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FINAL TECHNICAL MEMORANDUM FOR EVALUATION OF MONITORED NATURAL
ATTENUATION SITE 38 NAS PENSACOLA FL
12/6/1996
ENSAFE/ALLEN AND HOSHALL

FINAL TECHNICAL MEMORANDUM

**EVALUATION OF MONITORED NATURAL
ATTENUATION**

**SITE 38 (Buildings 71 and 604)
NAS PENSACOLA
PENSACOLA, FLORIDA**



**SOUTHNAVFACENGCOM
CONTRACT NO.: N62467-89-D0318
CTO-059**

Prepared for:

**Department of the Navy
Southern Division
Naval Facilities Engineering Command
North Charleston, South Carolina**

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The Contractor, EnSafe Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0318 are complete, accurate, and complies with all requirements of the contract.

Date: December 6, 1999
Signature: Allison Harris
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1.0 INTRODUCTION

A natural attenuation study was performed as part of the feasibility study (FS) for Site 38 (Buildings 71 and 604) at the Naval Air Station (NAS) Pensacola. The primary focus of this study was to assess whether natural attenuation is occurring in groundwater and if it is a viable option for degrading volatile organic compounds (VOCs) to less harmful constituents. The impact of geochemical processes on detected inorganic compounds (specifically lead) in groundwater was also evaluated. This technical memorandum reviews the investigative process, evaluates the data, and presents the study results.

Information in this technical memorandum is referenced in the Site 38 Final FS Report to supplement the evaluation of remedial alternatives, and therefore this technical memorandum is to be used for information only. A glossary of monitored natural attenuation terms is provided in Appendix A. No effort has been made to formalize the document, nor has any background information on site history, geology, or previous investigations been included. Please refer to the following documents, prepared by EnSafe Inc. for additional information:

Site 38 Final Sampling and Analysis Plan (May 11, 1993)

Site 38 Final Remedial Investigation Report (September 5, 1997) with Baseline Risk Assessment Errata (September 30, 1998)

Site 38 Final Remedial Investigation Report Addendum (September 23, 1999).

2.0 DESCRIPTION OF MONITORED NATURAL ATTENUATION

Natural attenuation is the use of natural processes to contain the spread of contamination, reduce its concentration in the subsurface, and transform it into non-toxic or less toxic end-products at hazardous waste sites. Natural attenuation is applicable to organic contaminants such as petroleum compounds and chlorinated solvents, as well as inorganics such as lead and chromium. It is now increasingly being used as a remedial alternative at sites contaminated with chlorinated solvents such as perchloroethylene (PCE) and trichloroethylene (TCE). It is an in situ remediation approach method which means that contaminants are left in place while natural processes mechanisms transform them.

2.1 Natural Attenuation Processes

Biological, chemical, and physical processes all contribute to natural attenuation. Biological and chemical processes are termed "destructive" because contaminant mass is reduced as constituents are destroyed or transformed into innocuous end-products. Physical processes such as adsorption, dispersion, and advection are termed "non-destructive" because they reduce contaminant concentrations or decreasing their mobility without a total mass reduction within the aquifer.

Biological attenuation, the most important destructive process for chlorinated solvents, utilizes naturally occurring microorganisms (bacteria or fungi) to break down or degrade hazardous substances into less toxic or non-toxic ones. Microorganisms, like humans, eat and digest organic substances for nutrition and energy. Certain microorganisms in the subsurface can digest organic substances such as fuels or chlorinated solvents that are hazardous to humans. Biodegradation can occur in the presence of oxygen (aerobic) or without oxygen (anaerobic); the highly chlorinated solvents such as PCE and TCE generally require anaerobic conditions for degradation.

2.2 Biodegradation of Chlorinated Solvents

Reductive dechlorination is the most important process in biodegradation of chlorinated solvents. As the name suggests, reductive dechlorination occurs when chlorine atoms in PCE and TCE are substituted with hydrogen to successively transform these compounds into daughter products such as cis-1,2, dichloroethene (cis- 1,2-DCE) and vinyl chloride (VC). The process does not proceed chemically, but uses indigenous microorganisms in the subsurface that possess the enzymatic capability to carry out the degradation. However, reductive dechlorination occurs only under reducing conditions, i.e, the aquifer must be reduced or anaerobic in nature (low in dissolved oxygen).

As a result of the natural reductive dechlorination process, daughter products or intermediate biological breakdown products are formed. These products, such as VC, are also contaminants of concern and require evaluation for further natural degradation. However, daughter breakdown products generally degrade under different geochemical conditions than their parent compounds. Because some (such as DCE and VC) degrade faster under aerobic or oxidized conditions, the pattern of degradation, or the degradative pathway, may be different from that for highly chlorinated compounds. These patterns require screening and evaluation to assess the potential for monitored natural attenuation (MNA) at a contaminated site.

In addition to interference by dissolved oxygen (DO) in biological reductive dechlorination, other natural organic and inorganic compounds play a significant role in determining a site's suitability for natural attenuation. These parameters are collectively known as the geochemistry of the aquifer, which refers to the availability of natural organic matter (total organic carbon) or anthropogenic carbon in the form of BTEX , and the presence of iron species, nitrate, and sulfate. DO, iron species (specifically ferric iron), nitrate, and sulfate compete with PCE and TCE in the microbial breakdown of natural or anthropogenic carbon. In other words, these inorganic species,

particularly DO above certain concentrations, impede or even block microbial utilization and eventual destruction of PCE and TCE.

Biological reductive dechlorination is a specific process that can proceed naturally under specific conditions. These geochemical conditions must be examined thoroughly by obtaining site-specific geochemical data and evaluating the potential for natural attenuation.

2.3 Evaluation of Natural Attenuation

MNA evaluation follows the same general process as any other engineered remedial alternative. However, since the MNA alternative is a natural process that occurs without human intervention, more thorough and specific chemical and microbial monitoring is required to ensure that the contaminants are degrading, and that the process is protective of human health and the environment. The United States Environmental Protection Agency (USEPA) has established a technical protocol to identify the steps in evaluating natural attenuation of chlorinated solvents in groundwater. The protocol provides recommendations for analyzing and interpreting the data from site characterization and geochemical analysis (USEPA, September 1998). USEPA Region 4 has also provided suggested practices for evaluating natural attenuation at chlorinated solvent sites (November 1997).

Evaluating biological processes, which are the prime mechanisms for destroying chlorinated solvents, is the most critical step in the MNA evaluation. Once basic site characterization is complete and the nature and extent of contamination is determined, groundwater geochemistry is evaluated to determine the potential for successful natural attenuation. If geochemistry shows that the site is conducive to natural attenuation (primarily natural biodegradation), the evaluator then decides how to implement natural attenuation and verify its effectiveness. However, if aquifer geochemistry shows little potential for natural biodegradation to occur, the evaluator generally concludes the MNA investigation at this stage and recommends evaluation of active or engineered remediation alternatives.

Figure 2.1 is a flow chart of the natural attenuation evaluation process depicting how natural attenuation fits into the remedial selection process. Generally, successful implementation of the MNA remedial option includes the following steps:

1. Review of available site data and development of a preliminary conceptual model.
2. Site screening for MNA potential.
3. Collection of additional site characterization data, as required.
4. Evaluation of natural attenuation potential and examination of different lines of evidence for its success, such as:
 - a. geochemical evaluation and screening
 - b. estimating reductive capacity of the site
 - c. historical evidence of contaminant reduction, if available
 - d. microcosm tests, if required and applicable
 - e. fate and transport modeling, if required and applicable
5. Identification of current and future receptors and analysis of exposure pathways.
6. Presentation of findings and long-term MNA verification plan to the regulatory agency.

Steps 1 through 6 are generally a sequential procedure in the MNA evaluation and serve as a guide for the MNA evaluator. However, depending on the needs of a particular site, these steps could overlap considerably.

REVIEW AVAILABLE SITE DATA. IF SITE DATA ARE ADEQUATE DEVELOP PRELIMINARY CONCEPTUAL MODEL.

GATHER ANY ADDITIONAL DATA NECESSARY TO COMPLETE THE SCREENING OF THE SITE

ARE SCREENING CRITERIA MET?

NO

YES

COLLECT ADDITIONAL SITE CHARACTERIZATION DATA AS REQUIRED

DOES GEOCHEMISTRY INDICATE SCREENING CRITERIA ARE MET? DOES HISTORICAL DATA SHOW CONCENTRATIONS DECREASING OVER TIME?

NO

YES

EVALUATE ALTERNATE ENGINEERED REMEDIES

DOES NATURAL ATTENUATION APPEAR FEASIBLE?

YES

COMPARE REMEDIAL ALTERNATIVE IN FEASIBILITY STUDY

SUBMIT FINDINGS TO REGULATORY AGENCY



SITE 38
MNA EVALUATION
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FIGURE 2.1
NATURAL ATTENUATION OF
CHLORINATED SOLVENTS DECISION
FLOW CHART

DWG DATE: 07/14/99 DWG NAME: 0059B016

3.0 PROTOCOL FOR EVALUATING NATURAL ATTENUATION

The USEPA (September 1998) technical protocol identifies parameters for evaluating natural attenuation of chlorinated solvents in groundwater, and provides recommendations for analyzing and interpreting data from site characterization and geochemical analysis (USEPA, September 1998).

3.1 Screening Processes for Natural Attenuation

The protocol lists three lines of evidence to demonstrate natural attenuation:

1. Historical evidence of decreasing contaminant concentrations over time at critical monitoring or sampling locations in the aquifer; and a decrease in contaminant concentrations in the direction of groundwater flow.
2. Hydrogeological and geochemical data to indirectly demonstrate a decrease in contaminant concentrations.
3. Data from field or microcosm studies which directly demonstrate the effectiveness of a particular natural attenuation process in degrading the contaminants of concern.

Historical evidence is generally obtained from existing site chemical data, although many sites do not have enough data actually showing decreased contaminant concentrations over time. Even where decreases can be demonstrated, it is important to know the mechanisms for reduction in order to predict the future trend and capacity of the aquifer to naturally degrade contaminants of concern and daughter products. This can be obtained using the second line of evidence, namely geochemistry. The third line of evidence, microcosm testing is used (if required) to supplement geochemical data and if fate and transport modeling is envisioned. Therefore, MNA field testing

mainly entails collecting and analyzing groundwater samples for geochemical analysis and interpretation.

