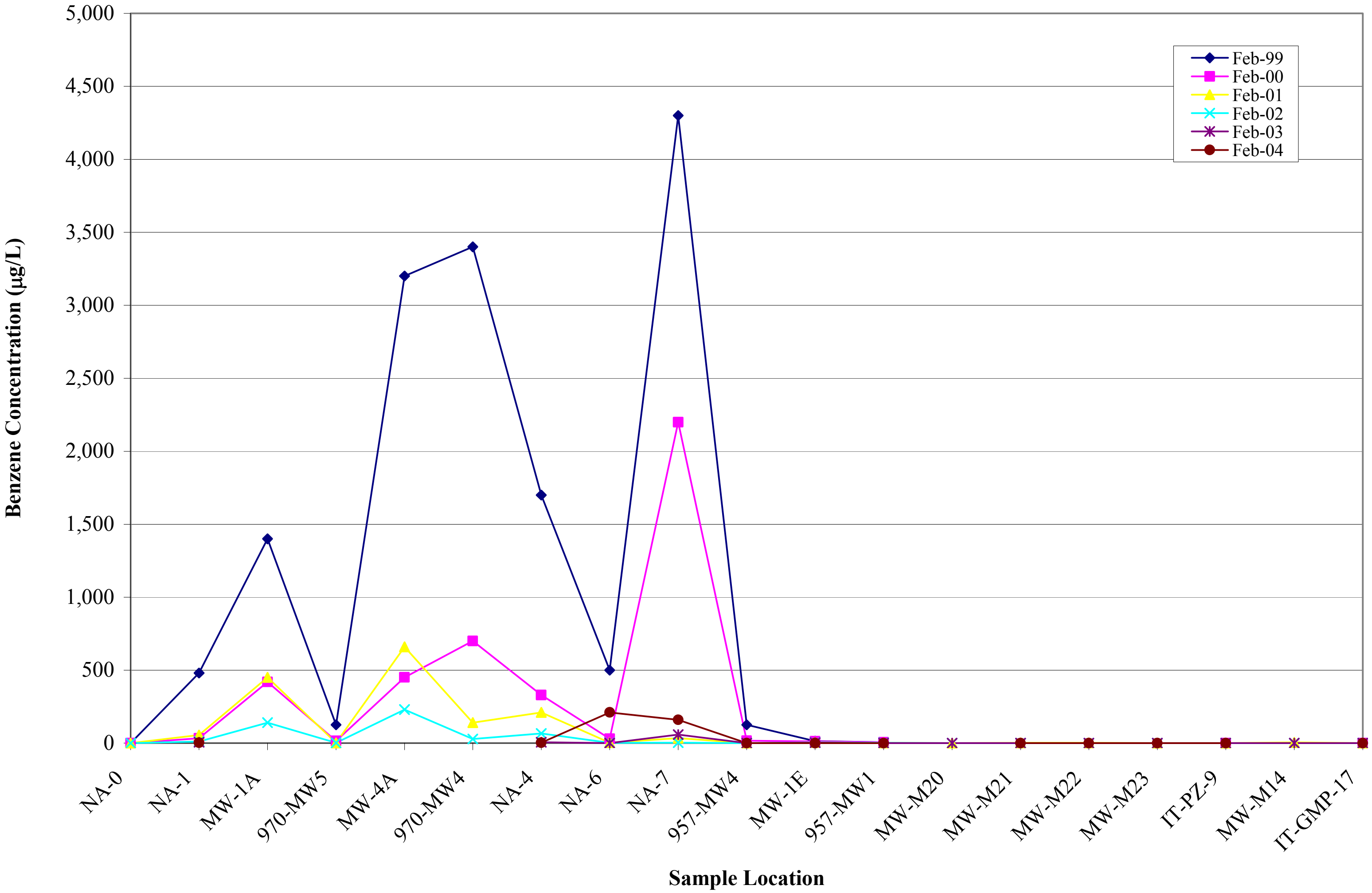


Figure 19. Centerline of Benzene Plume Annual Trends – February

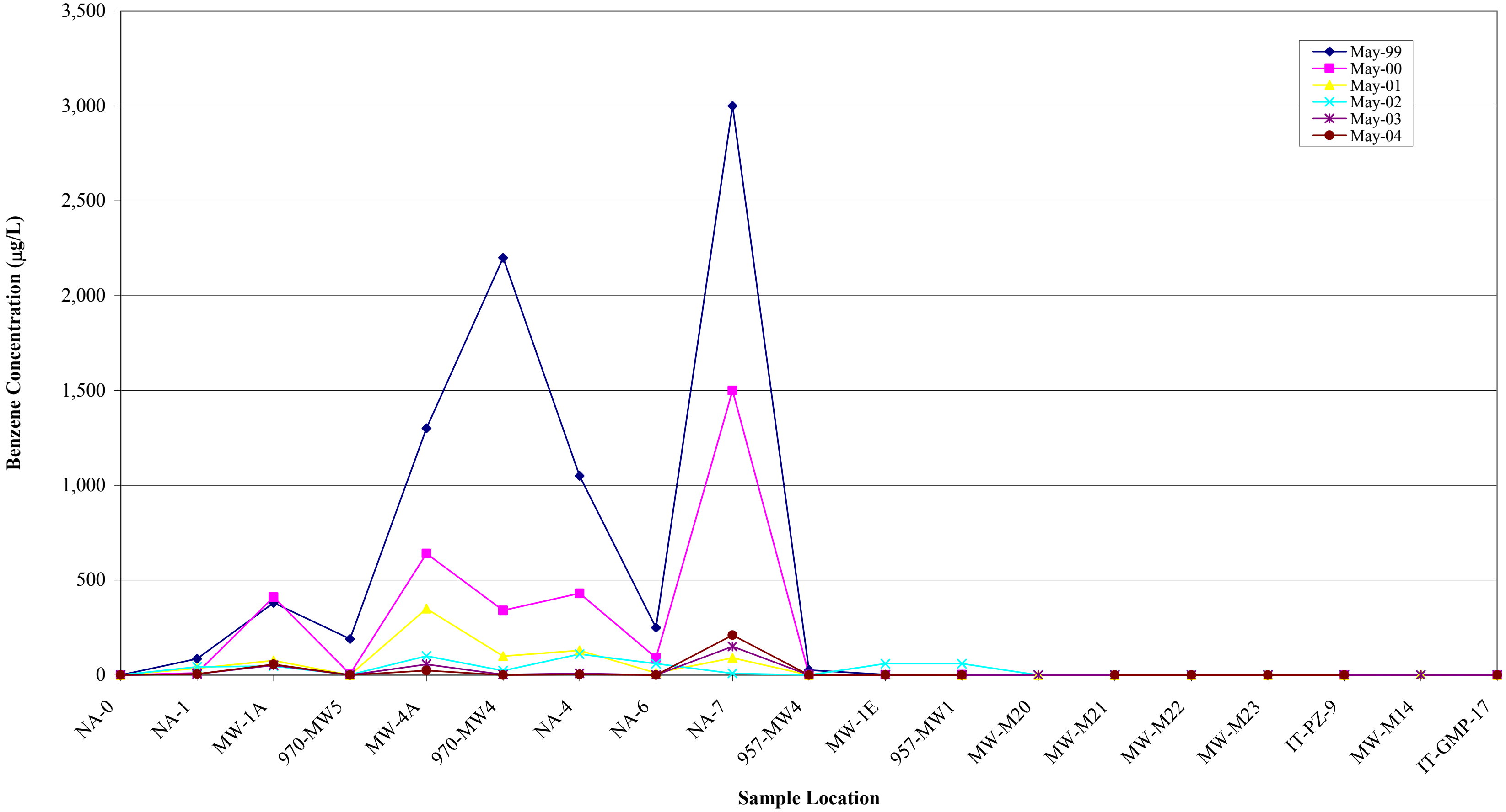


Figure 20. Centerline of Benzene Plume Annual Trends – May

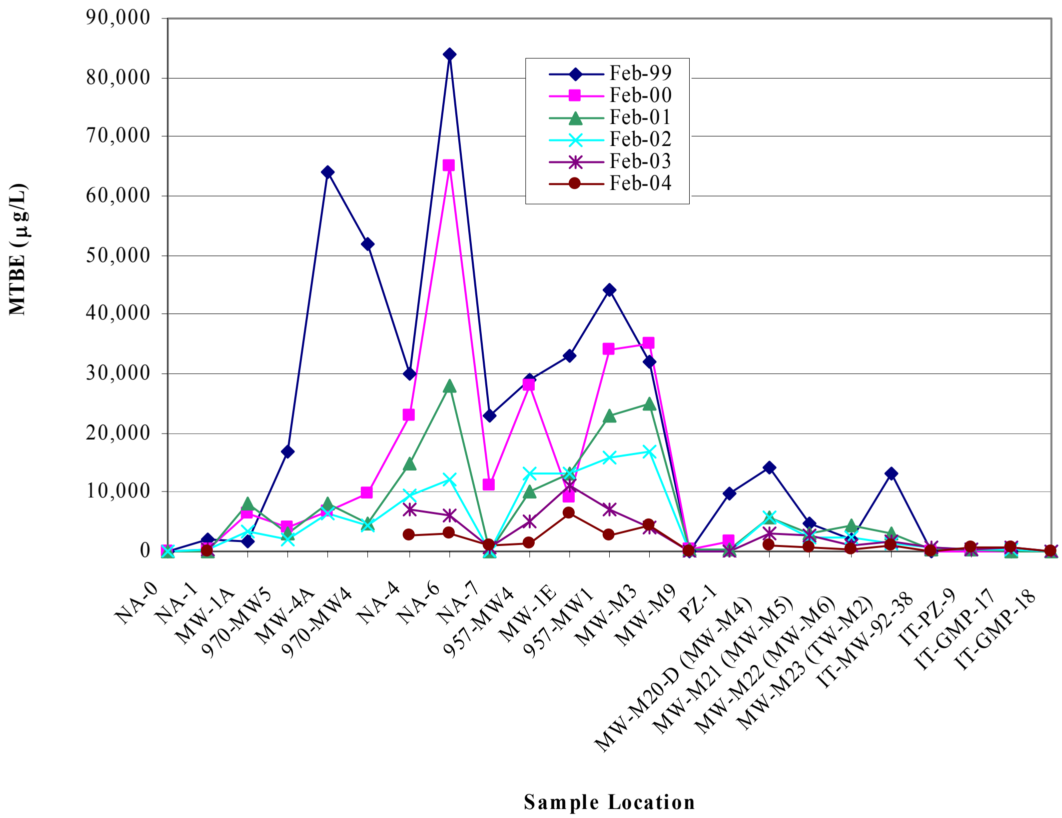


Figure 21A. Centerline of MTBE Plume Annual Trends – February

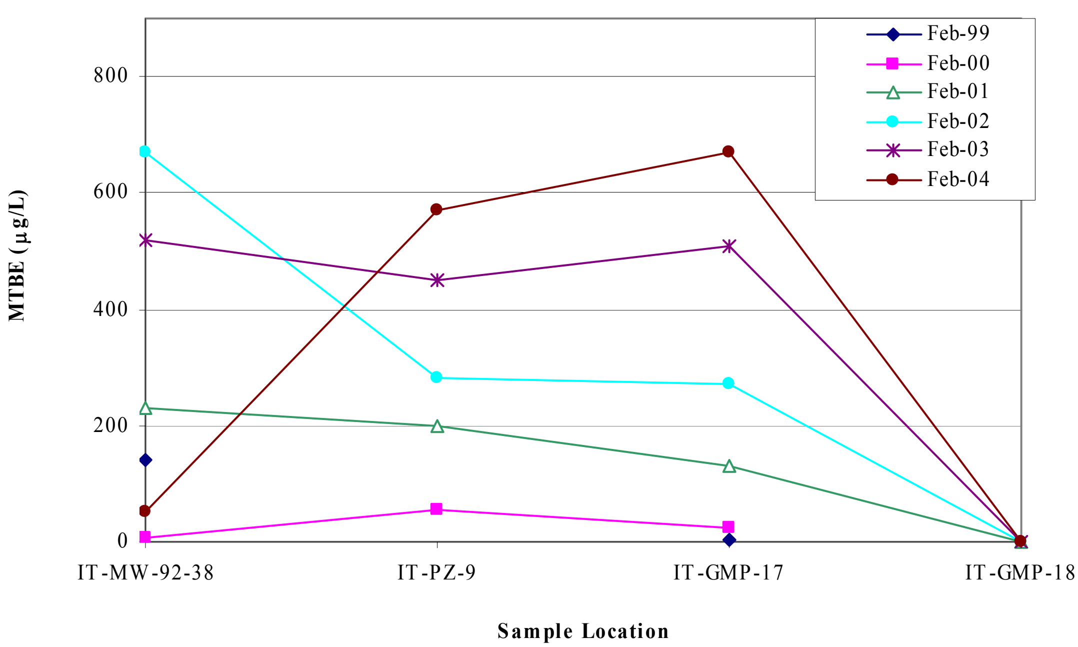


Figure 21B. Centerline of MTBE Plume (Northeast Leading Edge) Annual Trends – February