3.2 Groundwater Chemistry and Geochemistry

As explained in Section 2, the most important factor governing the potential or feasibility of natural attenuation is the aquifer geochemistry, which provides an indication of the natural attenuation capacity of the aquifer. In the evaluation process, this is very significant because biological degradation is a destructive process that transforms contaminants into innocuous products, compared to the non-destructive processes of advection, dispersion, and dilution by recharge, which reduce contaminant concentrations but do not destroy them. Therefore, unless the evaluator can demonstrate that biodegradation is the primary process in contaminant reduction, it becomes difficult to recommend natural attenuation as the remedial alternative.

USEPA protocol lists the various groundwater physical, chemical, and biological parameters that require analysis to determine if aquifer geochemistry is favorable for natural attenuation. Groundwater samples are collected from wells in the center of the plume area, and upgradient and downgradient of the center. These results are compared with values designated in the USEPA protocol, which attaches a scoring or ranking to each geochemical parameter. The total score for each individual well is then used to determine if that particular location shows inadequate evidence, limited evidence, adequate evidence, or strong evidence of degradation. Using these scores, overall site suitability for MNA can be evaluated. Appendix B lists the parameters that require geochemical analysis, the analytical methods for their determination, and USEPA's screening and scoring system and interpretations. The following section explains the significance of each parameter.

Volatile Organic Compounds (VOCs) and Semi-volatile Organic Compounds (SVOCs): VOCs and SVOCs are used to determine the type, concentration, and distribution of contaminants and

daughter products in the aquifer. They provide information on the amount of anthropogenic carbon available (in the form of BTEX) that can be used for microbial activity. VOC and SVOC concentrations also determine if contaminants are present at levels toxic to indigenous microbes, in which case natural attenuation would be infeasible until they are reduced to non-toxic levels. The presence and distribution of daughter products indicates the extent of parent compound degradation.

VOC data can be used to infer if the contaminant or its daughter breakdown products are decreasing in the direction of groundwater flow. VOC data collected over time can be used to determine whether mass decreases are occurring.

Dissolved Oxygen (DO): DO provides the most thermodynamically favorable respiratory pathway (or electron acceptor) used by microorganisms for biodegradation. DO concentrations are very critical to natural attenuation of chlorinated solvents. Because anaerobic bacteria generally cannot function at DO concentrations greater than 0.5 milligrams per liter (mg/L), reductive dechlorination will not proceed effectively above this concentration. Since native microorganisms prefer to use oxygen for respiration, the DO must be depleted before they begin utilizing other electron acceptors. The general sequence of electronic acceptor use proceeds from DO to nitrate, followed by ferric iron [Iron (III)], sulfate, and finally carbon dioxide (methanogenesis). Each sequential microbial reaction renders the aquifer more anaerobic, creating favorable conditions for reductive dechlorination.

Once the parent compound is reduced to less chlorinated compounds, aerobic conditions could play a more significant role in further degrading these by-products. This often occurs at the downgradient or leading edge of a plume, resulting in microbial destruction of daughter products such as VC.

Nitrate: After DO has been used by microorganisms, nitrate is the next favored electron acceptor for anaerobic degradation. Nitrate concentrations in the contaminated portion of the aquifer must be less than 1.0 mg/L for reductive dechlorination to occur. Nitrate concentrations exceeding 1.0 mg/L could interfere with or decrease the natural reduction of chlorinated solvents.

Total Organic Carbon (TOC): TOC concentrations in the aquifer are used to determine the amount of electron donor that microorganisms require to metabolically degrade chlorinated solvents. TOC could be natural organic carbon or anthropogenic carbon (BTEX and other petroleum constituents). The USEPA has specified that TOC in the aquifer must be greater than 20 mg/L to supply sufficient carbon for microorganisms. However, 20 mg/L is relative to the amount of chlorinated solvents in the aquifer or the type of TOC present. In other words, TOC utilization involves a qualitative understanding in addition to USEPA's stipulated criteria. At some sites, TOCs at concentrations of 2 to 5 mg/L could be sufficient to carry out the reductive dechlorination of chlorinated solvents.

Iron (II): Ferrous iron (Fe [II]) is produced from ferric iron (Fe [III]) by microbial activity. Reduction from Iron (III) to Iron (II) could occur during anaerobic degradation of natural or anthropogenic carbon during reductive dechlorination of the lesser chlorinated by-products of PCE and TCE, namely DCE and VC. Therefore, ferrous iron concentrations in the aquifer can be used to indicate the feasibility of chlorinated solvent degradation, particularly VC.

Sulfate and Sulfide: After microbes have depleted DO and nitrate, sulfate may be used as the next electron acceptor. This process, termed "sulfate reduction" results in the production of sulfide. Sulfate at concentrations greater than 20 mg/L could inhibit the reductive dechlorination. The presence of sulfide in the aquifer indicates that conditions are conducive to the reductive dechlorination process.

Methane: During methanogenesis, carbon dioxide is used as an electron acceptor and converted to methane. Methanogenesis generally occurs after microorganisms have already utilized oxygen, nitrate, and sulfate. The presence of methane in the aquifer is indicative of strongly reducing conditions.

Hydrogen: The amount of hydrogen in the aquifer indicates its reduced or anaerobic nature. Hydrogen concentrations can thus be used to delineate the site with respect to oxidation-reduction potential and confirm or establish methanogenic, sulfate-reducing, ferric-reducing, iron-reducing, nitrate-reducing, or aerobic zones. At some sites, this information is critical and adds to the weight of evidence for the occurrence of natural attenuation.

Alkalinity: Alkalinity sometimes increases above background in areas with significant natural microbial activity. Therefore, groundwater alkalinity in the plume could indicate the level of microbial activity and enhance the likelihood of reductive dechlorination.

Oxidation-Reduction Potential (ORP): The ORP of groundwater, also known as redox indicates the relative oxidized or reduced state of the aquifer. Biological processes generally occur within a prescribed ORP range. For instance, an ORP of <50 millivolts (mVs) indicates reducing conditions depleted of DO. ORP levels greater than this indicate aerobic conditions exist that will tend to hinder reductive dechlorination. ORP levels less than -100 mV are ideal for reductive dechlorination.

pH and Temperature: pH affects microbial activity and some types of microbial reactions.. Microorganisms capable of degrading chlorinated solvents generally prefer a pH between 6 and 8 standard units. Groundwater temperature also affects microbial activity, which tends to increase with temperature up to a certain level. Below certain temperatures (generally 10° C), microbial activity decreases until it stops completely at freezing temperatures.

Chloride: Chloride produced by reductive dechlorination is generally inert and can serve as a conservative indicator parameter in the aquifer. Reductive dechlorination generally results in chloride concentrations above background in the contaminated portion of the aquifer, and chloride is, therefore, an indirect estimator of microbial activity.

3.3 Verification of MNA through Groundwater Monitoring

Groundwater monitoring, in accordance with a sampling and monitoring program, ultimately provides the most conclusive evidence of natural attenuation of chlorinated solvents in the aquifer. Groundwater monitoring becomes the final verification step in the MNA remedy once aquifer geochemistry indicates that it is conducive to natural attenuation, that chlorinated solvent concentrations (including biological daughter products) are decreasing over time, that chlorinated solvent concentrations continue to decrease in the direction of groundwater flow, and that groundwater receptors are not threatened. Monitoring can also be used to decide if other contingency or backup remedial alternatives (active, engineered alternatives) need to be implemented based on trends in chlorinated solvent concentrations over time during the MNA program.

3.4 Effect of Geochemistry on Lead Concentrations

Geochemical conditions in the aquifer have a direct impact on the ionic and chemical state of lead in groundwater. Lead precipitates or drops out of solution under reducing conditions (which can be inferred from ORP, sulfate/sulfide concentrations, DO, and hydrogen concentrations). Under sulfate-reducing conditions, lead precipitates out in the form of lead sulfide (PbS). Because PbS is insoluble in water, groundwater lead concentrations decrease under these conditions. This type of physical-chemical reaction is the most common form of natural attenuation of metals in the aquifer. As long as reducing conditions exist in the vicinity of lead occurrences, concentrations of the metal in the groundwater will continue to drop and result in an effective natural remedy.

4.0 SUMMARY OF MNA DATA

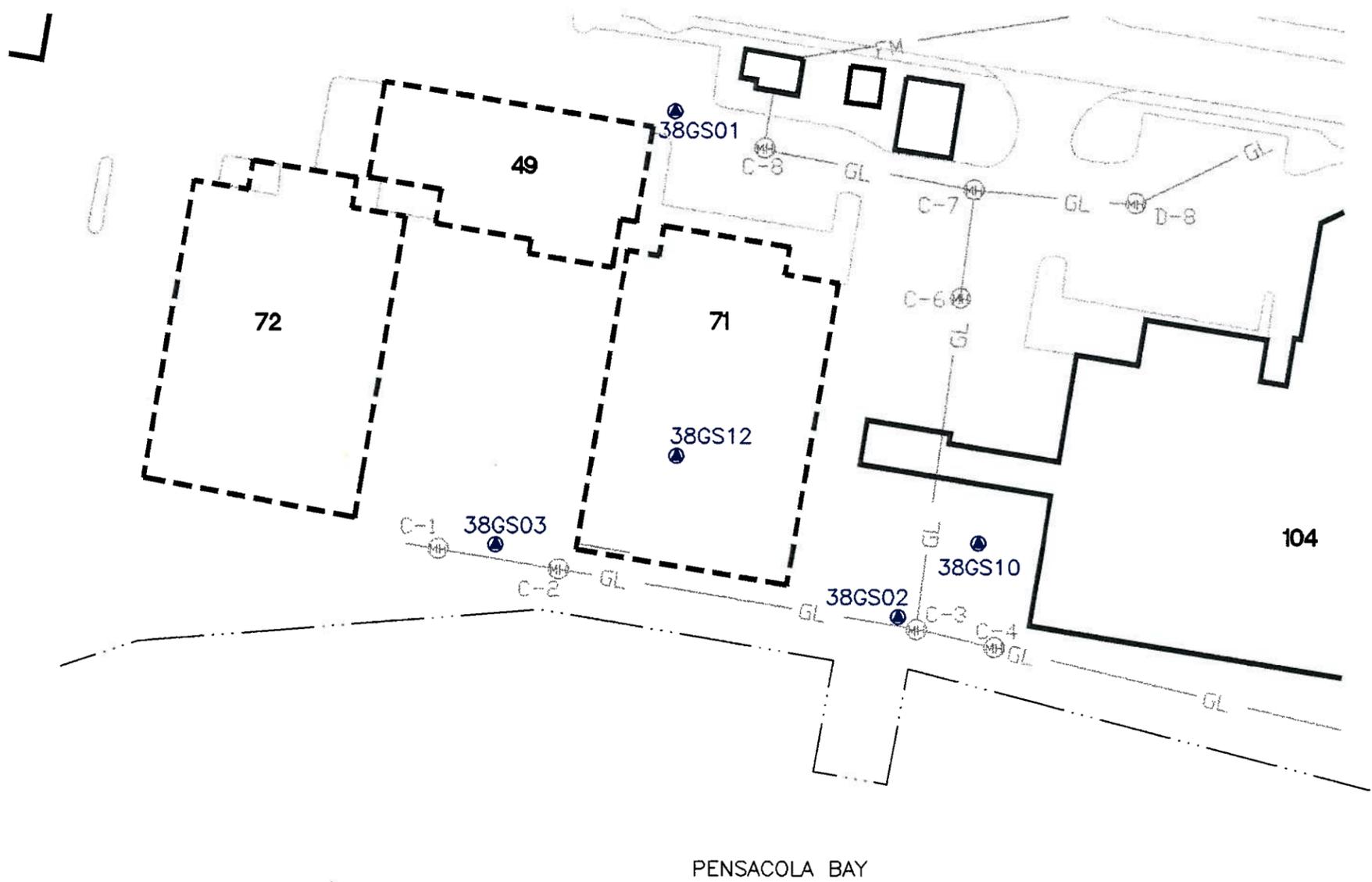
Site 38 has been divided into two areas due to historical reasons and remedial investigation results. Therefore, the Building 71 Area and the Building 604 Area were examined separately during MNA evaluation.

Building 71 Area

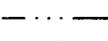
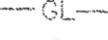
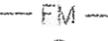
Figure 4.1 is a site map of the Building 71 Area showing the wells which were sampled for MNA evaluation. Figure 4.2 is a potentiometric flow map depicting groundwater flow direction in the area. Six wells were sampled during two sampling events. The first event in December 1998 was the preliminary site screening step for MNA potential, in which groundwater samples were collected from wells 38GS01 (which is considered an upgradient or background well), 38GS03, and 38GS12 and analyzed for specific geochemical parameters, VOCs, and metals. Based on this sampling, a second sampling event was performed in April 1999 to (a) confirm some of the geochemical findings of the first event, (b) collect and analyze groundwater for hydrogen concentrations which were considered critical to confirm the occurrence of sulfate-reduction (and thereby the reduction of chlorinated solvents and the decrease in lead concentrations), and (c) include additional wells for geochemical analysis, namely 38GS10 and 38GS02, which would supplement evidence for the occurrence of natural attenuation in the area. VOC data were also collected from wells 38GS10 and 38GS02.

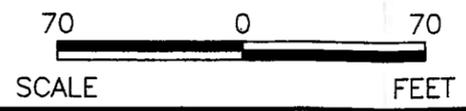
Building 604 Area

Figure 4.3 is a site map of the Building 604 Area showing the locations of the MNA wells that were sampled. Figure 4.4 is a potentiometric flow map depicting groundwater flow direction in the area. As at the Building 71 Area, two sampling events were performed, the first in December 1998 and the second in April 1999. During the first event, samples were collected from wells 38GS28 (which is considered an upgradient or background well), 38GS19, 38GS08, and 38GS32 and analyzed for the same constituents as the Building 71 Area samples. Two more wells, 38GS17 and 38GS20, were added to the list for the second sampling event. Hydrogen was also added to the list of geochemical constituents.



LEGEND

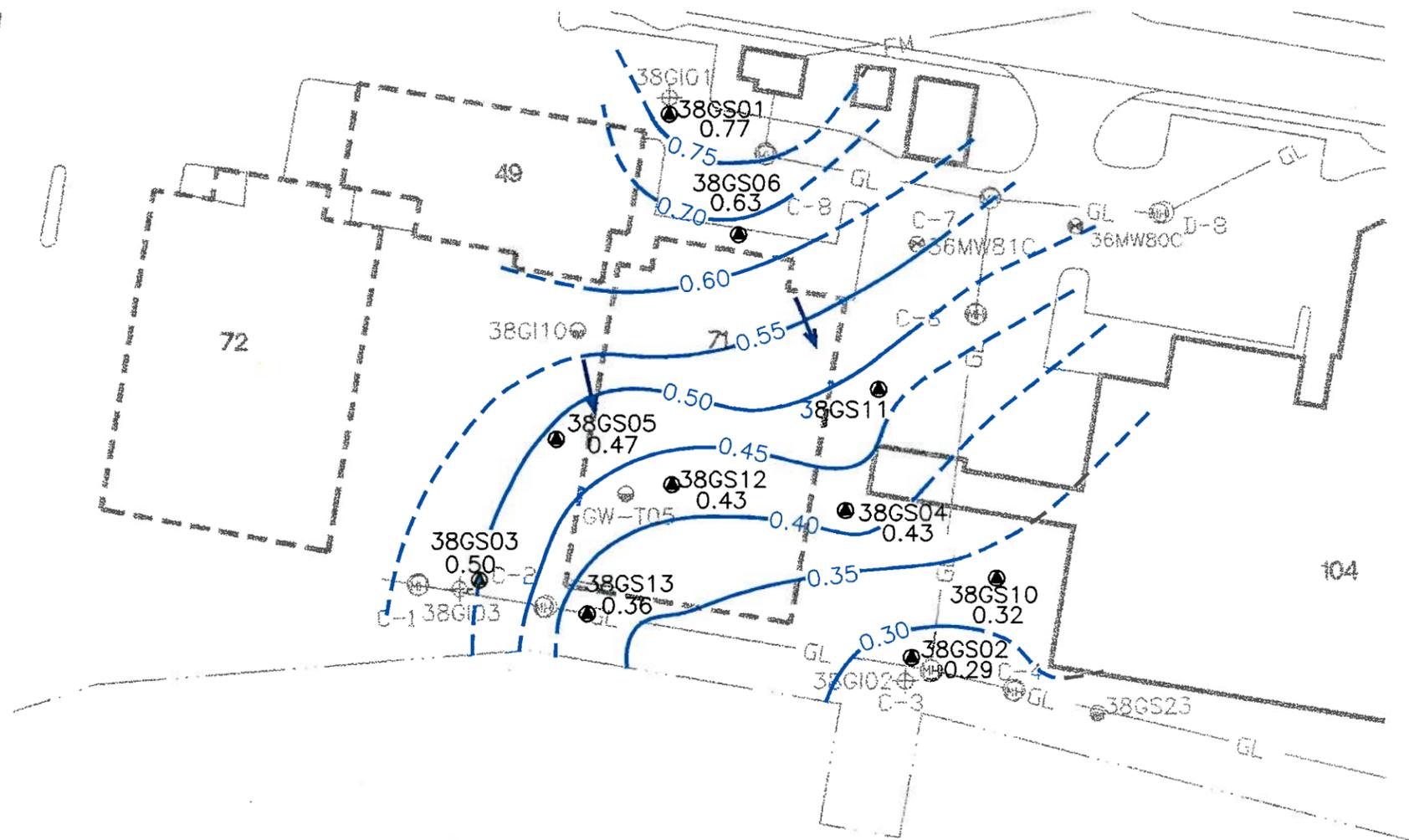
-  - BUILDINGS AND STRUCTURES PREVIOUSLY REMOVED
-  - SHORELINE
-  - MNA EVALUATION WELLS
-  - GRAVITY LINE (SEWER)
-  - FORCE MAIN (SEWER)
-  - MANHOLE



SITE 38
MNA EVALUATION
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PENSACOLA, FLORIDA

FIGURE 4-1
BUILDING 71 STUDY AREA
MONITORING WELLS

DWG DATE: 07/14/99 | DWG NAME: 059MWB71



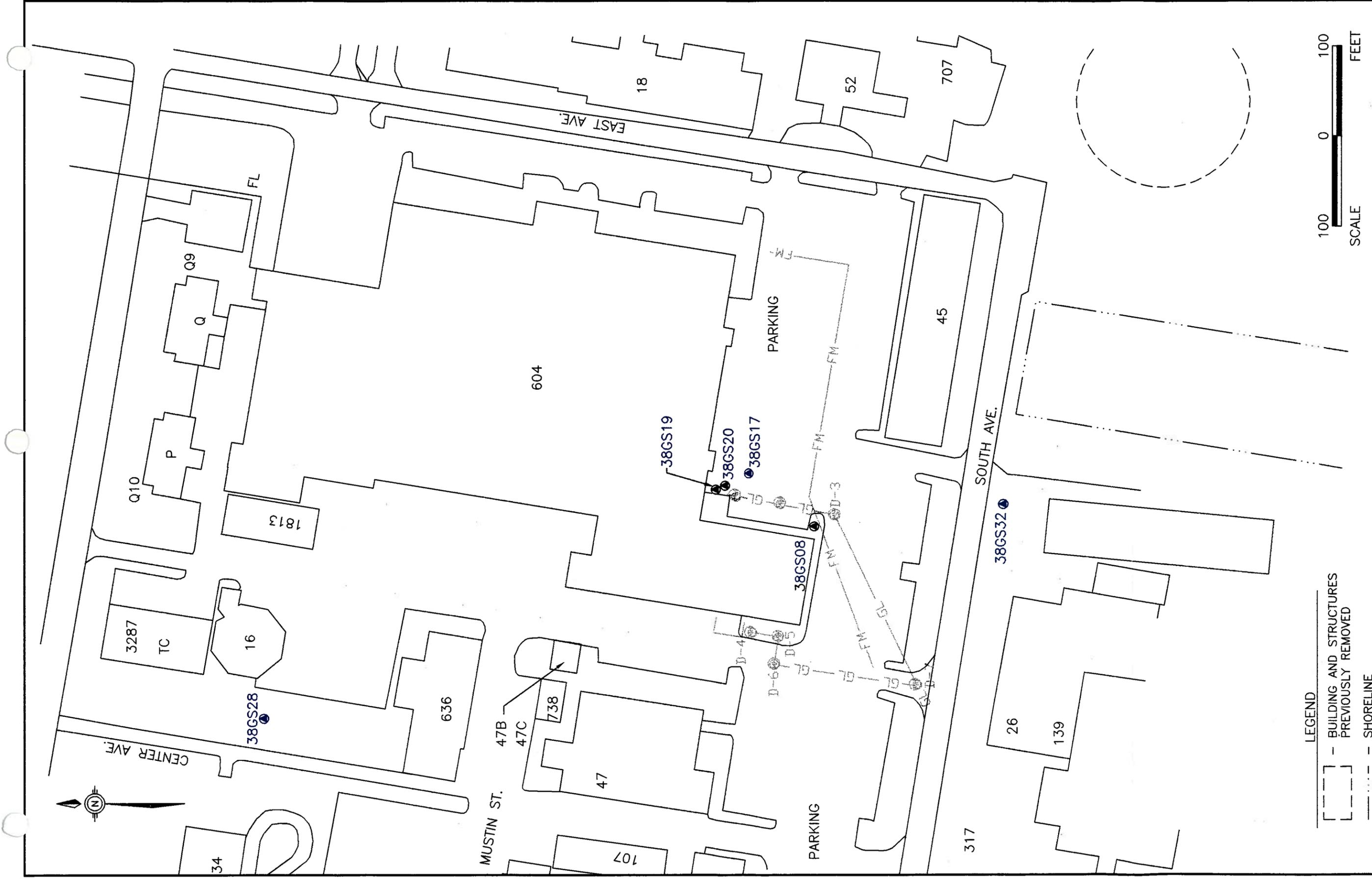
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- BUILDINGS AND STRUCTURES PREVIOUSLY REMOVED
 - SHORELINE
 - IWTP SEWERLINE STUDY TEMPORARY SHALLOW MONITORING WELL
 - E/A&H SITE 38 INTERMEDIATE MONITORING WELL
 - E/A&H SITE 38 SHALLOW MONITORING WELL
 - EPA WELL
 - GL - GRAVITY LINE (SEWER)
 - FM - FORCE MAIN (SEWER)
 - MANHOLE
 - GROUNDWATER FLOW DIRECTION