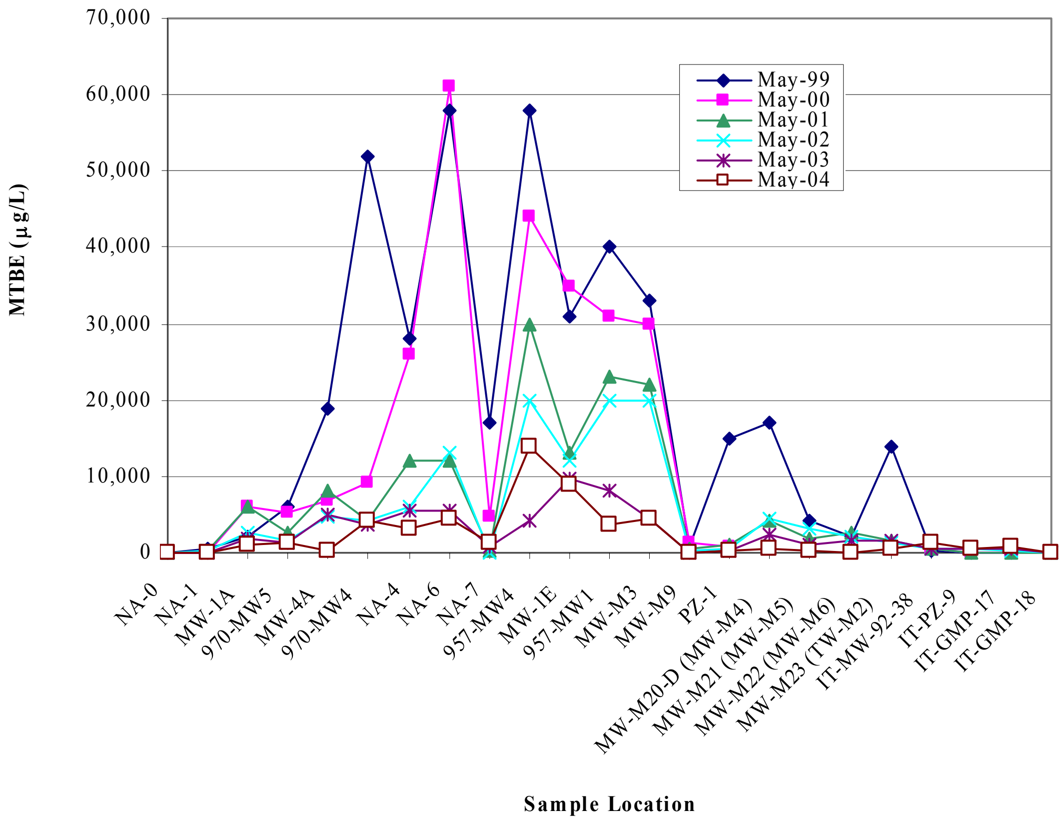


Figure 22A. Centerline of MTBE Plume Annual Trends – May

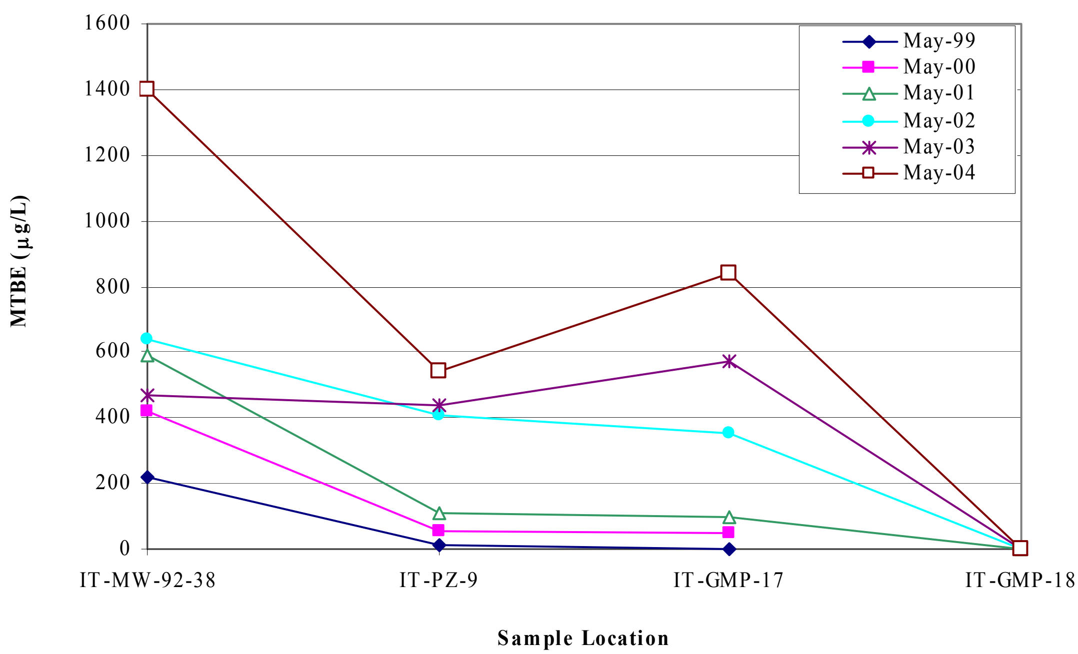


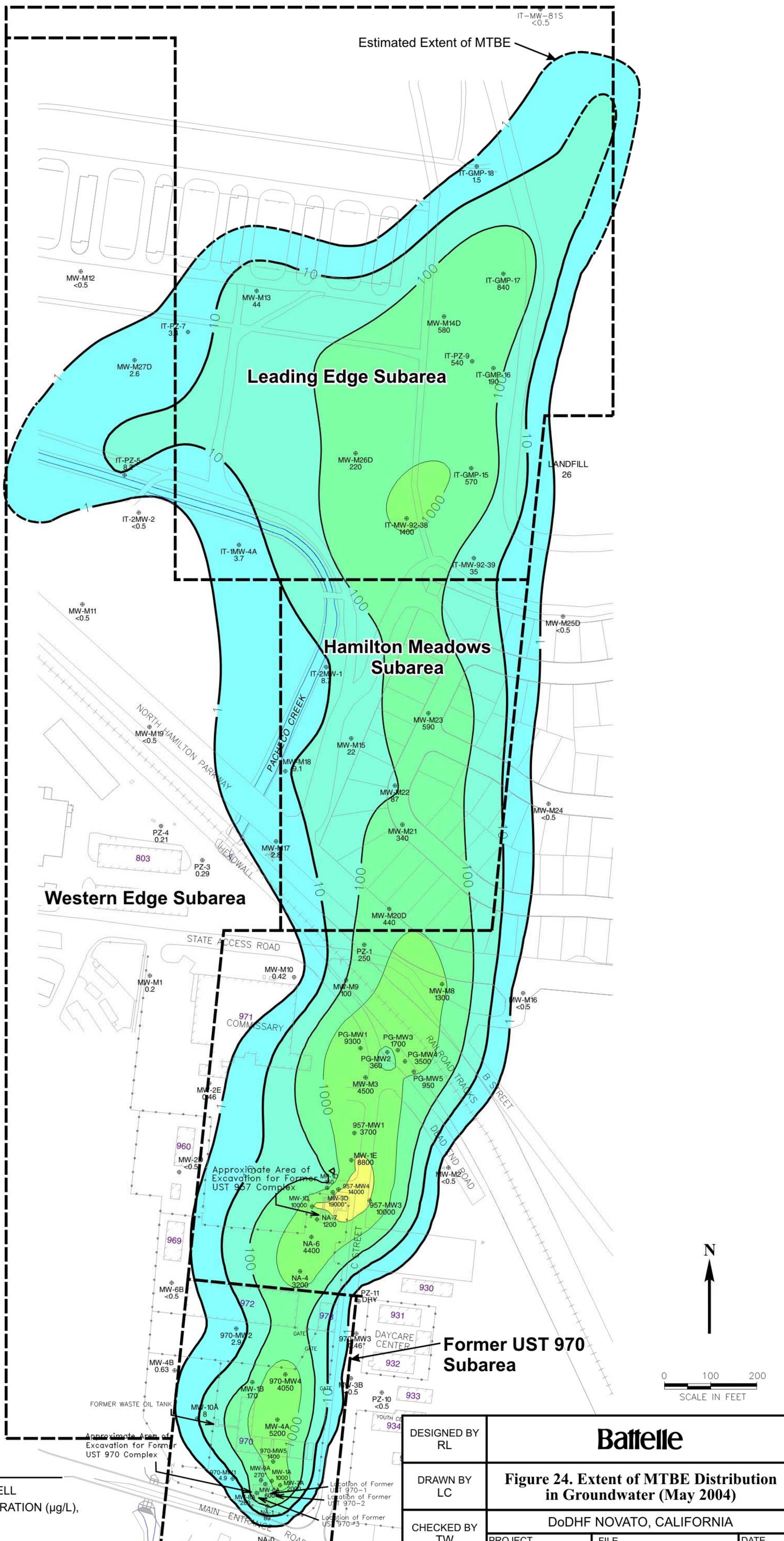
Figure 22B. Centerline of MTBE Plume (Northeast Leading Edge) Annual Trends – May

EXPLANATION

⊕ MONITORING WELL

<0.5 BENZENE CONCENTRATION (µg/L), May, 2004

DESIGNED BY RL	Battelle
DRAWN BY LC	**Figure 23. Extent of Benzene Distribution in Groundwater (May 2004)**
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA
	PROJECT G486026-21 | BTEX_04MAY_COLOR.CDR | DATE 07/04

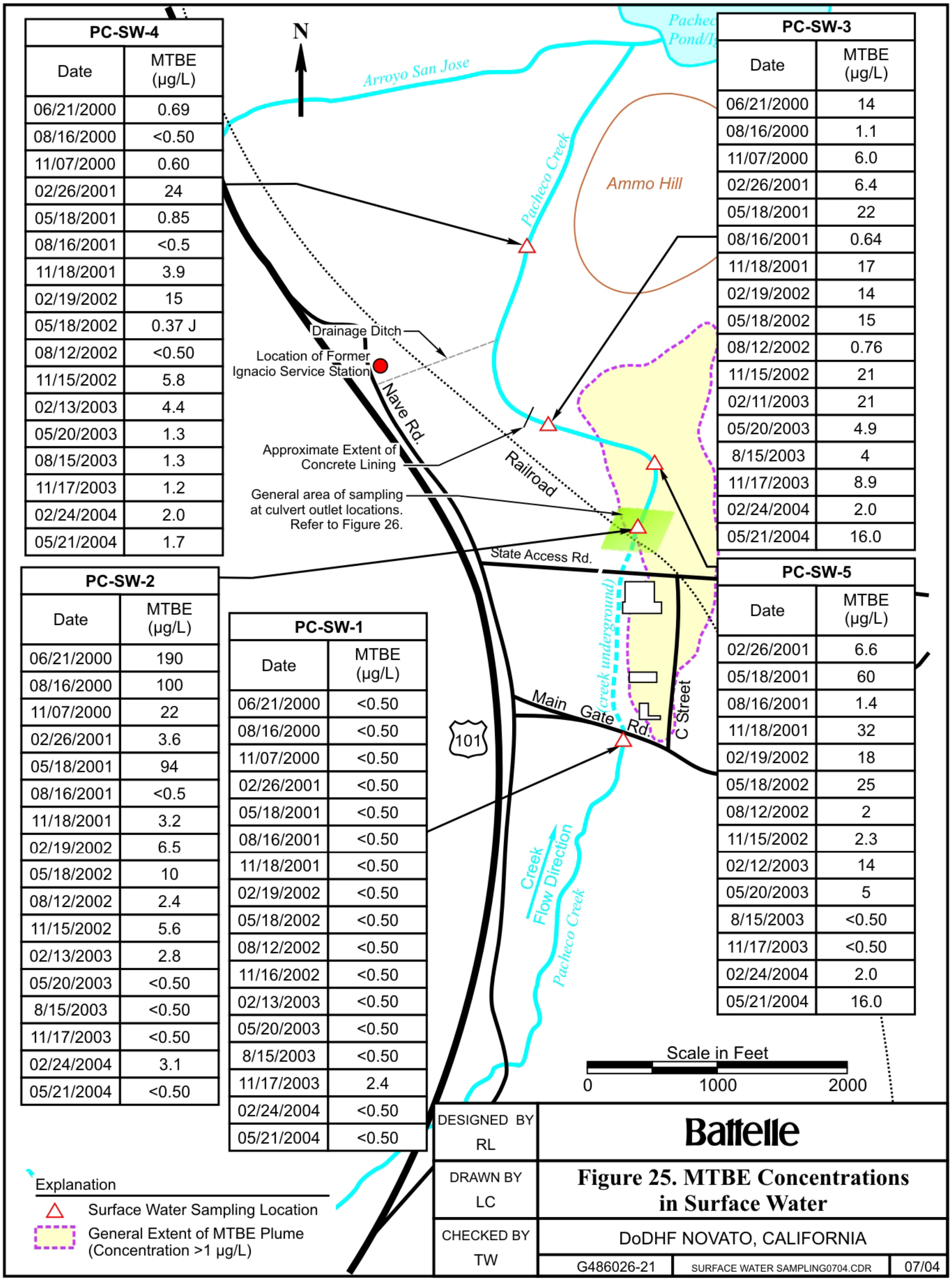


EXPLANATION

⊕ MONITORING WELL

<0.5 MTBE CONCENTRATION (µg/L), May, 2004

DESIGNED BY RL	Battelle		
DRAWN BY LC	**Figure 24. Extent of MTBE Distribution in Groundwater (May 2004)**		
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA		
	PROJECT G486026-21	FILE MTBE_04MAY.CDR	DATE 07/04



PC-SW-4

Date	MTBE (µg/L)
06/21/2000	0.69
08/16/2000	<0.50
11/07/2000	0.60
02/26/2001	24
05/18/2001	0.85
08/16/2001	<0.5
11/18/2001	3.9
02/19/2002	15
05/18/2002	0.37 J
08/12/2002	<0.50
11/15/2002	5.8
02/13/2003	4.4
05/20/2003	1.3
08/15/2003	1.3
11/17/2003	1.2
02/24/2004	2.0
05/21/2004	1.7