SITE 38
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FIGURE 4-2
BUILDING 71 STUDY AREA
GROUNDWATER CONTOUR MAP
HIGH TIDE DURING DRY PERIOD
12/16/98

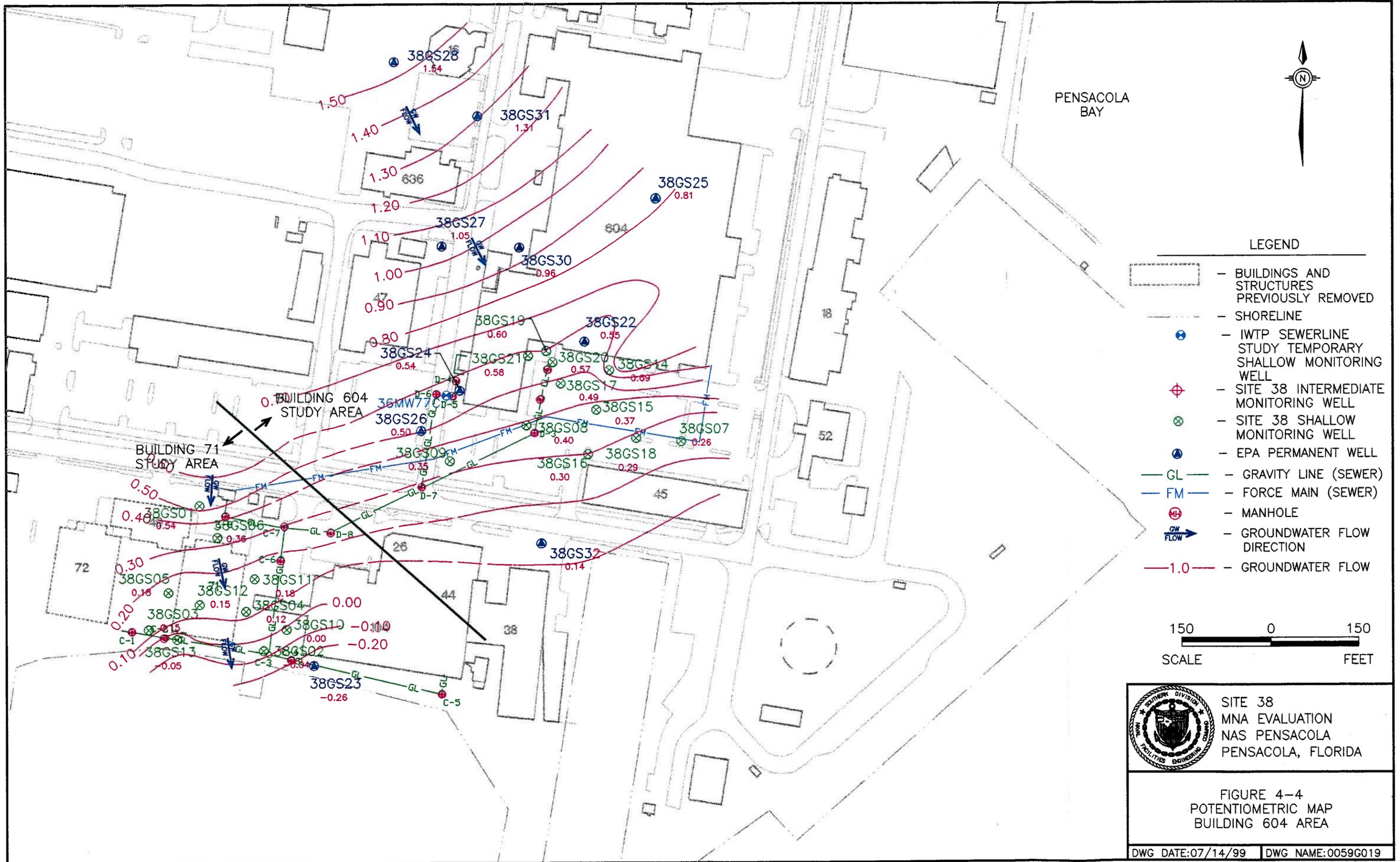
DWG DATE: 12/01/99 | DWG NAME: 0059S004



- LEGEND**
- [] - BUILDING AND STRUCTURES PREVIOUSLY REMOVED
 - - - - - SHORELINE
 - - MNA EVALUATION WELLS
 - GL - GRAVITY LINE (SEWER)
 - FM - FORCE MAIN (SEWER)
 - ⊕ - MANHOLE


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FIGURE 4-3
 BUILDING 604 STUDY AREA
 MONITORING WELLS



Sampling Protocol and Analysis

Groundwater samples for off-site laboratory analysis were collected and analyzed in accordance with the site-specific sampling and analysis plan. Field sample collection and geochemical analysis were performed in accordance with the USEPA 1998 protocols listed in Appendix B. Tables 4.1 and 4.2 summarize chemical and geochemical sampling results used to assess MNA feasibility at the Building 71 and 604 areas, respectively. Field and laboratory sampling results for chemistry and geochemistry are also summarized in Appendix C.

Table 4.1
 Summary of Chemical and Geochemical Analysis

Building 71 Area

Parameter	Units	38GS01	38GS02	38GS03	38GS10	38GS12
Dissolved Oxygen (DO)	mg/L	0.38	ND	ND	0.17	ND
pH		pH between 6.0 and 8.0				
Temperature	°C	24.9	24.8	24.0	25.0	24.3
Oxidation Reduction Potential (ORP)	millivolts (mV)	5	-345.7	-262	-327.2	-291.8
Chloride	mg/L	35	>150	150	120	75
Alkalinity	mg/L	100	160	120	120	160
Ferrous Iron (Iron II)	mg/L	ND	0.10	0.11	0.01	0.06
Nitrate	mg/L	0.5	NS	ND	NS	ND
Sulfate	mg/L	9	1.0	16.2	0	18.2
Sulfide	mg/L	ND	1.42	0.282	1.090	1.53
Methane	µg/L*	ND	360	330	580	210
Hydrogen	nM*	NS	1.34	2.5	1.34	1.94
Carbon Dioxide	mg/L	NS	NS	34.4	NS	23.06
Total Organic Carbon (TOC)	mg/L	2.87	1.6	4.56	2.3	12.4
TCE	µg/L	ND	ND	4	ND	25
cis-1,2-DCE	µg/L	ND	ND	5	ND	27
Vinyl Chloride (VC)	µg/L	ND	ND	3	ND	15
Dichloroethane (DCA)	µg/L	ND	ND	3	ND	13

Notes:
 38GS01 is the background well for comparison purposes at Area 71
 ND — Non-detect. NS — Not Sampled. nM — Nano-moles per liter. µg/L — micrograms per liter

Table 4.2
 Summary of Chemical and Geochemical Analysis

Building 604 Area

Parameter	Units	38GS08	38GS17	38GS19	38GS20	38GS28	38GS32
Dissolved Oxygen (DO)	mg/L	0.51	ND	1.39	ND	0.22	0.17
pH		pH between 6.0 and 8.0					
Temperature	°C	24.1	25.0	23.8	22.4	23.8	25.2
Oxidation Reduction Potential (ORP)	millivolts (mV)	-30	-324.8	114	-305	45	-114.5
Chloride	mg/L	55	55	33.4	25	74.2	60
Alkalinity	mg/L	100	220	100	80	120	140
Ferrous Iron (Iron II)	mg/L	ND	0.03	0.01	0.12	0.06	0.15
Nitrate	mg/L	0.737	NS	1.86	NS	0.136	ND
Sulfate	mg/L	18	16	24	15	11.8	8.8
Sulfide	mg/L	ND	10.75	0.001	0.440	0.001	0.004
Methane	µg/L*	ND	5303	ND	1700	460	210
Hydrogen	nM*	0.90	5.6	0.50	3.11	0.67	0.73
Carbon Dioxide	mg/l	NS	60.76	NS	5.86	43.55	9.52
Total Organic Carbon (TOC)	mg/L	2.94	29	2.44	3.9	7.10	3.37
TCE	µg/L	24	ND	22	ND	ND	5
cis-1,2-DCE	µg/L	25	ND	27	ND	ND	25
Vinyl Chloride (VC)	µg/L	ND	ND	3	15	ND	14
DCA	µg/L	ND	ND	ND	ND	ND	ND

Notes:
 38GS28 is the background well for comparison purposes at Area 604
 ND — Non-detect. NS — Not Sampled. nM — Nano-moles per liter. µg/L — micrograms per liter

5.0 RESULTS AND EVALUATION OF NATURAL ATTENUATION

Groundwater sampling results, summarized in Tables 4.1 and 4.2, were processed using USEPA's MNA ranking system to assess the adequacy or feasibility of MNA at the site. The following interpretation of the scoring (Table 5.1), or points system is adapted from USEPA's MNA protocol.

**Table 5.1
Interpretation Criteria for Examining MNA Feasibility**

Score	Interpretation
0 to 5	Inadequate evidence
6 to 14	Limited evidence
15 to 20	Adequate evidence
> 20	Strong evidence

Table 5.2 summarizes the scoring system for the two areas. Wells 38GS01 and 38GS28 were considered background wells and were used primarily to allocate scores for chloride and alkalinity concentrations in each area.