PC-SW-3

Date	MTBE (µg/L)
06/21/2000	14
08/16/2000	1.1
11/07/2000	6.0
02/26/2001	6.4
05/18/2001	22
08/16/2001	0.64
11/18/2001	17
02/19/2002	14
05/18/2002	15
08/12/2002	0.76
11/15/2002	21
02/11/2003	21
05/20/2003	4.9
8/15/2003	4
11/17/2003	8.9
02/24/2004	2.0
05/21/2004	16.0

PC-SW-2

Date	MTBE (µg/L)
06/21/2000	190
08/16/2000	100
11/07/2000	22
02/26/2001	3.6
05/18/2001	94
08/16/2001	<0.5
11/18/2001	3.2
02/19/2002	6.5
05/18/2002	10
08/12/2002	2.4
11/15/2002	5.6
02/13/2003	2.8
05/20/2003	<0.50
8/15/2003	<0.50
11/17/2003	<0.50
02/24/2004	3.1
05/21/2004	<0.50

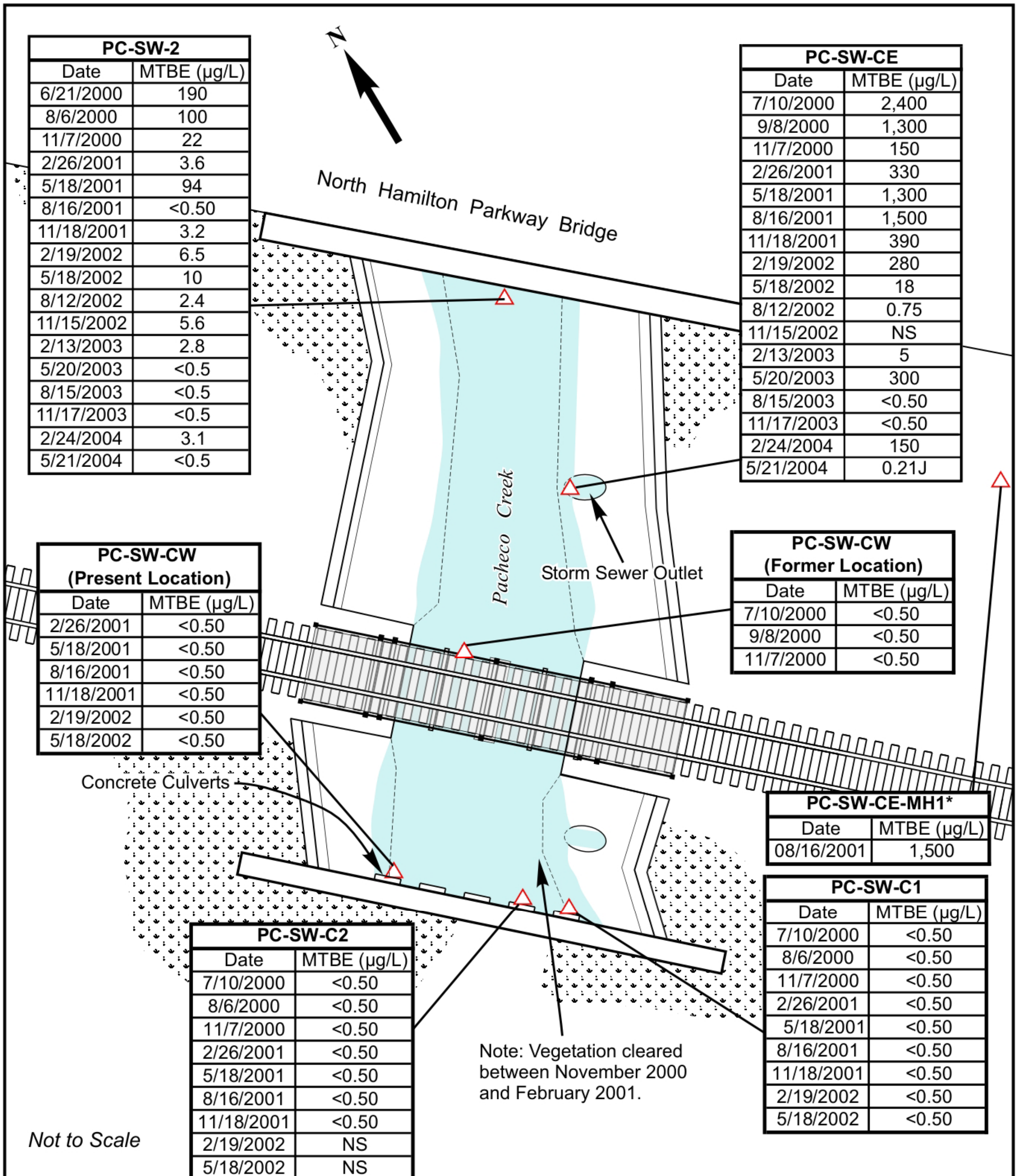
PC-SW-1

Date	MTBE (µg/L)
06/21/2000	<0.50
08/16/2000	<0.50
11/07/2000	<0.50
02/26/2001	<0.50
05/18/2001	<0.50
08/16/2001	<0.50
11/18/2001	<0.50
02/19/2002	<0.50
05/18/2002	<0.50
08/12/2002	<0.50
11/16/2002	<0.50
02/13/2003	<0.50
05/20/2003	<0.50
8/15/2003	<0.50
11/17/2003	2.4
02/24/2004	<0.50
05/21/2004	<0.50

PC-SW-5

Date	MTBE (µg/L)
02/26/2001	6.6
05/18/2001	60
08/16/2001	1.4
11/18/2001	32
02/19/2002	18
05/18/2002	25
08/12/2002	2
11/15/2002	2.3
02/12/2003	14
05/20/2003	5
8/15/2003	<0.50
11/17/2003	<0.50
02/24/2004	2.0
05/21/2004	16.0

DESIGNED BY	Battelle
RL	
DRAWN BY	**Figure 25. MTBE Concentrations in Surface Water**
LC	
CHECKED BY	DoDHF NOVATO, CALIFORNIA
TW	G486026-21 / SURFACE WATER SAMPLING0704.CDR / 07/04



PC-SW-2	
Date	MTBE (µg/L)
6/21/2000	190
8/6/2000	100
11/7/2000	22
2/26/2001	3.6
5/18/2001	94
8/16/2001	<0.50
11/18/2001	3.2
2/19/2002	6.5
5/18/2002	10
8/12/2002	2.4
11/15/2002	5.6
2/13/2003	2.8
5/20/2003	<0.5
8/15/2003	<0.5
11/17/2003	<0.5
2/24/2004	3.1
5/21/2004	<0.5

PC-SW-CE	
Date	MTBE (µg/L)
7/10/2000	2,400
9/8/2000	1,300
11/7/2000	150
2/26/2001	330
5/18/2001	1,300
8/16/2001	1,500
11/18/2001	390
2/19/2002	280
5/18/2002	18
8/12/2002	0.75
11/15/2002	NS
2/13/2003	5
5/20/2003	300
8/15/2003	<0.50
11/17/2003	<0.50
2/24/2004	150
5/21/2004	0.21J

PC-SW-CW (Present Location)	
Date	MTBE (µg/L)
2/26/2001	<0.50
5/18/2001	<0.50
8/16/2001	<0.50
11/18/2001	<0.50
2/19/2002	<0.50
5/18/2002	<0.50

PC-SW-CW (Former Location)	
Date	MTBE (µg/L)
7/10/2000	<0.50
9/8/2000	<0.50
11/7/2000	<0.50

PC-SW-CE-MH1*	
Date	MTBE (µg/L)
08/16/2001	1,500

PC-SW-C1	
Date	MTBE (µg/L)
7/10/2000	<0.50
8/6/2000	<0.50
11/7/2000	<0.50
2/26/2001	<0.50
5/18/2001	<0.50
8/16/2001	<0.50
11/18/2001	<0.50
2/19/2002	<0.50
5/18/2002	<0.50

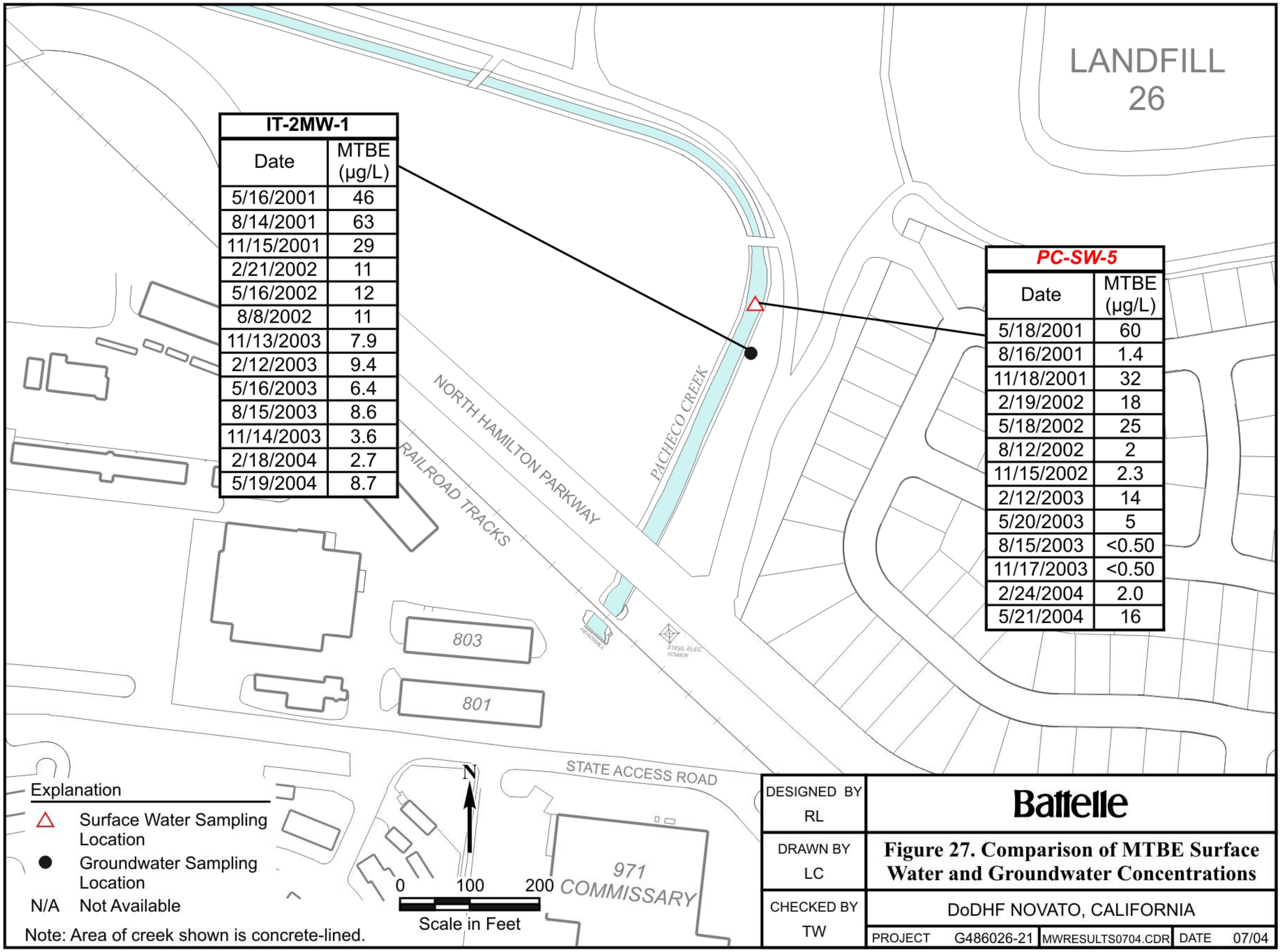
PC-SW-C2	
Date	MTBE (µg/L)
7/10/2000	<0.50
8/6/2000	<0.50
11/7/2000	<0.50
2/26/2001	<0.50
5/18/2001	<0.50
8/16/2001	<0.50
11/18/2001	<0.50
2/19/2002	NS
5/18/2002	NS

Explanation

- △ Surface Water Sampling Location
- Vegetation
- NS Could Not Be Sampled Due to Low Flow Conditions

*Water sample collected from open manhole of storm sewer drainage pipe before outlet to Pacheco Creek.

DESIGNED BY RL	Battelle
DRAWN BY LC	**Figure 26. MTBE Concentrations at Culvert Outlet Locations**
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA
	PROJECT G486026-21 | NSAMPLES0704.CDR | DATE 07/04



IT-2MW-1

Date	MTBE (µg/L)
5/16/2001	46
8/14/2001	63
11/15/2001	29
2/21/2002	11
5/16/2002	12
8/8/2002	11
11/13/2003	7.9
2/12/2003	9.4
5/16/2003	6.4
8/15/2003	8.6
11/14/2003	3.6
2/18/2004	2.7
5/19/2004	8.7

PC-SW-5

Date	MTBE (µg/L)
5/18/2001	60
8/16/2001	1.4
11/18/2001	32
2/19/2002	18
5/18/2002	25
8/12/2002	2
11/15/2002	2.3
2/12/2003	14
5/20/2003	5
8/15/2003	<0.50
11/17/2003	<0.50
2/24/2004	2.0
5/21/2004	16

Explanation

- △ Surface Water Sampling Location
- ● Groundwater Sampling Location
- N/A Not Available

Note: Area of creek shown is concrete-lined.

DESIGNED BY RL	Battelle
DRAWN BY LC	**Figure 27. Comparison of MTBE Surface Water and Groundwater Concentrations**
CHECKED BY TW	DoDHF NOVATO, CALIFORNIA
	PROJECT G486026-21 · MWRESULTS0704.CDR · DATE 07/04

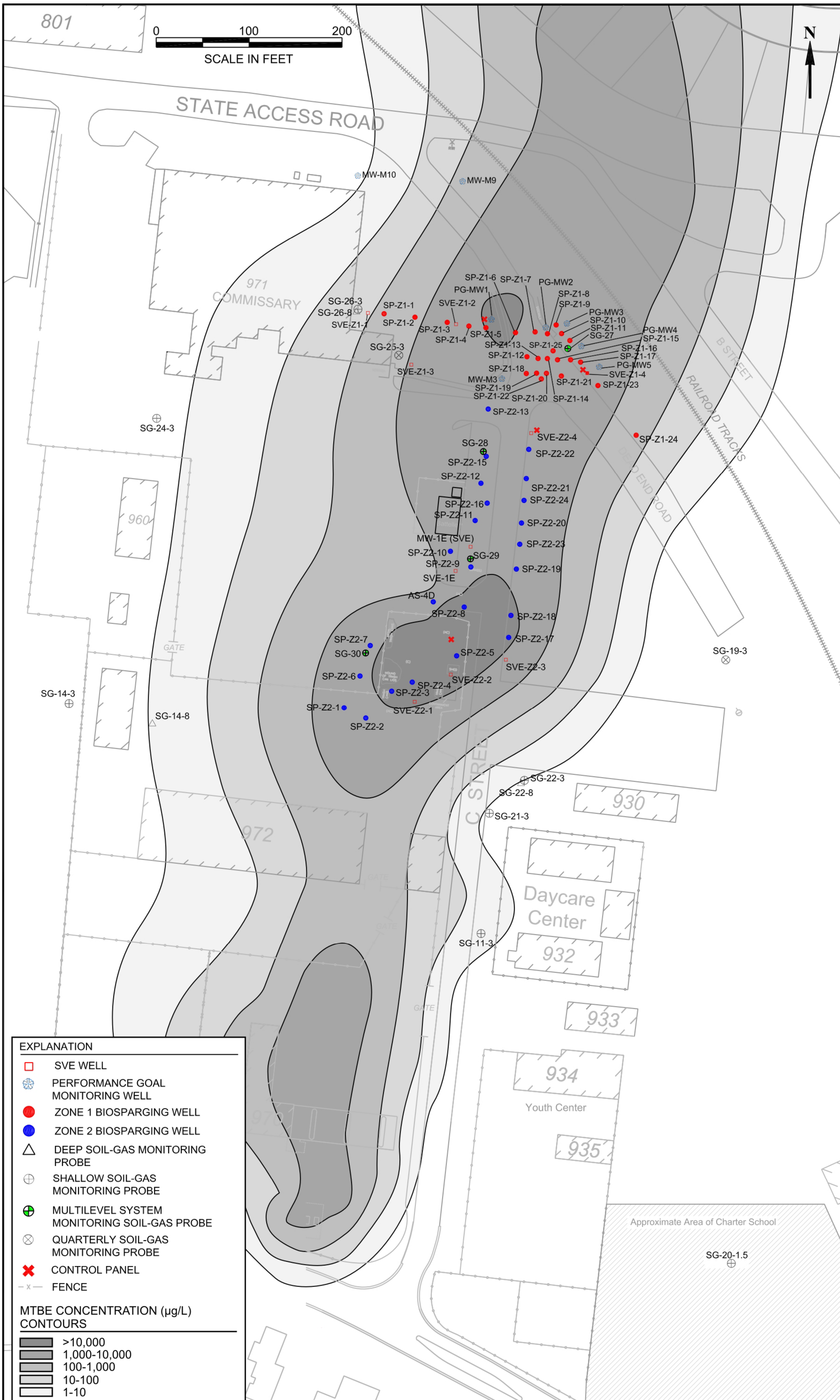


Figure 28. Biosparging System Layout

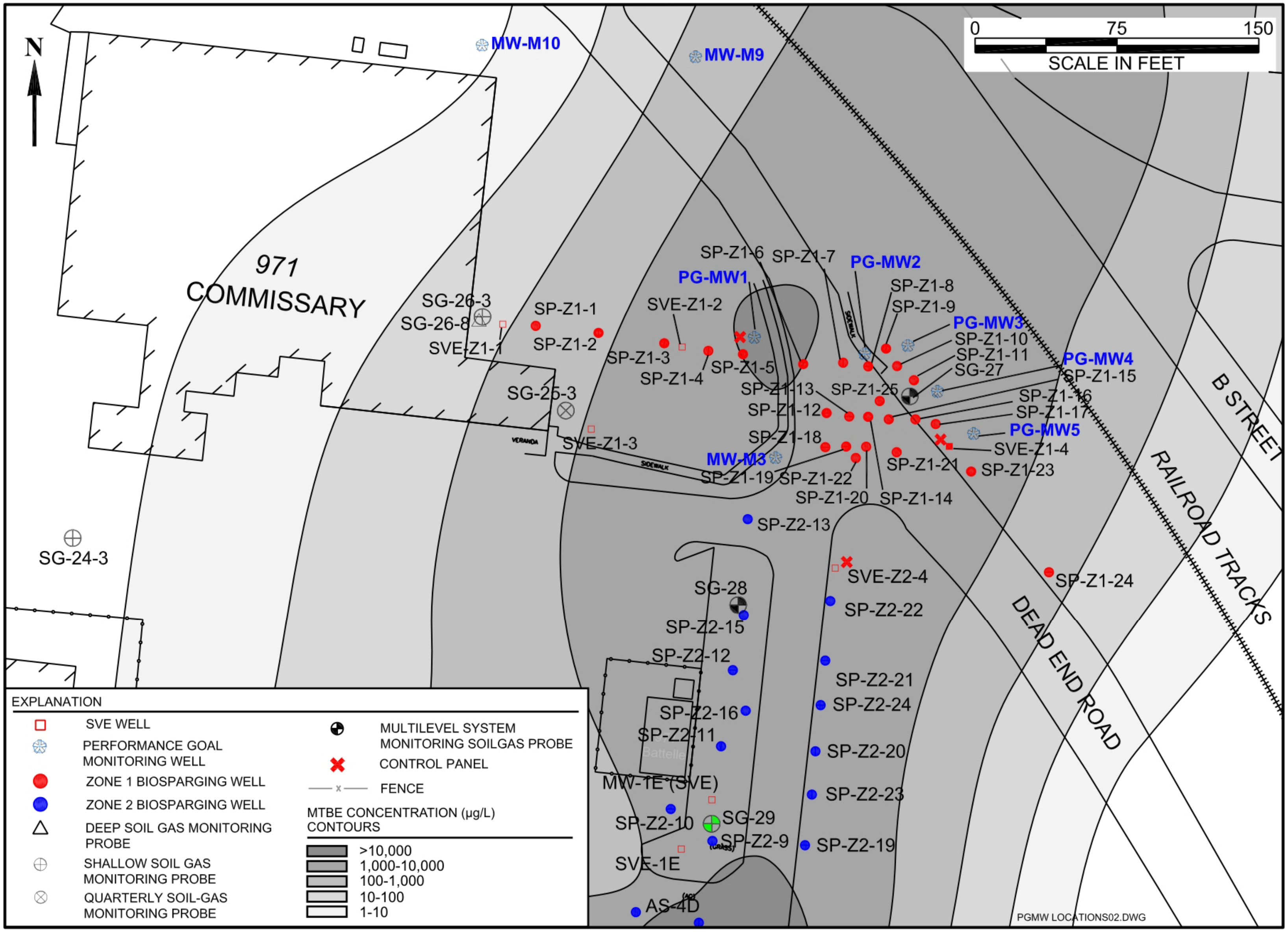


Figure 29. Performance Goal Monitoring Well Locations

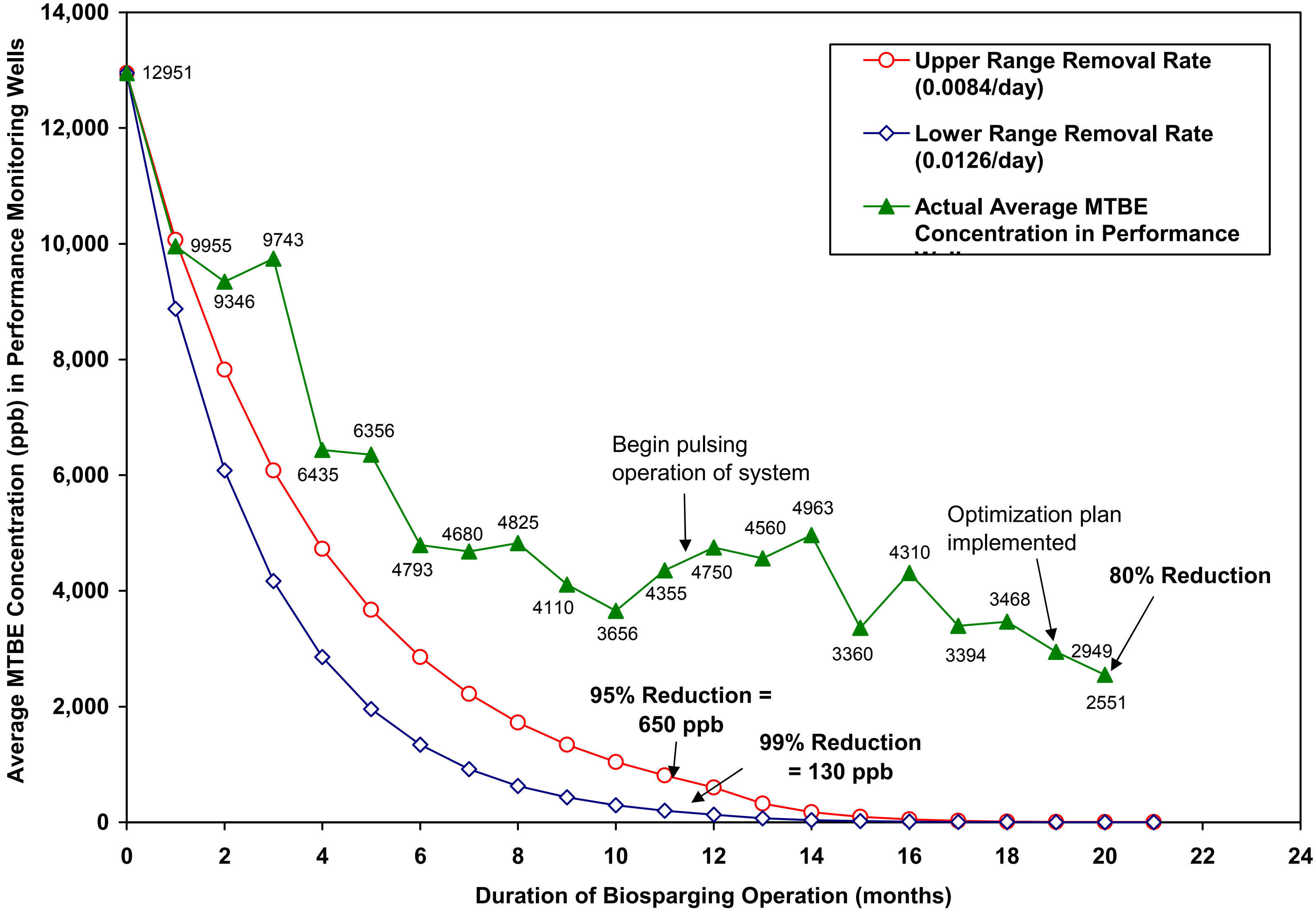
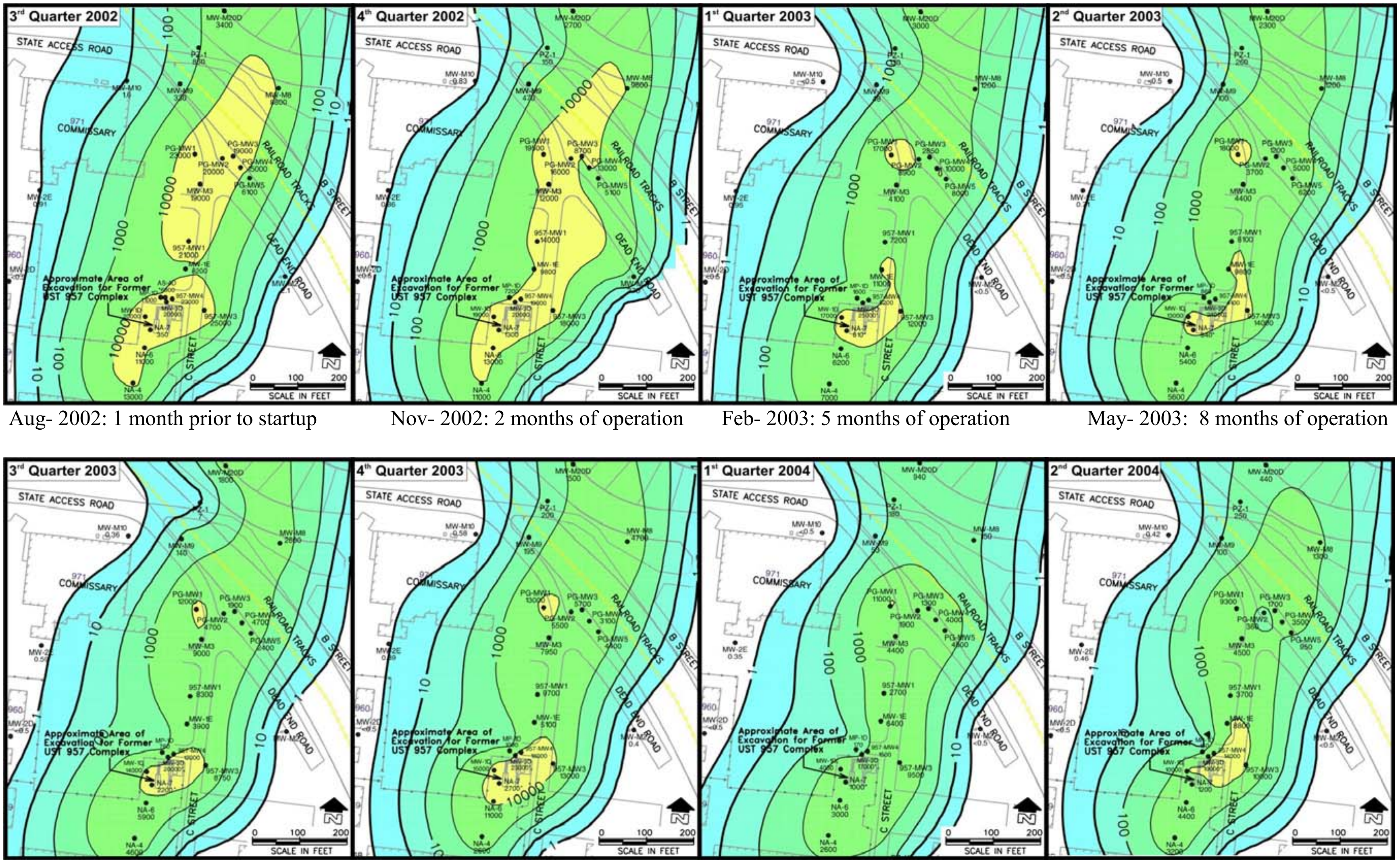