5.1 Interpretation of Geochemical and Chemical Analysis and its Effect on Reductive Dechlorination

5.1.1 Building 71 Area

Geochemistry

Table 5.2 shows considerable evidence to demonstrate the occurrence of reductive dechlorination of PCE and TCE in the Building 71 area. Well 38GS12 in the center of the contamination, had a score or ranking of 27 which suggests that there is strong evidence of natural reductive chlorination. Downgradient location well 38GS03 also showed strong evidence of reductive dechlorination, while two other downgradient wells, 38GS02 and 38GS10, also showed adequate evidence of its occurrence. Significant chemical and geochemical parameters and findings of the MNA investigation that support strong evidence of MNA are summarized below:

*Final Technical Memorandum — Evaluation of Monitored Natural Attenuation
NAS Pensacola — Site 38
December 6, 1999*

Table 5.2
MNA Effectiveness Evaluation Summary
Building 71 Area

Parameter	Well	38GS02	38GS03	38GS10	38GS12	38GS08	38GS17	38GS19	38GS20	38GS32
DO		3	3	3	3	3	3	0	3	3
Temperature		1	1	1	1	0	0	0	0	0
pH		0	0	0	0	1	1	1	1	1
ORP		2	2	2	2	1	2	0	2	2
Chloride		2	2	2	2	0	0	0	0	0
Alkalinity		0	0	0	0	0	1	0	0	0
Iron II		0	0	0	0	0	0	0	0	0
Nitrate		NS	2	NS	2	2	NS	NS	NS	2
Sulfate		2	2	2	2	2	2	0	2	2
Sulfide		3	2	3	3	0	3	0	1	0
Methane		3	3	3	3	0	3	0	3	2
Hydrogen		3	3	3	3	1	3	0	3	0
Carbon Dioxide		NS	0	NS	0	NS	NS	0	0	0
TOC		0	0	0	0	0	2	0	0	0
cis-1,2-DCE		0	2	0	2	2	0	2	0	2
Vinyl Chloride		0	2	0	2	0	0	2	2	2
DCA		0	2	0	2	0	0	0	0	NS
Total Points Scored		19	26	19	27	12	20	5	17	16
Interpretation/Effectiveness/Evidence		Adequate	Strong	Adequate	Strong	Limited	Adequate	Inadequate	Adequate	Adequate

Note:
NS — Not sampled

Dissolved Oxygen (DO): DO is probably the most critical parameter in the geochemical suite. Low or non-detect concentrations of DO are supportive of natural reductive dechlorination because high DO hinders, or even prevents, chlorinated solvent degradation. Table 4.1 indicates that the aquifer is almost devoid of DO which makes it anaerobic or highly reducing.

Oxidation-Reduction Potential (ORP): ORP measurements in groundwater provide further evidence of the reductive nature of the aquifer, a condition that is vital to the reductive dechlorination process. ORP readings less than 50 mV generally suggest anaerobic or reducing conditions. At all the wells in the plume except for upgradient well 38GS01, the ORP was well below -100 mV indicating conditions strongly favor reductive dechlorination.

Nitrate: Nitrate at higher concentrations (> 1 mg/L) could impede the reductive dechlorination process. Nitrate at 38GS12 and one of the other downgradient locations (38GS03) was below the method detection level. Therefore, it is unlikely that nitrate will inhibit reductive dechlorination.

Sulfate and Sulfide: Sulfate below 20 mg/L generally does not interfere with the reductive dechlorination process. However, at higher concentrations, sulfate could compete with TCE and PCE for microbial respiration. Sulfate concentrations in this area were all below 20 mg/L. However, sulfide was present at concentrations of 16.2 and 18.2 mg/L at 38GS03 and 38GS12, respectively, indicating a significant mass of electron acceptors in present.

The presence of sulfide indicates reducing conditions in the aquifer which facilitate reductive pathways for TCE and PCE. Sulfide was detected in all area wells with a maximum concentration of 1.53 mg/L at 38GS12 clearly indicating the reductive nature of the aquifer.

Hydrogen: Hydrogen was measured during the second event (April 1999) to support evidence for reductive dechlorination found in the December 1998 sampling. The range of hydrogen

concentrations (1.34 to 2.5 nM) further indicates that the majority of the aquifer is in the sulfate-reducing mode of anaerobic activity, making it conducive to reductive dechlorination.

Methane: Methane was detected in the aquifer with a maximum concentration of 580 $\mu\text{g/L}$ at 38GS10. Methane detections further indicate that methanogenesis is occurring along with sulfate reduction, although to a lesser degree. Methanogenic conditions are considered the most favorable for reductive dechlorination of PCE, TCE, and their daughter products. The higher the methane concentrations ($> 1,000 \mu\text{g/L}$ and above are considered optimal), the more it is likely that PCE and TCE will degrade completely to innocuous end-products such as ethane and ethene. However, even methane concentrations in the 100 to 500 $\mu\text{g/L}$ range can indicate there are pockets of methanogenic activity in the aquifer.

Chloride: The end-product of reductive dechlorination is chloride, which is a non-reactive (conservative) constituent often used as an indicator parameter to demonstrate chlorinated solvent breakdown. When chloride is present at concentrations greater than twice the background, it is likely that significant reductive dechlorination is occurring. In the Building 71 Area, chloride concentrations were consistently four to five times background concentrations.

Total Organic Carbon (TOC): For reductive dechlorination to occur, the microorganisms must have an adequate supply of natural or anthropogenic carbon. The 20 mg/L value listed in the USEPA protocol is an optimal concentration for reductive dechlorination and is relative to the concentrations of TCE and PCE. However, at most sites, a TOC concentration much less than this is sufficient to drive the reductive dechlorination, provided the aquifer is a reducing one. In the Building 71 Area, TOC values of 12.4 mg/L at 38GS12 and 4.56 mg/L at 38GS03 are relatively high compared to the concentrations of PCE and TCE and should support continuing degradation in the aquifer.

Site Chemical Data and Historical Trends

Table 5.3 summarizes chlorinated solvent concentrations in Building 71 Area since sampling first began in January 1994. Figures 5.1 through 5.5 depict changes in concentration of chlorinated solvents and their daughter breakdown products in each well in the area (for which data are available) since 1994 when sampling began. Figures 5.6 through 5.8 show changes in concentration in the approximate direction of groundwater flow in the area. Concentrations of chlorinated solvents show an overall decreasing trend in the direction of groundwater flow from well 38GS12 to the downgradient wells 38GS03, 38GS02, and 38GS10. This indicates that PCE and TCE are undergoing reductive dechlorination before reaching the downgradient wells. Overall, since sampling began in 1994, concentrations have also decreased over time (with the exception of PCE at 38GS12). However, evidence points to a decrease in groundwater PCE concentrations during all sampling events and very strong geochemical evidence at 38GS12 which should assist PCE degradation.

The products of reductive dechlorination, cis-1,2-DCE and vinyl chloride shows trends similar to their parent compounds, indicating that these by-products are not accumulating in the aquifer. Detections at well 38GS03 for TCE ($5 \mu\text{g/L}$) and vinyl chloride ($3 \mu\text{g/L}$) are only slightly above their screening concentrations. The overall geochemical screening indicated that conditions are still very favorable for reductive dechlorination at this location, indicating that downgradient accumulation of parent or daughter compounds is not likely.

5.1.2 Building 604 Area

Geochemistry

Table 5.2 shows fair evidence of reductive dechlorination of PCE and TCE in the Building 604 area. Among the wells in the center of contamination (38GS17, 38GS19, and 38GS20), 38GS19 was the only one that showed inadequate evidence of reductive dechlorination. However, this location is probably an isolated aerobic locale or micro-environment within the aquifer. Even at