Figure 30. Actual Versus Expected Average MTBE Concentration Trends in Performance Goal Monitoring Wells



Aug- 2002: 1 month prior to startup
Nov- 2002: 2 months of operation
Feb- 2003: 5 months of operation
May- 2003: 8 months of operation
Aug- 2003: 11 months of operation
Nov- 2003: 14 months of operation
Feb- 2004: 17 months of operation
May- 2004: 20 months of operation

Figure 31. MTBE Plume Contours in the Biosparging Treatment Area

TABLES

Table 1. Groundwater Monitoring Network and Decision Criteria by Objective[a]

Location	Monitoring Wells	Decision Criteria
Transect		
Area A (970 Source Area)	970-MW1, MW-5A, MW-6A, MW-1A, MW-7A	Concentration trends which show a general decrease or do not increase over time indicate that a continuing source to groundwater does not exist; consistently increasing concentrations indicate that a potential source to groundwater exists.
Area D (957 Source Area)	MW-1D, MP-1D, 957-MW4, 957-MW3	
Area B	MW-4B, MW-1B, 970-MW4, MW-3B	If consistently increasing concentrations are observed, the potential impacts to downgradient receptors will be evaluated; consistently decreasing or stable concentrations indicate that internal plume migration is not occurring in these areas.
Property boundary (State Access Road)	MW-M1, MW-M10, MW-M9, MW-M8, MW-M16	
Downgradient MTBE transect	IT-2MW-2, IT-1MW-4A, IT-MW-92-38, IT-MW-92-39, MW-M25 (S and D)	
Perimeter		
Benzene plume perimeter	NA-0, 970-MW1, 970-MW2, 957-MW1, 957-MW3, 970-MW3, MW-3B, MW-10A	Concentrations remaining below detection limits at perimeter wells of the respective plumes indicate that the extent of the plume is not expanding; if benzene and/or MTBE is consistently detected in wells in which they previously had not been detected, this may be an indication of potential plume migration.
MTBE plume perimeter	NA-0, MW-4B, MW-6B, MW-2D, MW-2E, MW-M1, PZ-3, PZ-4, MW-M19, MW-M11, IT-2MW-2, IT-PZ-5, MW-M12, MW-M13, IT-GMP-17, IT-GMP-18, IT-EW-91-1, IT-MW-81S, IT-MW-81D, MW-M25 (S and D), MW-M24, MW-M16, MW-M2, 970-MW3, MW-3B	
Centerline		
Centerline of plume from NA-0 to IT-GMP-18 (approximately 3,000 ft downgradient)	NA-0, NA-1, MW-1A, 970-MW5, MW-4A, 970-MW4, NA-4, NA-6, NA-7, 957-MW4, MW-1E, 957-MW1, MW-M3, MW-M9, PZ-1, IT-MW-92-38, MW-M20 (S and D), MW-M21, MW-M22, MW-M23, IT-PZ-9, IT-GMP-17, IT-GMP-18	Concentrations will be compared to established risk levels to ensure that they are within acceptable levels; if consistent increases in concentration are observed, a determination of the potential impacts will be made and the monitoring network reevaluated.
Development Area MTBE Monitoring		
Development area north of Navy Property	PZ-1, PZ-3, PZ-4, MW-M11, MW-M15, IT-2MW-1, IT-PZ-5, IT-2MW-2, IT-1MW-4A, IT-MW-92-38, IT-MW-92-39, IT-GMP-15, EW-91-1, MW-M12, IT-PZ-7, MW-M13, IT-PZ-9, IT-GMP-17, MW-M14 (S and D), MW-M17, MW-M18, MW-M19, MW-M20 (S and D), MW-M21, MW-M22, MW-M23, MW-M24, MW-M25 (S and D), MW-M26 (S and D), MW-M27 (S and D), IT-GMP-16, IT-GMP-18, IT-MW-81 (S and D), MW-M8, MW-M16	MTBE concentrations will be compared to residential risk values to ensure that concentrations are protective of future residents; consistently increasing concentrations (one full cycle) will indicate internal migration of the plume.

Table 1. Groundwater Monitoring Network and Decision Criteria by Objective (Continued)

Location	Monitoring Wells	Decision Criteria
Special Features		
Northbay Children's Center	970-MW3, MW-3B, PZ-10, PZ-11	If concentrations do not exceed residential risk levels, no further action is warranted; if changing concentrations indicate that risk levels will likely be exceeded in the future, further evaluation or more extensive monitoring may be warranted.
Property boundary (State Access Road)	MW-M1, MW-M10, MW-M9, MW-M8, MW-M16	Consistently increasing concentrations (one full cycle) will be indicative of internal plume migration; consistently decreasing or stable concentrations (one full cycle) will indicate that elevated concentrations are not migrating across the property boundary.
Pacheco Creek vicinity	IT-PZ-5, IT-2MW-2, IT-1MW-4A, IT-2MW-1, MW-M17, MW-M18	Decreasing concentrations will indicate that the extent of impact to Pacheco Creek will likely decrease; increasing concentrations will indicate that future impact to Pacheco Creek may increase (if the surrounding groundwater is in fact the source of impact).
Bedrock wells	MW-9A, MW-3D	Comparison of constituent concentrations detected in bedrock wells to nearby shallower screened wells will determine impact to fractured bedrock.
Former UST 970-3 tank pit excavation	MW-8A	Concentration trends, which show a general decrease or do not increase over time, indicate that a continuing source to groundwater does not exist; consistently increasing concentrations indicate that a potential source to groundwater exists.
Nested well pairs	MW-M14 (S and D), MW-M20 (S and D), MW-M25 (S and D), MW-M26 (S and D), MW-M27 (S and D)	Comparable concentrations between samples from shallow and deep intervals indicate that MTBE is distributed equally between upper and lower aquifer zones; varying concentrations indicate stratification of MTBE in the aquifer zone which could potentially be associated with surface water infiltration.

(a) This table updates the original groundwater monitoring network provided in Table 3 of the *Groundwater Monitoring Plan* (Battelle, 2000a).

Table 2. Sampling and Analytical Methods

Analyte	Method	Container	Sample Size	Preservation	Holding Time
Groundwater					
BTEX, MTBE, TBA[(a)], TBF, ETBE, TAME, DIPE	SW-8260B	Borosilicate glass	3 × 40 mL VOA vials[(c)]	HCl to pH <2, @ 4°C	14 days
TPH (purgeable)	*California LUFT Manual*[(b)]	Borosilicate glass	3 × 40 mL VOA vials[(c)]	HCl to pH <2, @ 4°C	14 days
Surface Water					
BTEX, MTBE	SW-8260B	Borosilicate glass	3 × 40 mL VOA vials	HCl to pH <2, @ 4°C	14 days

(a) Sample collected without the preservative HCl.
(b) Source: CSWRCB, 1989.
(c) One set of three VOA vials is sufficient for all groundwater analysis with the exception of additional VOA vials collected for lower laboratory detection limits
LUFT – Leaking Underground Fuel Tank

Table 3. Laboratory Practical Quantitation Limits Based on Clean Matrices

Analyte	Reporting Limit for Water
TPH (purgeable)	0.05 mg/L
BTEX	0.5 µg/L
MTBE	0.5 µg/L
TBA	10 µg/L
TBF	5 µg/L
ETBE	2 µg/L
TAME	1 µg/L
DIPE	2 µg/L

Table 4. QC Samples

Type of Sample	Number of Samples
Field duplicates	10% of total samples collected
Equipment rinsate[(a)]	20% of total samples collected
Trip blank	1 per cooler
Field blank	1 per day
Laboratory QA[(b)]	5%

(a) Required to verify decontamination between samples where nondedicated equipment is used.
(b) For matrix spike/matrix spike duplicate analysis.

Table 5. Groundwater Monitoring Analytical Program[a]

Well ID	TPH-G (Method: *California LUFT Manual* [CSWRCB, 1989])	BTEX and MTBE (EPA Method 8260B)	TBA, TBF, ETBE, TAME, DIPE (8260B)
MW-1A[b]	x	x	x
MW-4A[b]	x	x	-
MW-5A[b]	x	x	x
MW-6A[b]	x	x	x
MW-7A	x	x	x
MW-8A	x	x	-
MW-9A	x	x	-
MW-10A[b]	x	x	x
MW-1B[b]	x	x	-
MW-3B	x	x	x
MW-4B[b]	x	x	-
MW-6B[b]	x	x	-
MW-1D	x	x	x
MW-2D	x	x	-
MW-3D[c]	x	x	-
MP-1D[c]	x	x	x
MW-1E	x	x	-
MW-2E[c]	x	x	x
MW-2E-BR[c]	-	x	x
957-MW1	x	x	x
957-MW3	x	x	x
957-MW4[c]	x	x	x
970-MW1[b]	x	x	x
970-MW2[b]	x	x	x
970-MW3	x	x	x
970-MW4[b]	x	x	-
970-MW5[b]	x	x	-
NA-0[b]	x	x	x
NA-1	x	x	-
NA-4	x	x	-
NA-6	x	x	-
NA-7	x	x	-

Table 5. Groundwater Monitoring Analytical Program[a] (Continued)

Well ID	TPH-G (Method: *California LUFT Manual* [CSWRCB, 1989])	BTEX and MTBE (EPA Method 8260B)	TBA, TBF, ETBE, TAME, DIPE (8260B)
PZ-1	-	x	-
PZ-3	-	x	-
PZ-4[b]	-	x	-
PZ-10	x	x	-
PZ-11	-	x	-
MW-M1	-	x	-
MW-M2[c]	-	x	x
MW-M2-BR[c]	-	x	x
MW-M3[d]	x	x	TBA/TBF
MW-M8[c]	-	x	x
MW-M8-BR[c]	-	x	x
MW-M9[d]	-	x	TBA/TBF
MW-M10[d]	-	x	TBA/TBF
MW-M11[b]	-	x	-
MW-M12[b]	-	x	-
MW-M13	-	x	-
MW-M14D	-	x	-
MW-M14S	-	x	-
MW-M15	-	x	-
MW-M16	-	x	-
MW-M17	-	x	-
MW-M18	-	x	-
MW-M19	-	x	-
MW-M20D	-	x	-
MW-M20S[e]	-	x	-
MW-M21	-	x	-
MW-M22	-	x	-
MW-M23	-	x	-
MW-M24[b]	-	x	-
MW-M25D[b]	-	x	-
MW-M25S[e]	-	x	-
MW-M26D[b]	-	x	-
MW-M26S[e]	-	x	-
MW-M27D[b]	-	x	-

Table 5. Groundwater Monitoring Analytical Program[a] (Continued)

Well ID	TPH-G (Method: *California LUFT Manual* [CSWRCB, 1989])	BTEX and MTBE (EPA Method 8260B)	TBA, TBF, ETBE, TAME, DIPE (8260B)
MS-M27S[e]	-	x	-
IT-PZ-5	-	x	-
IT-PZ-7	-	x	-
IT-PZ-9	-	x	-
IT-1MW-4A[b]	-	x	-
IT-GMP-15	-	x	-
IT-GMP-16	-	x	-
IT-GMP-17	-	x	-
IT-GMP-18	-	x	-
IT-MW92-38	-	x	-
IT-MW92-39	-	x	-
IT-EW-91-1[e]	-	x	-
IT-2MW-1	-	x	-
IT-2MW-2[b]	-	x	-
IT-MW-81D	-	x	-
IT-MW-81S[b]	-	x	-
PG-MW1[d]	-	x	TBA/TBF
PG-MW2[d]	-	x	TBA/TBF
PG-MW3[d]	-	x	TBA/TBF
PG-MW4[d]	-	x	TBA/TBF
PG-MW5[d]	-	x	TBA/TBF
PC-SW-1	-	x	-
PC-SW-2	-	x	-
PC-SW-3	-	x	-
PC-SW-4	-	x	-
PC-SW-5	-	x	-
PC-SW-CE	-	x	-

(a) This table updates the original groundwater monitoring analytical program provided in Table 2 of the *Groundwater Monitoring Plan* (Battelle, 2000a).
(b) Semiannual monitoring (November and May quarterly monitoring events).
(c) Inorganic parameters (sulfate, chloride, alkalinity, calcium, magnesium, sodium, potassium) and metals. Require 1 preserved 250 mL plastic bottle, 1 unpreserved. Both should be field-filtered before sent to lab.
(d) Performance monitoring (MTBE, BTEX, TBA/TBF, acetone)
(e) Annual monitoring (November monitoring event).

Table 6. Historical Maximum and Average Concentrations of MTBE and Benzene

Date	MTBE (μg/L)		Benzene (μg/L)	
	Maximum	Average	Maximum	Average
Nov-96[(a)]	240,000	73,568	12,000	2,128
Mar-98[(a)]	77,000	24,004	9,400	1,436
May-98	280,000	32,058	14,000	1,791
Aug-98	140,000	21,645	10,000	1,002
Nov-98	130,000	19,288	11,000	982
Feb-99	84,000	12,360	4,300	418
May-99	140,000	16,762	6,300	368
Aug-99[(b)]	78,000	9,214	3,900	198
Nov-99	82,000	10,925	4,000	139
Feb-00[(b)]	65,000	9,425	2,200	114
May-00	61,000	8,162	1,500	94
Aug-00	43,000	5,135	2,300	83
Nov-00[(c)]	35,000 [(d)]	4,700	1,600	40
Feb-01	43,000	3,779	660	31
May-01	33,000	3,268	350	15
Aug-01	45,000	4,684	250	16
Nov-01	32,000	3,316	300	18
Feb-02	26,000	2,374	230	10
May-02	22,000	2,518	120	11
Aug-02[(e)]	25,000	3,391	130	8
Nov-02	20,000	2,441	240	9
Feb-03	25,000	1,950	65	5
May-03	24,000	1,593	150	6
Aug-03	20,000	1,964	110	5
Nov-03	23,000	1,776	230	7
Feb-04	17,000	1,184	160	5
May-04	19,000	1,413	210	5

(a) Prior to system installation. Only nine existing wells.
(b) Monitoring well network modified due to well abandonment.
(c) Monitoring well network modified due to installation of replacement wells.
(d) A duplicate sample was collected from this well and reported an MTBE concentration of 29,000 μg/L.
(e) Monitoring well network modified according to recommendations in the *Annual Site Status Report (for the Year 2001)* (Battelle, 2002a).

Table 7. Bedrock Well and Nearby Monitoring Well Sampling Results

Bedrock Well ID	Sample Date	MTBE (µg/L)	Benzene (µg/L)	Nearby Monitoring Well ID	Sample Date	MTBE (µg/L)	Benzene (µg/L)
MW-9A	10/21/00	220	<2.0	MW-5A	NS	NS	NS
	11/17/00[a]	120/120	<2.0/<2.0		11/13/00	2,300	2.0
	3/1/01	600	16		2/25/01	1,100	<1.0
	5/22/01	350	<1.3		5/16/01	380	0.57
	8/19/01	310	<0.5		8/14/01	330	<0.5
	11/19/01	260	<0.5		11/18/01	530	1.9
	2/21/02	530	<0.5		2/19/02	330	<0.5
	5/20/02	390	<0.5		5/21/02	170	0.23 J
	8/11/02	330	<5		8/11/02	130	<5
	11/17/02	310	<0.5		11/17/02	250	<0.5
	2/10/03	290	<0.5		2/10/03	250	<0.5
	5/21/03	300	<0.5		5/13/03	200	<0.5
	8/12/03	270	<0.5		NS	NS	NS
	11/15/03	150	<0.5		11/10/03	110	<0.5
	2/24/04	94	<0.5		NS	NS	NS
	5/24/04	270	<0.5		NS[b]	NS	NS
MW-3D	10/21/00	25,000	<10	957-MW4	NS	NS	NS
	11/17/00	34,000	<10		11/15/00	34,000	2.7
	2/28/01	43,000	<20		2/25/01	10,000	<1.0
	5/22/01	28,000	<2.5		5/14/01	30,000	<0.5
	8/19/01[a]	31,000/34,000	<2.5/<2.5		8/14/01	39,000	<6.3
	11/19/01[a]	25,000/26,000	<2.5/<2.5		11/18/01	32,000	<2.5
	2/20/02	26,000	<5.0		2/18/02	13,000	<1.0
	5/20/02	22,000	<120		5/20/02	20,000	<0.5
	8/12/02	20,000	<2.5		8/12/02	23,000	<2.5
	11/12/02	20,000	<2.5		11/12/02	19,000	<2.5
	2/5/03	25,000	<0.5		2/5/03	5,200	<0.5
	5/8/03	24,000	<2.5		5/8/03	4,100	<0.5
	8/11/03	20,000	<0.5		8/11/03	12,000	<0.5
	11/6/03	23,000	<0.5		11/6/03	18,000	<0.5
	2/12/04	17,000	<0.5		2/12/04	1,500	<0.5
	5/14/04	19,000	<0.5		5/14/04	14,000	<0.5
MW-2E-BR	12/4/03	0.46 J	<0.5	MW-2E	11/15/03	0.89	<0.5
	2/24/04	0.35 J	<0.5		2/23/04	0.35 J	<0.5
	6/4/04	<0.5	<0.5		5/21/04	0.46 J	<0.5
MW-M2-BR	12/4/03	140	<0.5	MW-M2	11/15/03	0.4 J	<0.5
	2/24/04	9.9	<0.5		2/23/04	<0.5	<0.5
	6/4/04	0.64	<0.5		5/21/04	<0.5	<0.5
MW-M8-BR	12/4/03	19	<0.5	MW-M8	11/15/03	4,700	<0.5
	2/24/04	7.3	<0.5		2/20/04	150	<0.5
	6/4/04	1.9	<0.5		5/20/04	1300	<0.5

(a) Results of duplicate sample are shown.
(b) MW-5A was inadvertently omitted during this sampling event.
J = estimated value below the detection limit of 0.5 µg/L
NS = not sampled.

Table 8. Nested Well Sampling Results

Sample ID[a]	Sample Date	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)
November 2000						
MW-M14S	11/7/00	13	<2.5	<2.5	<2.5	<2.5
MW-M14D	11/8/00	11	<0.5	<0.5	<0.5	<0.5
MW-M20S[b]	NS	NS	NS	NS	NS	NS
MW-M20D	11/16/00	2,000	<1.0	<1.0	<1.0	<1.0
MW-M25S	11/14/00	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M25D	11/15/00	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26S	11/14/00	280	<0.5	<0.5	<0.5	<0.5
MW-M26D	11/15/00	280	<0.5	<0.5	<0.5	<0.5
MW-M27S	11/9/00	<1.3	<1.3	<1.3	<1.3	<1.3
MW-M27D	11/10/00	1.3	<0.5	<0.5	<0.5	<0.5
February 2001						
MW-M14S	2/27/01	39	<10	<10	<10	<20
MW-M14D	2/28/01	30	<0.05	<0.5	<0.5	<1.0
MW-M20S[b]	NS	NS	NS	NS	NS	NS
MW-M20D	2/26/01	5,600	<0.5	0.58	<0.5	<1.0
MW-M25S	2/27/01	<10	<10	<10	<10	<20
MW-M25D	2/28/01	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M26S	2/27/01	370	<0.5	<0.5	<0.5	<1.0
MW-M26D	2/28/01	320	<0.5	<0.5	<0.5	<1.0
MW-M27S	2/27/01	1.7	<0.5	<0.5	<0.5	<1.0
MW-M27D	2/28/01	1.7	<0.5	<0.5	<0.5	<1.0
May 2001						
MW-M14S	5/15/01	46	<5.0	<5.0	<5.0	<5.0
MW-M14D	5/17/01	30	<0.5	<0.5	<0.5	<0.5
MW-M20S[b]	NS	NS	NS	NS	NS	NS
MW-M20D	5/18/01	4,100	<0.5	<0.5	<0.5	<0.5
MW-M25S	5/15/01	<2.5	<2.5	<2.5	<2.5	<2.5
MW-M25D	5/21/01	<0.5	<0.5	0.52	<0.5	<0.5
MW-M26S	5/15/01	200	<0.5	<0.5	<0.5	<0.5
MW-M26D	5/17/01	180	<0.5	0.91	<0.5	<0.5
MW-M27S	5/15/01	1.1	<0.5	<0.5	<0.5	<0.5
MW-M27D	5/17/01	1.0	<0.5	1.1	<0.5	<0.5
August 2001						
MW-M14S	8/14/01	56	<2.5	<2.5	<2.5	<2.5
MW-M14D	8/15/01	44	<0.5	1.8	<0.5	<0.5
MW-M20S[b]	NS	NS	NS	NS	NS	NS
MW-M20D	8/18/01	6,900	<0.5	1.6	<0.5	<0.5
MW-M25S	8/14/01	<0.5	<0.5	0.73	<0.5	<0.5
MW-M25D	8/16/01	<0.5	<0.5	1.4	<0.5	<0.5
MW-M26S	8/14/01	310	<0.5	<0.5	<0.5	<0.5
MW-M26D	8/15/01	320	<0.5	1.6	<0.5	<0.5
MW-M27S	8/14/01	1.5	<0.5	<0.5	<0.5	<0.5
MW-M27D	8/15/01	1.3	<0.5	2.2	<0.5	<0.5
November 2001						
MW-M14S	11/16/01	91	<1.0	<1.0	<1.0	<1.0
MW-M14D	11/19/01	58	<0.5	<0.5	<0.5	<0.5
MW-M20S[b]	NS	NS	NS	NS	NS	NS
MW-M20D	11/19/01	5,200	<0.5	<0.5	<0.5	<0.5

Table 8. Nested Well Sampling Results (Continued)

Sample ID[(a)]	Sample Date	MTBE (μg/L)	Benzene (μg/L)	Toluene (μg/L)	Ethylbenzene (μg/L)	Total Xylenes (μg/L)
MW-M25S	11/15/01	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M25D	11/19/01	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26S	11/17/01	310	<0.5	<0.5	<0.5	<0.5
MW-M26D	11/19/01	330	<0.5	<0.5	<0.5	<0.5
MW-M27S	11/14/01	1.7	<0.5	<0.5	<0.5	<0.5
MW-M27D	11/19/01	1.2	<0.5	<0.5	<0.5	<0.5
February 2002						
MW-M14S	2/23/02	79	<1.0	<1.0	<1.0	<1.0
MW-M14D	2/25/02	130	<0.5	<0.5	<0.5	<0.5
MW-M20S	2/23/02	22	<0.5	<0.5	<0.5	<0.5
MW-M20D	2/25/02	5,600	<0.5	<0.5	<0.5	<0.5
MW-M25S	2/22/02	<1.0	<1.0	<1.0	<1.0	<1.0
MW-M25D	2/25/02	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26S	2/23/02	280	<0.5	<0.5	<0.5	<0.5
MW-M26D	2/25/02	340	<0.5	<0.5	<0.5	<0.5
MW-M27S	2/22/02	1.7	<0.5	<0.5	<0.5	<0.5
MW-M27D	2/25/02	1.9	<0.5	<0.5	<0.5	<0.5
May 2002						
MW-M14S	5/13/02	54	<0.5	<0.5	<0.5	<1.0
MW-M14D	5/14/02	170	<0.5	<0.5	<0.5	<1.0
MW-M20S	5/17/02	18	<0.5	<0.5	<0.5	<1.0
MW-M20D	5/18/02	4,400	<250	<250	<250	<500
MW-M25S	5/15/02	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M25D	5/16/02	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M26S	5/15/02	360	<0.5	<0.5	<0.5	<1.0
MW-M26D	5/16/02	430	<0.5	<0.5	<0.5	<1.0
MW-M27S	5/15/02	1.6	<0.5	<0.5	<0.5	<1.0
MW-M27D	5/16/02	1.7	<0.5	<0.5	<0.5	<1.0
August 2002[(c)]						
MW-M14D	8/7/02	170	<0.5	<0.5	<0.5	<1.0
MW-M20D	8/6/02	3,400	<0.5	<0.5	<0.5	<1.0
MW-M25D	8/7/02	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M26D	8/6/02	320	<0.5	<0.5	<0.5	<1.0
MW-M27D	8/8/02	1.7	<0.5	<0.5	<0.5	<1.0
November 2002						
MW-M14S	11/15/02	52	<0.5	<0.5	<0.5	<1.0
MW-M14D	11/18/02	280	<0.5	<0.5	<0.5	<1.0
MW-M20S	11/16/02	23	<0.5	<0.5	<0.5	<1.0
MW-M20D	11/13/02	2,700	<0.5	<0.5	<0.5	<1.0
MW-M25S	11/14/02	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M25D	11/18/02	<0.5	<0.5	<0.5	<0.5	<1.0
MW-M26S	11/14/02	410	<0.5	<0.5	<0.5	<1.0
MW-M26D	11/16/02	350	<0.5	<0.5	<0.5	<1.0
MW-M27S	11/14/02	2.1	<0.5	<0.5	<0.5	<1.0
MW-M27D	11/18/02	2.5	<0.5	<0.5	<0.5	<1.0
February 2003[(c)]						
MW-M14D	2/11/03	310	<0.5	0.24	<0.5	<0.5
MW-M20D	2/13/03	3,000	<0.5	<0.5	<0.5	<0.5
MW-M25D	2/11/03	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26D	2/11/03	360	<0.5	<0.5	<0.5	<0.5

Table 8. Nested Well Sampling Results (Continued)