Figure 5.1 Tetrachloroethene Building 71 Well Concentrations

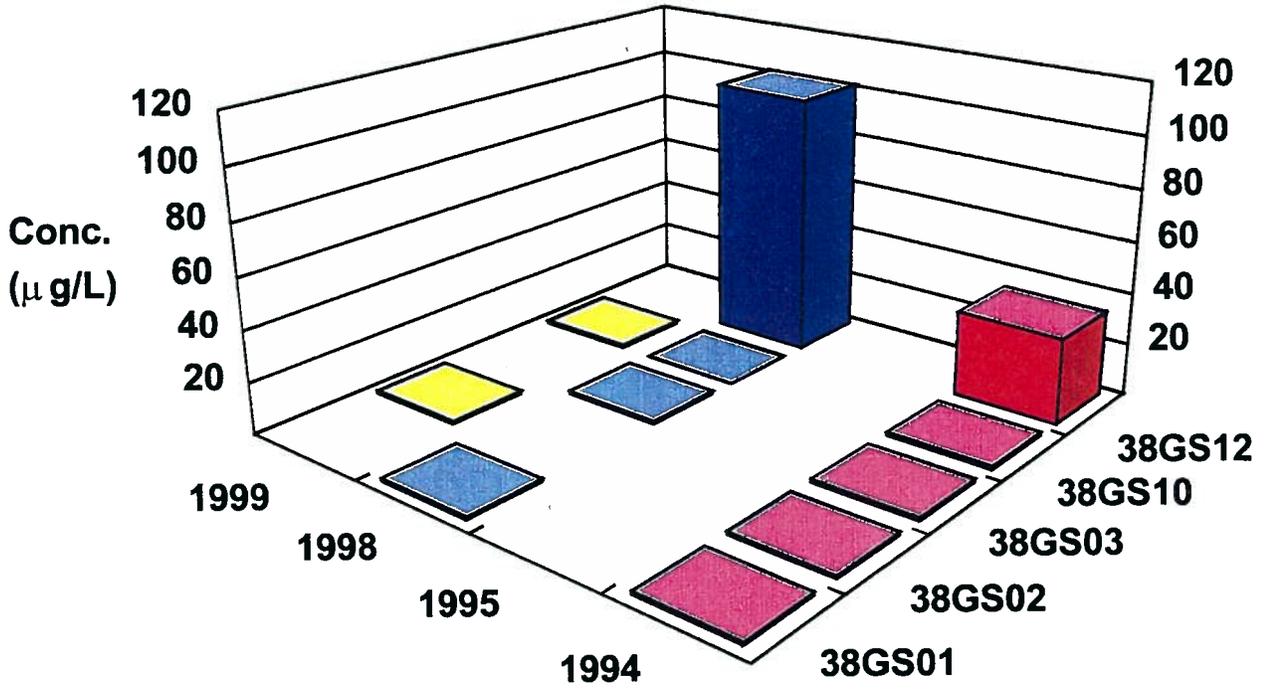


Figure 5.2 Trichloroethene Building 71 Well Concentrations

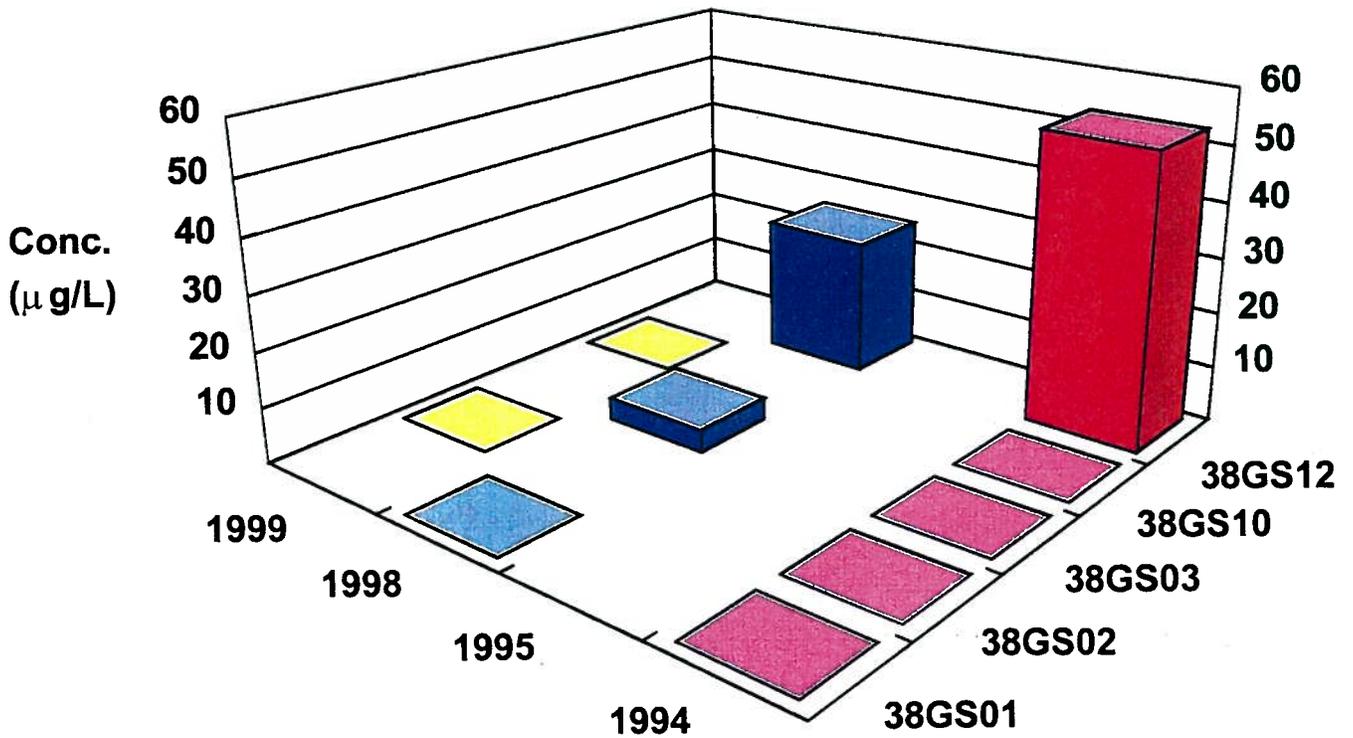


Figure 5.3 cis-1,2 -Dichloroethene Building 71 Well Concentrations

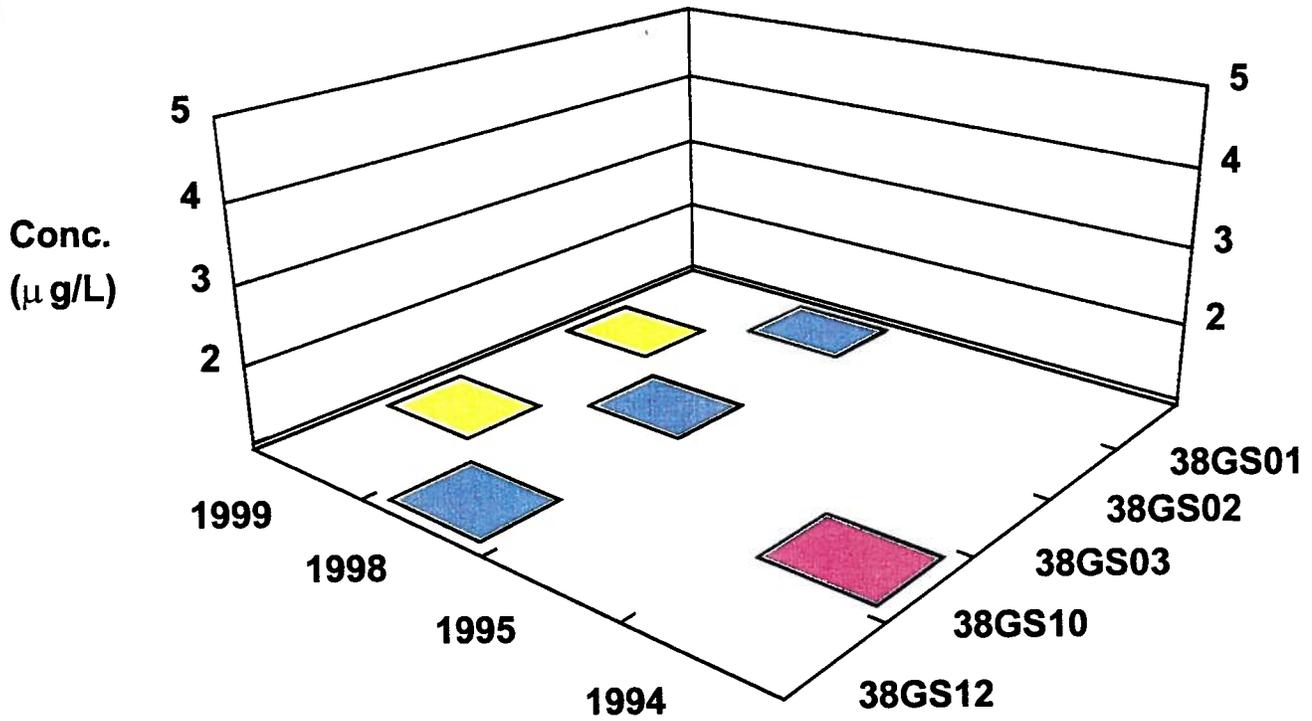


Figure 5.4 1,1-Dichloroethane Building 71 Well Concentrations

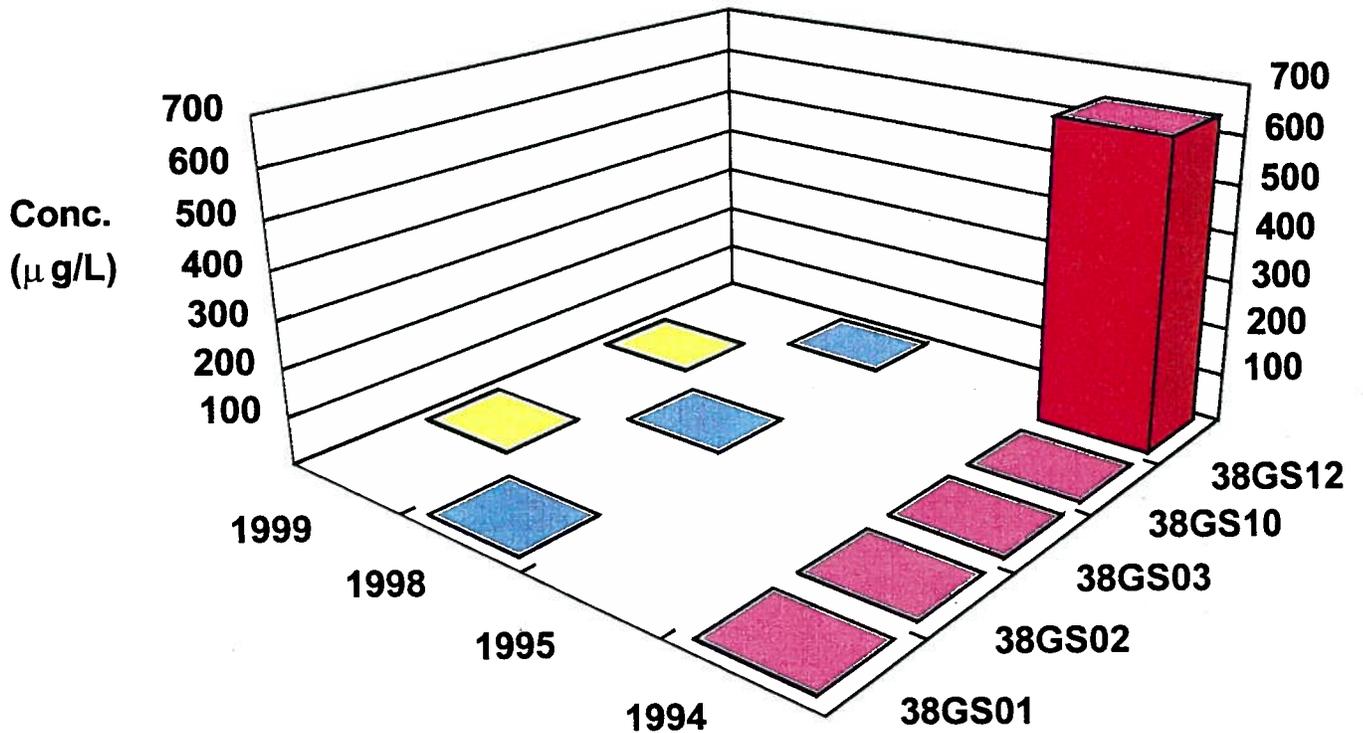