Sample ID[(a)]	Sample Date	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)
MW-M27D	2/11/03	2.2	<0.5	<0.5	<0.5	<0.5
May 2003[(d)]						
MW-M14S	5/15/03	120	<0.5	<0.5	<0.5	<0.5
MW-M14D	5/16/03	360	<0.5	<0.5	<0.5	<0.5
MW-M20D	5/20/03	2300	<0.5	<0.5	<0.5	<0.5
MW-M25D	5/15/03	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26D	5/16/03	290	<0.5	<0.5	<0.5	<0.5
MW-M27D	5/14/03	2.4	<0.5	<0.5	<0.5	<0.5
August 2003[(d)]						
MW-M14S	8/15/03	87	<0.5	<0.5	<0.5	<0.5
MW-M14D	8/13/03	480	<0.5	<0.5	<0.5	<0.5
MW-M20D	8/14/03	1800	<0.5	<0.5	<0.5	<0.5
MW-M25D	NS	NS	NS	NS	NS	NS
MW-M26D	8/15/03	240	<0.5	<0.5	<0.5	<0.5
MW-M27D	NS	NS	NS	NS	NS	NS
November 2003						
MW-M14S	11/13/03	210	<0.5	<0.5	<0.5	<0.5
MW-M14D	11/12/03	400	<0.5	<0.5	<0.5	<0.5
MW-M20S	11/15/03	110	<0.5	<0.5	<0.5	<0.5
MW-M20D	11/13/03	1500	<0.5	<0.5	<0.5	<0.5
MW-M25S	11/12/03	<0.5	<0.5	0.49 J	<0.5	0.43 J
MW-M25D	11/11/03	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26S	11/13/03	380	<0.5	0.84	0.28 J	1.93
MW-M26D	11/12/03	290	<0.5	<0.5	<0.5	<0.5
MW-M27S	11/14/03	2.8	<0.5	<0.5	<0.5	<0.5
MW-M27D	11/11/03	2.8	<0.5	<0.5	<0.5	<0.5
February 2004[(d)]						
MW-M14S	2/23/04	230	<0.5	<0.5	<0.5	<0.5
MW-M14D	2/19/04	600	<0.5	<0.5	<0.5	<0.5
MW-M20D	2/20/04	940	<0.5	<0.5	<0.5	<0.5
MW-M25D	NS	NS	NS	NS	NS	NS
MW-M26D	2/19/04	320	<0.5	<0.5	<0.5	<0.5
MW-M27D	NS	NS	NS	NS	NS	NS
May 2004[(d)]						
MW-M14S	5/19/04	350	<0.5	<0.5	<0.5	<0.5
MW-M14D	5/18/04	580	<0.5	<0.5	<0.5	<0.5
MW-M20D	5/20/04	440	<0.5	<0.5	<0.5	<0.5
MW-M25D	5/18/04	<0.5	<0.5	<0.5	<0.5	<0.5
MW-M26D	5/19/04	220	<0.5	<0.5	<0.5	<0.5
MW-M27D	5/19/04	2.6	<0.5	<0.5	<0.5	<0.5

NS = not sampled.

(a) S indicates shallow interval; D indicates deep interval.

(b) MW-M20S was not sampled during this quarterly monitoring event due to dryness.

(c) Shallow wells not sampled due to changes in monitoring requirements as presented in Table 13 of the *Annual Site Status Report (for the Year 2001)* (Battelle, 2002a).

(d) Sampling of shallow wells MW-M20S, MW-M25S, MW-M26S, and MW-M27S has been changed to annually, whereas MW-M14S has been changed from semiannually to quarterly as presented in Table 12 of the *Annual Site Status Report (for the Year 2002)* (Battelle, 2003a).

Table 9. Dissolved MTBE and Benzene Mass Estimates

Date	Dissolved MTBE Mass (kg)	Dissolved Benzene Mass (kg)
May-98[a]	N/A	5.0
Aug-98[a]	N/A	3.9
Nov-98[a]	287	3.4
Jan-99[a]	256	2.3
May-99[a]	277	1.8
Aug-99[b]	183	0.91
Nov-99	163	0.52
Feb-00[b]	126	0.74
May-00	118	0.74
Aug-00	73	0.44
Nov-00[c]	115	0.26
Feb-01	156	0.34
May-01	120	0.18
Aug-01	138	0.09
Nov-01	119	0.09
Feb-02	148	0.11
May-02	144	0.08
Aug-02	Not estimated [d]	Not estimated [d]
Nov-02	124	0.05
Feb-03	Not estimated [d]	Not estimated [d]
May-03	126	0.05
Aug-03	Not estimated [d]	Not estimated [d]
Nov-03	126	0.03
Feb-04	Not estimated [d]	Not estimated [d]
May-04	116	0.02

N/A = not applicable (MTBE plume not fully delineated at this time).

(a) Estimated mass of MTBE and benzene was modified from past estimates using consistent methods and refinements to improve the data quality for each sampling event.

(b) Monitoring well network modified due to well abandonment.

(c) Monitoring well network modified due to installation of replacement wells.

(d) Mass estimates not calculated for this sampling quarter as a result of changes in monitoring requirements as presented in Table 13 of the *Annual Site Status Report (for the Year 2001)* (Battelle, 2002a).

Table 10. Regression Results for Subareas and Individual Wells

Zone	Subarea Results			Individual Well Results						
						Parametric		Nonparametric		
Zone	Slope (annual reduction rate)	p-value	Sen (annual reduction rate)	Well	No. observations	Slope	p-value	M-K Stat	p-value	Sen Est.
Former UST 970 (South of the Biosparging Area)	-0.3708 (31%)	<.0001	-0.4426 (36%)	970-MW1	22	-0.14556	0.4910	91	0.010	-0.33322
				970-MW2	22	-0.32171	0.0000	166	<0.001	-0.25017
				970-MW4	22	-0.48371	0.0002	170	<0.001	-0.72546
				970-MW5	22	-0.50178	0.0000	192	<0.001	-0.62598
				MW-10A	10	-0.14750	0.0608	18	0.132	-0.08971
				MW-1A	20	-0.45677	0.0008	134	<0.01	-0.78611
				MW-1B	20	-0.54321	0.0000	145	<0.001	-0.7588
				MW-2A	5	-1.04319	0.0214	10	0.016	-1.16562
				MW-2B	9	-0.24653	0.2197	9	0.417	-0.13642
				MW-3A	5	-1.38321	0.0192	10	0.016	-1.42316
				MW-4A	20	-0.35751	0.0018	126	<0.001	-0.47197
				MW-5A	12	-0.78245	0.0008	48	<0.001	-0.79421
				MW-5B	10	-1.10218	0.0002	39	<0.001	-1.06711
				MW-6A	14	-0.60303	0.0069	40	0.031	-0.62587
				MW-7A	14	0.09948	0.6021	10	0.629	-0.07566
				MW-8A	14	-0.52563	0.0053	45	0.014	-0.57004
				MW-9A	14	-0.14353	0.2568	42	0.023	-0.28638
				NA-0	20	-0.03987	0.1866	11	0.749	0
				NA-1	24	-0.38565	0.0014	173	<0.001	-0.49803
Hamilton Meadows (North of State Access Road)	-0.4014 (33%)	<.0001	-0.4527 (36%)	IT-2MW-1	20	-1.26256	<0.0001	-165	<0.001	-1.24071
				IT-PZ-2	3	3.02163	0.00033	3	0.333	3.00274
				MW-M15	18	0.50642	0.09874	32	0.245	0.45645
				MW-M18	14	0.38923	0.22689	-9	0.668	-0.13324
				MW-M20D	14	-0.49795	<0.0001	-74	<0.001	-0.59647
				MW-M21	14	-0.31074	0.00232	-53	0.004	-0.37739
				MW-M22	14	-0.85788	0.00001	-78	<0.001	-0.71385
				MW-M23	14	-0.3212	0.0002	-49	0.006	-0.26325
				MW-M4	5	1.03254	0.14601	6	0.234	1.04434
				MW-M5	7	0.18189	0.49957	1	1.000	0.10743
				MW-M6	7	0.4348	0.15504	9	0.238	0.51055
				TW-M1	4	-0.98862	0.20615	-4	0.333	-1.24164
				TW-M2	5	-0.29505	0.47359	-6	0.234	-0.73154

Table 10. Regression Results for Subareas and Individual Wells (Continued)

Zone	Subarea Results			Individual Well Results						
	Slope (annual reduction rate)	p-value	Sen (annual reduction rate)	Well	No. observations	Parametric		Nonparametric		
						Slope	p-value	M-K Stat	p-value	Sen Est.
Western Edge	-0.1184 (11%)	0.0007	0.00000	IT-2MW-2	16	-0.06855	0.72038	-3	0.929	-1.24071
				IT-PZ-5	22	-0.31396	0.16727	-47	0.198	0
				MW-2D	24	-0.00369	0.83486	-3	0.961	0
				MW-2E	14	-0.51591	0.00082	-74	<0.001	-0.34442
				MW-4B	22	-0.46988	<0.0001	-158	<0.001	-0.46201
				MW-6B	12	-0.10717	0.12053	-11	0.503	0
				MW-M1	22	0.02497	0.14002	19	0.616	0
				MW-M11	17	NA	NA	0	1.000	0
				MW-M12	18	NA	NA	0	1.000	0
				MW-M17	14	-0.20781	0.55003	3	0.914	0.08831
				MW-M19	14	-0.09258	0.1074	-13	0.518	0
				MW-M27D	12	0.29057	0.00061	42	0.004	0.32911
				PZ-2	4	0.63853	0.72913	2	0.750	1.16909
				PZ-3	23	-0.03097	0.77639	-2	0.979	0
				PZ-4	19	-0.02146	0.39198	-10	0.756	0
Leading Edge	0.6460 (-91%)	<.0001	0.4892 (-63%)	IT-1MW-4A	23	-0.34796	0.10356	-130	<0.001	-0.56278
				IT-GMP-15	22	1.08054	<0.0001	211	<0.001	0.98066
				IT-GMP-16	21	1.03099	<0.0001	162	<0.001	0.59936
				IT-GMP-17	22	1.41892	<0.0001	205	<0.001	1.05538
				IT-GMP-18	15	0.1276	0.07011	23	0.282	0
				IT-MW-81D	13	NA	NA	0	1.000	0
				IT-MW-81S	11	-0.13275	0.22678	-8	0.595	0
				IT-MW-92-38	23	0.13263	0.30313	71	0.064	0.21148
				IT-MW-92-39	23	0.7391	<0.0001	171	<0.001	0.63482
				IT-PZ-7	23	0.14648	0.00018	136	<0.001	0.12848
				IT-PZ-9	21	0.93632	<0.0001	194	<0.001	0.90392
				MW-M13	22	1.15261	<0.0001	214	<0.001	1.15833
				MW-M14D	14	1.1501	<0.0001	87	<0.001	1.1664
				MW-M26D	14	0.02485	0.66424	8	0.708	0.01173

NA – not applicable

Table 11. Summary of Statistical Evaluation by Region

Area ID	Annual MTBE Concentration Trend
Former UST 970 Area	35% to 39% decrease per year; 31% to 36% decrease per year since IAS/SVE system shutdown
Hamilton Meadows Subdivision	33% to 36% decrease per year
MTBE Plume Edge West	11% decrease per year
MTBE Plume Leading Edge	63% to 90% increase per year

Table 12. Surface Water Monitoring Network and Decision Criteria[(a)]

Location	Sample ID	Objective	Decision Criteria
Upstream of Site	PC-SW-1	Establish concentrations in Pacheco Creek before it encounters the Site	MTBE concentrations detected upgradient of the Site indicate that another source is contributing to MTBE in Pacheco Creek.
Within the MTBE plume (just after outfall from culvert)	PC-SW-2	Determine if MTBE enters the creek along its subsurface run	If MTBE concentrations at the outfall of the culvert are greater than concentrations at the upstream location, this indicates that MTBE is entering the creek through one of the culverts; the presence of MTBE at this location is not necessarily associated with Former UST Site 957/970 because other areas also drain into the creek.
Within the MTBE plume	PC-SW-5	Determine if MTBE-impacted groundwater interacts with surface water of Pacheco Creek in the area of IT-2MW-1	If MTBE concentrations at the surface water sampling location compare to those detected in IT-2MW-1 a determination can be made of groundwater-surface water interaction.
Immediately downstream of MTBE plume	PC-SW-3	Evaluate the presence and persistence of MTBE in Pacheco Creek	If MTBE concentrations decrease from the immediate downstream location to the further downstream location, this indicates that the processes of volatilization, photodegradation, biodegradation, and/or dilution are causing a reduction in MTBE concentrations in Pacheco Creek.
Further downstream of MTBE plume	PC-SW-4		
Individual culvert outlet upstream of PC-SW-2	PC-SW-CE	Identify MTBE concentrations in water originating from individual culverts entering the creek in this area	If MTBE is detected at the location of the culvert outfall, this indicates that it is a likely source of MTBE to Pacheco Creek.

(a) This table updates the original surface water monitoring network provided in Table 4 of the *Groundwater Monitoring Plan* (Battelle, 2000a).

Table 13. Tabulated Surface Water Sampling Results

Sample ID	Date	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	Total Xylenes (µg/L)	MTBE (µg/L)
PC-SW-1	6/21/00	NA	NA	NA	NA	<0.50
	8/6/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/7/00	<0.50	<0.50	<0.50	<1.0	<0.50
	03/01/01	<0.50	<0.50	<0.50	<1.0	<0.50
	5/18/01	<0.50	<0.50	<0.50	<0.50	<0.50
	8/16/01	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/01	<0.50	<0.50	<0.50	<0.50	<0.50
	02/19/02	<0.50	<0.50	<0.50	<0.50	<0.50
	5/18/02	<0.50	<0.50	<0.50	<1.0	<0.50
	8/12/02	<0.50	<0.50	<0.50	<1.0	<0.50
	11/16/02	<0.50	<0.50	<0.50	<1.0	<0.50
	2/31/03	<0.50	<0.50	<0.50	<1.0	<0.50
	5/20/03	<0.50	<0.50	<0.50	<1.0	<0.50
	8/15/03	<0.50	<0.50	<0.50	<1.0	<0.50
	11/17/03	<0.50	0.22 J	<0.50	<1.0	2.4
	2/24/04	<0.50	<0.50	<0.50	<1.0	<0.50
	5/21/04	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**<0.50**
PC-SW-2	6/21/00	NA	NA	NA	NA	190
	8/6/00	<0.50	<0.50	<0.50	<1.0	100
	11/7/00	<0.50	<0.50	<0.50	<1.0	22
	02/26/01	<0.50	<0.50	<0.50	<0.50	3.6
	5/18/01	<0.50	<0.50	<0.50	<0.50	94
	8/16/01	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/01	<0.50	<0.50	<0.50	<0.50	3.2
	02/19/02	<0.50	<0.50	<0.50	<0.50	6.5
	5/18/02	<0.50	<0.50	<0.50	<1.0	10
	8/12/02	<0.50	<0.50	<0.50	<1.0	2.4
	11/15/02	<0.50	<0.50	<0.50	<1.0	5.6
	2/13/03	<0.50	<0.50	<0.50	<1.0	2.8
	5/20/03	<0.50	<0.50	<0.50	<1.0	<0.50
	8/15/03	<0.50	<0.50	<0.50	<1.0	<0.50
	11/17/03	<0.50	<0.50	<0.50	<1.0	<0.50
	2/24/04	<0.50	<0.50	<0.50	<1.0	3.1
	5/21/04	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**<0.50**
PC-SW-3	11/7/00	<0.50	<0.50	<0.50	<1.0	6.0
	02/26/01	<0.50	<0.50	<0.50	<0.50	6.4
	5/18/01	<0.50	<0.50	<0.50	<0.50	22
	8/16/01	<0.50	<0.50	<0.50	<0.50	0.64
	11/18/01	<0.50	<0.50	<0.50	<0.50	17
	02/19/02	<0.50	<0.50	<0.50	<0.50	14
	5/18/02	<0.50	0.39 J	<0.50	<1.0	15
	8/12/02	<0.50	0.39 J	<0.50	<1.0	0.76
	11/15/02	<0.50	<0.50	<0.50	<1.0	21
	2/11/03	<0.50	<0.50	<0.50	<1.0	21

Table 13. Tabulated Surface Water Sampling Results (Continued)

Sample ID	Date	Benzene (μg/L)	Toluene (μg/L)	Ethylbenzene (μg/L)	Total Xylenes (μg/L)	MTBE (μg/L)
PC-SW-3 (Cont)	5/20/03	<0.50	<0.50	<0.50	<1.0	4.9
	8/15/03	<0.50	<0.50	<0.50	<1.0	4
	11/17/03	<0.50	<0.50	<0.50	<1.0	8.9
	2/24/04	<0.50	<0.50	<0.50	<1.0	1.7
	5/21/04	**<0.50**	**0.27 J**	**<0.50**	**<1.0**	**<0.50**
PC-SW-4	6/21/00	NA	NA	NA	NA	0.69
	8/6/00	<0.50	<0.50	<0.50	<1.0	<0.50
	11/7/00	<0.50	<0.50	<0.50	<1.0	0.60
	02/26/01	<0.50	<0.50	<0.50	<0.50	24
	5/18/01	<0.50	<0.50	<0.50	<0.50	0.85
	8/16/01	<0.50	<0.50	<0.50	<0.50	<0.50
	11/18/01	<0.50	<0.50	<0.50	<0.50	3.9
	02/19/02	<0.50	<0.50	<0.50	<0.50	15
	5/18/02	<0.50	<0.50	<0.50	<1.0	0.37 J
	8/12/02	<0.50	<0.50	<0.50	<1.0	<0.50
	11/15/02	<0.50	<0.50	<0.50	<1.0	5.8
	2/13/03	<0.50	<0.50	<0.50	<1.0	4.4
	5/20/03	<0.50	<0.50	<0.50	<1.0	1.3
	8/15/03	<0.50	<0.50	<0.50	<1.0	1.2
	11/17/03	<0.50	<0.50	<0.50	<1.0	<0.50
	2/24/04	<0.50	<0.50	<0.50	<1.0	2
	5/21/04	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**1.7**
PC-SW-5	02/26/01	<0.50	<0.50	<0.50	<0.50	6.6
	5/18/01	<0.50	<0.50	<0.50	<0.50	60
	8/16/01	<0.50	<0.50	<0.50	<0.50	1.4
	11/18/01	<0.50	<0.50	<0.50	<0.50	32
	02/19/02	<0.50	<0.50	<0.50	<0.50	18
	5/18/02	<0.50	<0.50	<0.50	<1.0	25
	8/12/02	<0.50	<0.50	<0.50	<1.0	2
	11/15/02	<0.50	<0.50	<0.50	<1.0	2.3
	2/12/03	<0.50	0.32	<0.50	<1.0	14
	5/20/03	<0.50	<0.50	<0.50	<1.0	5
	8/15/03	<0.50	<0.50	<0.50	<1.0	<0.5
	11/17/03	<0.50	<0.50	<0.50	<1.0	<0.5
	2/24/04	<0.50	<0.50	<0.50	<1.0	2
	5/21/04	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**16**
PC-SW-CE	7/10/00	NA	NA	NA	NA	2,400
	9/8/00	<0.50	<0.50	<0.50	<1.0	1,300
	11/7/00	<0.50	<0.50	<0.50	<1.0	150
	02/26/01	<0.50	<0.50	<0.50	<0.50	330
	5/18/01	<2.5	<2.5	<2.5	<2.5	1,300
	8/16/01	<2.5	<2.5	<2.5	<2.5	1,500
	11/18/01	<0.50	<0.50	<0.50	<0.50	390
	02/19/02	<0.50	<0.50	<0.50	<0.50	280
	5/18/02	<0.50	<0.50	<0.50	<1.0	18
	8/12/02	<0.50	<0.50	<0.50	<1.0	0.75
	11/15/02 [(a)]	NA	NA	NA	NA	NA

Table 13. Tabulated Surface Water Sampling Results (Continued)

Sample ID	Date	Benzene (μg/L)	Toluene (μg/L)	Ethylbenzene (μg/L)	Total Xylenes (μg/L)	MTBE (μg/L)
PC-SW-CE (Cont)	2/13/03	<0.50	<0.50	<0.50	<1.0	5
	5/20/03	<0.50	<0.50	<0.50	<1.0	300
	8/15/03	<0.50	<0.50	<0.50	<1.0	<0.5
	11/17/03	<0.50	<0.50	<0.50	<1.0	<0.5
	2/24/04	<0.50	<0.50	<0.50	<1.0	150
	5/21/04	**<0.50**	**<0.50**	**<0.50**	**<1.0**	**0.21 J**

Boldface indicates current sampling event.
NA = not analyzed
(a) Sampling of PC-SW-CE was unintentionally omitted in the November 2002 sampling event.

Table 14. Biosparging Optimization (Beginning April 8, 2004)

Group	Characteristics	Biosparging Points	Week 1	Week 2	Week 3	Week 4
A	In or near MTBE hotspot and low initial backpressure	SP-Z1-7; SP-Z2-2, -7, -17, -18, -19	on	on	on	on
B	In or near MTBE hotspot and moderate initial backpressure	SP-Z1-3, -4; SP-Z2-3, -4, -6, -8, -9, AS-4D	on	on	on	off
C	Near MTBE concentrations >1,000 μg/L and low to moderate initial backpressure	SP-Z1-1, -2, -13, -14, -18, -19, -20, -21, -22; SP-Z2-1, -10, -12, -13, -15, -16, -20, -21, -22, -23, -24	off	off	on	on
D	Near monthly performance goal monitoring wells and low to moderate initial backpressure	SP-Z1-5, -6, -8, -10, -11, -12, -15, -16, -17, -23, -25	on	on	off	off
E	High initial backpressure	SP-Z1-24; SP-Z2-5, -11	on	off	off	off

Note: SP-Z1-9 is not operational due to lack of water in well.

Table 15. Soil-Gas Monitoring Probes and Identification Labels

Shallow Soil-Gas Monitoring Probes	Deep Soil-Gas Monitoring Probes	System Monitoring Soil-Gas Probes	RWQCB-Requested Quarterly Soil-Gas Monitoring Probes
SG-14-3	SG-14-8	SG-27-5.5	SG-25-3
SG-20-1.5	SG-22-8	SG-27-8	SG-19-3
SG-21-3	SG-26-8	SG-28-5.5	
SG-22-3		SG-28-9	
SG-24-3		SG-29-6	
SG-11-3		SG-29-9	
SG-26-3		SG-30-5.5	
		SG-30-8	

Table 16. Schedule for Soil-Gas Sample Collection for Laboratory Analysis

Shallow Soil-Gas Monitoring Probes	Deep Soil-Gas Monitoring Probes	System Monitoring Soil-Gas Probes	RWQCB-Requested Quarterly Soil-Gas Monitoring Probes
June 11, 2003 July 8, 2003 August 4, 2003 September 9, 2003 October 7, 2003 November 4, 2003 December 2, 2003 January 13, 2004 February 10, 2004 March 9, 2004 April 6, 2004 May 11, 2004	July 8, 2003 September 9, 2003 November 4, 2003 January 13, 2004 March 9, 2004 May 11, 2004	July 8, 2003 September 9, 2003 November 4, 2003 January 13, 2004 March 9, 2004 May 11, 2004	June 11, 2003 September 9, 2003 December 2, 2003 March 9, 2004

Table 17. MTBE Concentrations in Performance Goal Monitoring Wells Before and During Biosparging System Operation

Collection Date	MTBE (μg/L)								Ave. MTBE Conc. (μg/L)	% Reduction in Ave. MTBE Conc.
	MW-M10	MW-M3	MW-M9	PG-MW1	PG-MW2	PG-MW3	PG-MW4	PG-MW5		
6/24/02	11	21,000	500	23,000/22,000	20,000	19,000	14,000/15,000	6,100	12,951	-
10/8/02	3.3	14,000	340	20,000	18,000	10,000	13,000/13,000	4,300	9,955	23
11/11/02	0.83	12,000	470	19,000/20,000	16,000	8,700	13,000	5,100	9,346	28
12/13/02	2.1	12,000	290	22,000	15,000	11,000	12,000	5,500/5,800	9,743	25
1/8/03	<0.5	8,600/8,600	180	18,000	5,400	2,800	8,200	8,300	6,435	50
2/5/03	<0.5	4,100	48	17,000	8,900	2,800/2,900	10,000	8,000	6,356	51
3/5/03	<0.5	4,600	41/43	14,000	6,000	1,300	7,000	5,400	4,793	63
4/2/03	0.31 J	4,200	150	14,000	6,300/5,300	990	6,700	5,600	4,680	64
5/7/03	<0.5	4,400	100	18,000	3,700	1,200	5,000	6,200	4,825	63
6/9/03	0.24 J	5,300	130	14,000	4,900	1,400	5,700/5,400	1,600	4,110	68
7/11/03	0.37 J	7,000	140	12,000	4,000	890/920	3,500	1,700	3,656	72
8/6/03	0.36 J	9,000	140/140	12,000	4,700	1,900	4,700	2,400	4,355	66
9/11/03	0.25 J	8,800	150	13,000	6,500	2,700	3,400	3,300/3,600	4,750	63
10/9/03	0.5	8,100	180	13,000/13,000	8,600	2,300	2,900	2,400	4,560	65
11/5/03	0.58	7,800	210/190	13,000	5,500	5,700	3,100	4,400	4,963	62
12/2/03	0.25	5,300	92	11,000	290	2,100	3,200	5,000/4,800	3,360	74
1/14/04	<0.5	5,700	79	12,000/14,000	3,600	3,100	4,400	4,600	4,310	67
2/11/04	<0.5	4,400	53	11,000/11,000	1,900	1,300	4,000	4,500	3,394	74
3/11/04	<0.5	5,100	99	11,000	700/850	970	5,600	4,200	3,468	73
4/7/04	<0.5	3,900	90	11,000	150	1,300/1,200	4,000	3,200	2,949	77
5/13/04	0.42J	4,500	100	9,300	360	1,700	3,700/3,300	950	2,551	80
Overall % Reduction Per Well	96	79	80	59	98	91	76	84	-	-

APPENDIX A

WELL PURGE AND MAINTENANCE LOGS
(Feb and May 04 Sampling Events)

APPENDIX B

TABULATED WATER-LEVEL DATA
(Cumulative)

APPENDIX C

**COPIES OF SIGNED CHAIN-OF-CUSTODY DOCUMENTATION,
SIGNED LABORATORY ANALYTICAL REPORTS, AND QA/QC REPORTS FOR
GROUNDWATER AND SURFACE WATER
(Feb and May 04 Sampling Event)**

APPENDIX D

TABULATED CONCENTRATION DATA FOR GROUNDWATER AND SURFACE WATER
(Cumulative)

APPENDIX E

WELL PURGE AND MAINTENANCE LOGS FOR BIOSPARGING PERFORMANCE WELLS (Dec 03 through May 04 Sampling Events)

APPENDIX F

COPIES OF SIGNED CHAIN-OF-CUSTODY DOCUMENTATION, SIGNED LABORATORY ANALYTICAL REPORTS, AND QA/QC REPORTS FOR BIOSPARGING PERFORMANCE WELLS
(Dec 03 through May 04 Sampling Events)

APPENDIX G

BIOSPARGING SOIL-GAS AND GROUNDWATER FIELD DATA, SOIL-GAS ANALYTICAL DATA (Dec 03 through May 04 Sampling Events)