Figure 5.5 Vinyl Chloride Well Concentrations Building 71

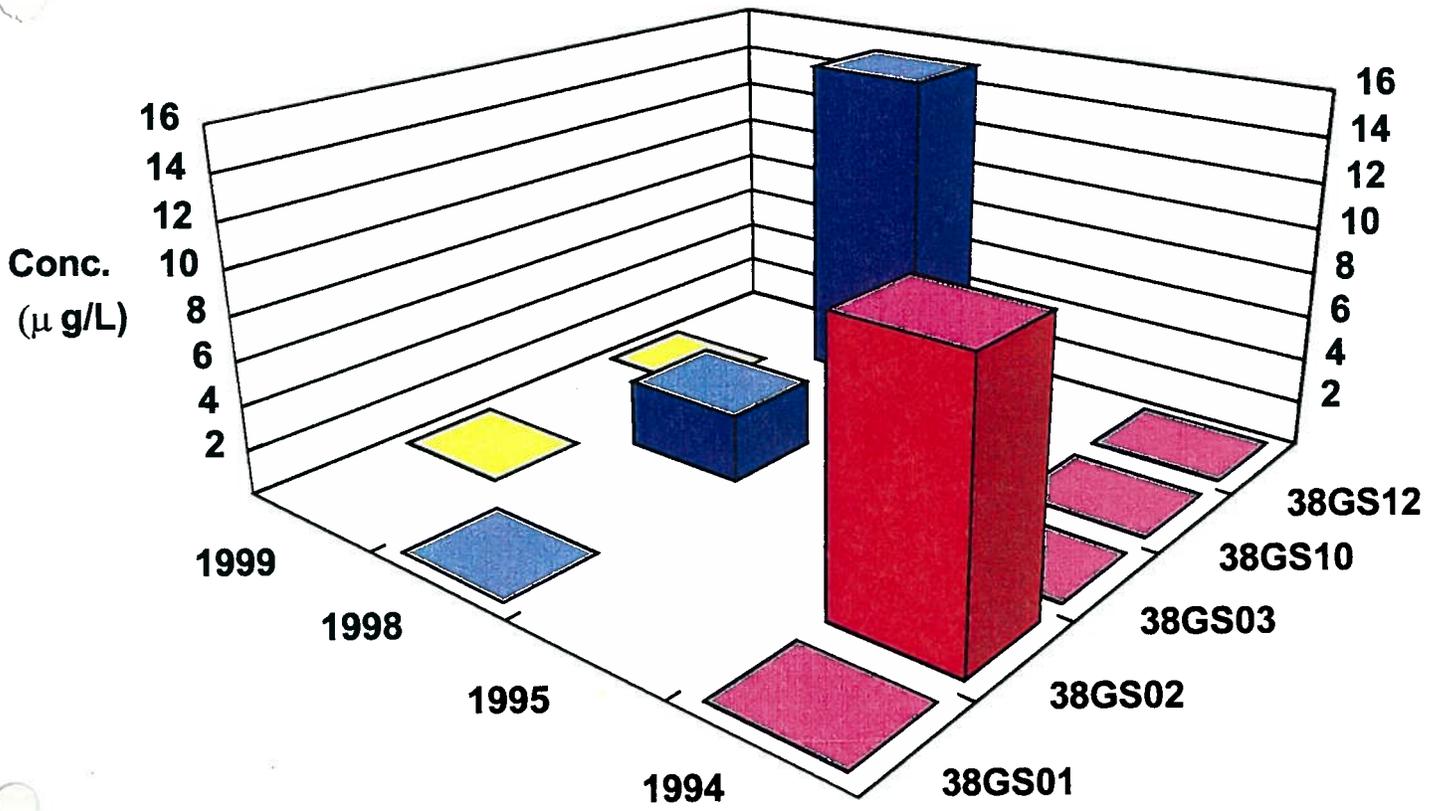


Figure 5.6 Bldg 71 1994 Natural Attenuation of Chlorinated Solvents

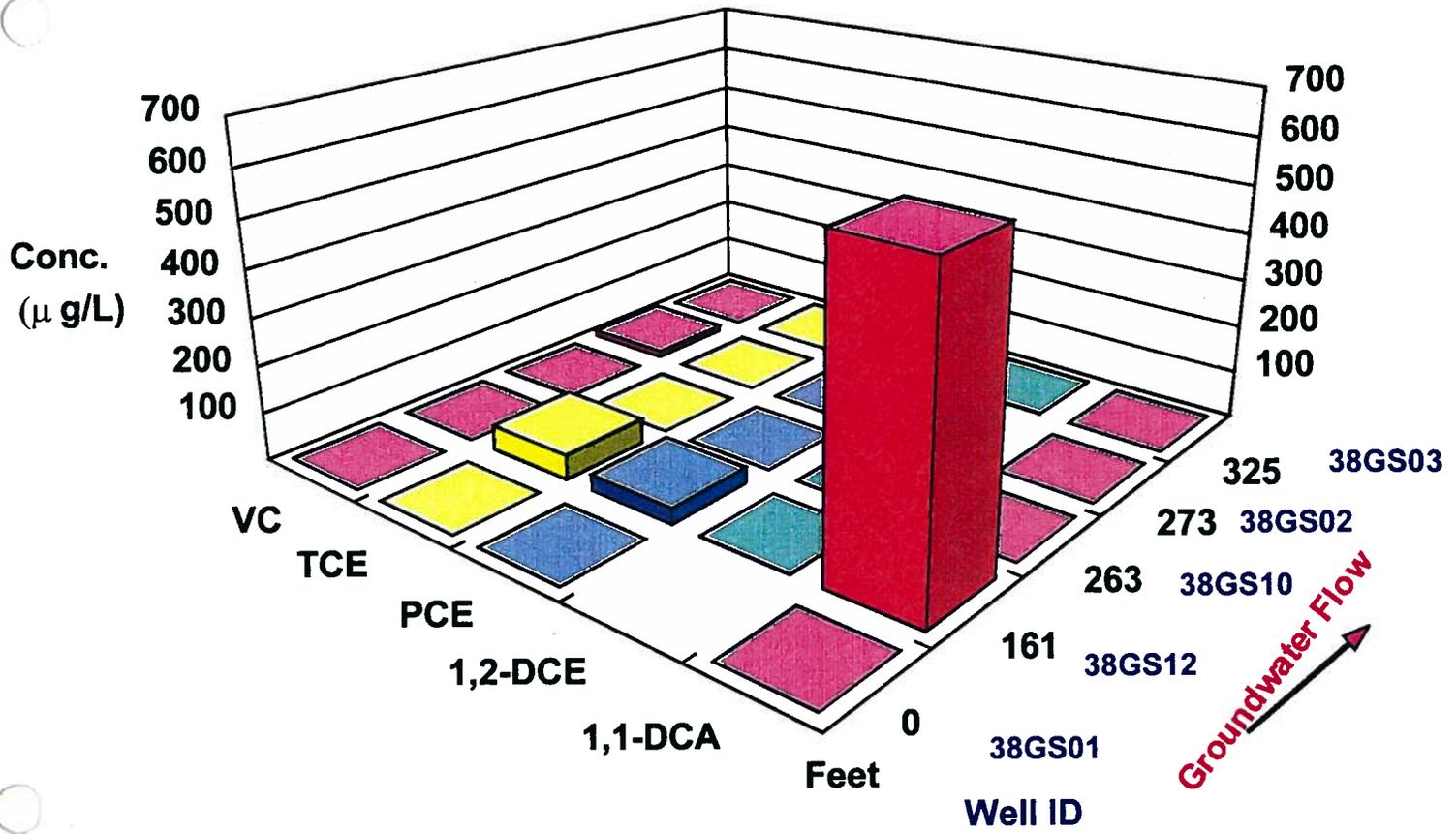


Figure 5.7 Bldg 71 1998 Natural Attenuation of Chlorinated Solvents

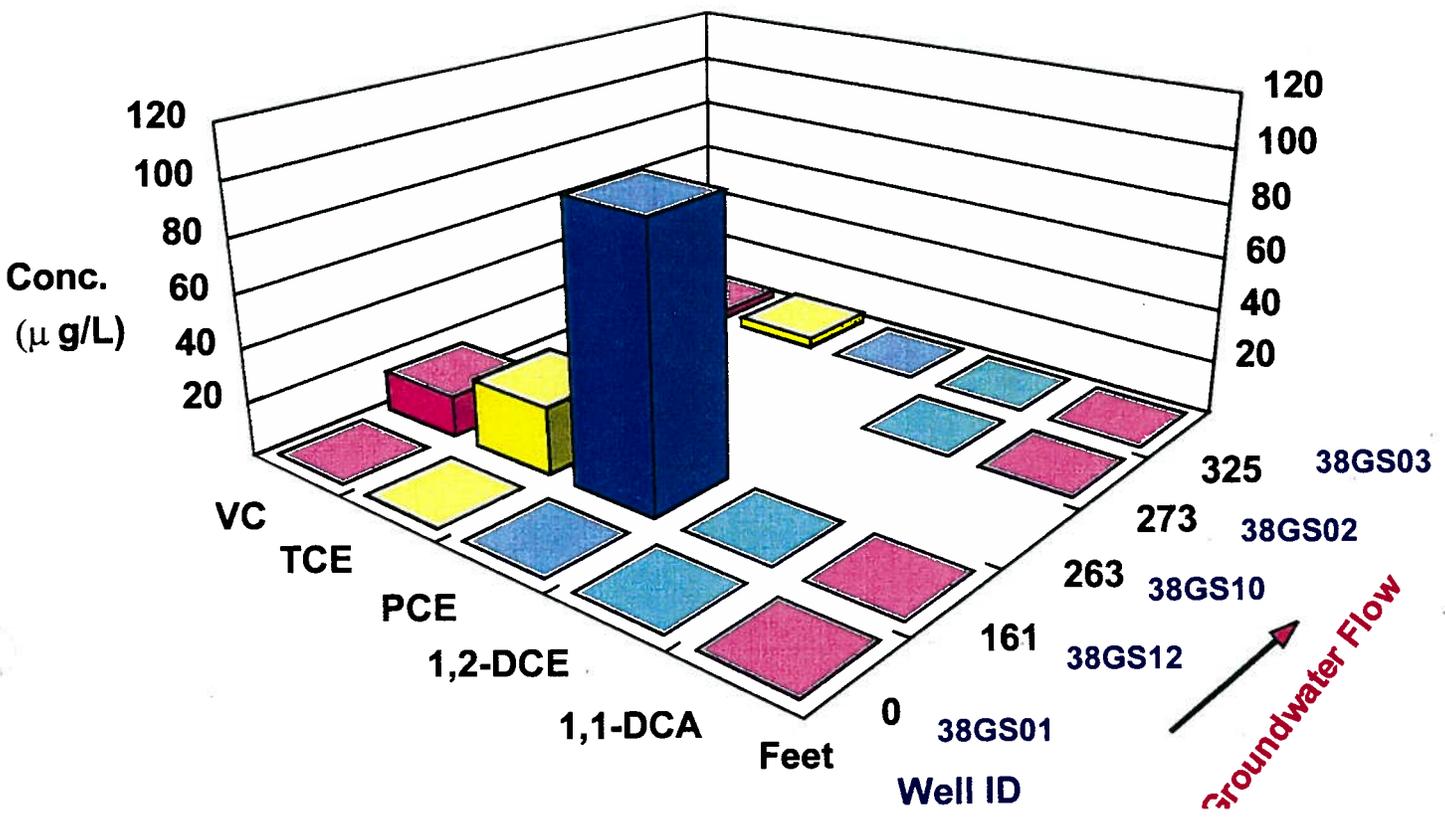


Figure 5.8 Bldg 71 1999 Natural Attenuation of Chlorinated Solvents in Groundwater NAS Pensacola

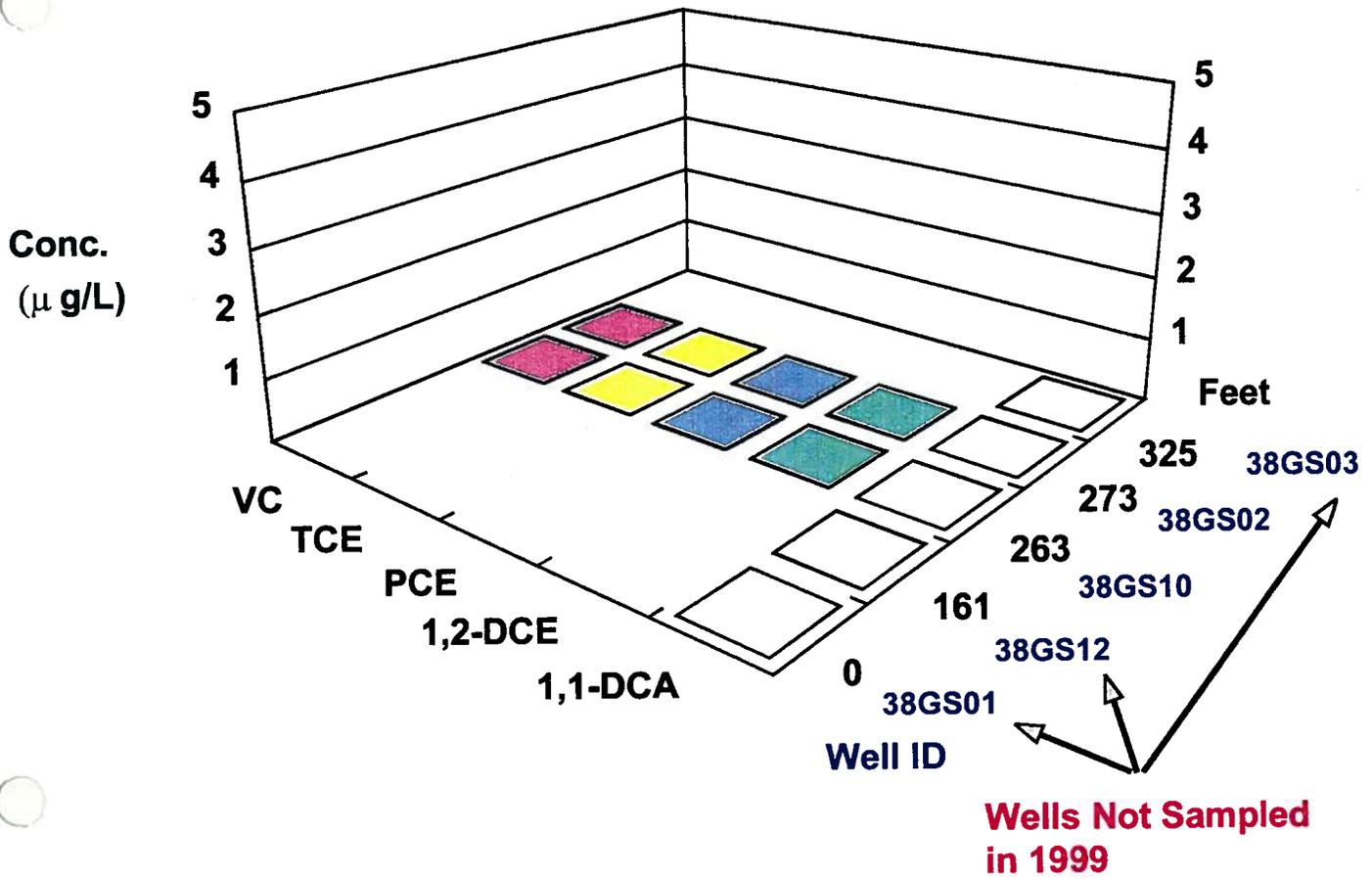


Table 5.3
 Site 38 — 1994-1999
 Historical Data for Chlorinated Solvents
 Detected in Groundwater at the Building 71 Area

Parameter	Location	RI Samples (Jan 1994)	EPA Samples (Oct 1995)	Samples (Dec 1998)	Samples (May 1999)	Screening Concentration	Screening Source
Volatile Organic Compounds (µg/L)							
1,1-Dichloroethane	38GS01	ND	NS	ND	NS	700	FGGC
	38GS02	44	NS	NS	ND		
	38GS03	ND	NS	3	NS		
	38GS10	ND	NS	NS	ND		
	38GS12	640	NS	13	NS		
cis-1,2-Dichloroethene	38GS01	NA	NS	ND	NS	70	FPDWS
	38GS02	NA	NS	NS	ND		
	38GS03	NA	NS	5	NS		
	38GS10	ND	NS	NS	ND		
	38GS12	NA	NS	27	NS		
Tetrachloroethene	38GS01	ND	NS	ND	NS	3	FPDWS
	38GS02	ND	NS	NS	ND		
	38GS03	ND	NS	ND	NS		
	38GS10	ND	NS	NS	ND		
	38GS12	33	NS	102	NS		
Trichloroethene	38GS01	ND	NS	ND	NS	3	FPDWS
	38GS02	ND	NS	NS	ND		
	38GS03	1	NS	4	NS		
	38GS10	2	NS	NS	ND		
	38GS12	53	NS	25	NS		
Vinyl Chloride	38GS01	ND	NS	ND	NS	1	FPDWS
	38GS02	12	NS	NS	ND		
	38GS03	ND	NS	3	NS		
	38GS10	ND	NS	NS	ND		
	38GS12	ND	NS	15	NS		

Notes:
 ND — Parameter not detected in this sample.
 NA — Parameter not analyzed for this sample.
 NS — Well not sampled during this event.
 Concentrations exceeding screening values are in bold.

this location (38GS19), PCE concentrations have decreased from 240 $\mu\text{g/L}$ to 22 $\mu\text{g/L}$ in a three-year period. 38GS32, which is farthest downgradient, showed adequate evidence of microbial degradation. Significant chemical and geochemical parameters and findings, and MNA investigation results that support the evidence of MNA are summarized below.

Dissolved Oxygen (DO): Table 4.2 indicates that DO concentrations in the aquifer (except at 38GS19) were generally below the critical value of 0.5 mg/L, the point at which anaerobic degradation occurs.

Oxidation-Reduction Potential (ORP): ORP readings less than 50 mV generally suggest anaerobic or reducing conditions. At three wells in the area (38GS17, 38GS20, and 38GS32), the ORP was well below -100 mV, indicating conditions strongly favor reductive dechlorination. The main exception was at 38GS19 where the ORP was 114 mV, confirming an aerobic locale around this well.

Nitrate: Nitrate at higher concentrations (> 1 mg/L) could impede or slow down the reductive dechlorination process. Nitrate was below 1.0 mg/L in the aquifer, except at 38GS19, which had a concentration of 1.86 mg/L. However, reductive dechlorination activity in the major portion of the aquifer in this area is unlikely to be impacted by nitrate.

Sulfate and Sulfide: Sulfate up to 20 mg/L generally does not interfere with the reductive dechlorination process. However, at higher concentrations, sulfate could compete with TCE and PCE for microbial consumption. Sulfate concentrations in this area were all below 20 mg/L (with the exception of 38GS19). Concentrations of 15 and 16 mg/L at 38GS20 and 38GS17, respectively, indicate an adequate mass of electron acceptors is available.

The presence of sulfide in the aquifer indicates that the aquifer is reducing and reductive pathways for TCE and PCE are possible. Sulfide was detected in two of the wells in the center of contamination, 38GS17 and 38GS20, indicating the reductive nature of the aquifer and its conduciveness to reductive dechlorination. The sulfide concentration of 10.75 mg/L at 38GS17 was very high, suggesting reductive dechlorination is occurring.

Hydrogen: Hydrogen was measured during the second event (April 1999) to support the evidence for reductive dechlorination found during the December sampling. Hydrogen concentrations in the critical wells (38GS17 and 38GS20) were above 3 mg/L, suggesting that sulfate-reduction and methanogenesis are occurring.

Methane: Methane was also detected at 1,700 $\mu\text{g/L}$ at 38GS20 and at 5,300 $\mu\text{g/L}$ at 38GS17. Methane detections further indicate that along with sulfate reduction, methanogenesis is also occurring. Methanogenic conditions are considered the most favorable for reductive dechlorination of PCE, TCE, and also its daughter products. The higher the methane concentrations ($> 1,000 \mu\text{g/L}$ and above are considered optimal), the more likely it is that PCE will degrade completely to innocuous end-products such as ethane and ethene.

Total Organic Carbon (TOC): For reductive dechlorination to occur, microorganisms must have a supply of natural or anthropogenic carbon. The value of 20 mg/L listed in the EPA protocol as being an optimal concentration for reductive dechlorination is relative to the concentrations of TCE and PCE. At most sites, a TOC concentration much less than this is sufficient to drive reductive dechlorination, provided the aquifer is a reducing one. In the Building 604 Area, TOC values of 29 mg/L at 38GS17 and 7.10 mg/L at 38GS20 are relatively high compared to PCE and TCE concentrations, and should support continued degradation in the aquifer.

Site Chemical Data and Historical Trends

Table 5.4 summarizes chlorinated solvent concentrations in the Building 604 Area since sampling began in January 1994. Figures 5.9 through 5.12 depict changes in concentration of chlorinated solvents and their daughter breakdown products in each well in the area (for which data are available) since 1994 when sampling began. Figures 5.13 through 5.15 show changes in concentration in the approximate direction of groundwater flow in the area. PCE concentrations have decreased over time in all wells sampled. The largest decrease has been noted at 38GS19, with reductions from 240 $\mu\text{g/L}$ to 22 $\mu\text{g/L}$ over three years. The wells that show the strongest evidence of reductive dechlorination (38GS17 and 38GS20) are now non-detect for PCE for PCE.

TCE concentrations have also decreased over a three-year monitoring period with wells 38GS17 and 38GS20 now at non-detect. TCE concentrations at downgradient well 38GS32 have shown the largest decrease, from 340 to 5 $\mu\text{g/L}$, in the same period.

Figures 5.13 through 5.15 show that in addition to reducing concentrations over time in each individual well, the general pattern indicates an overall decrease in chlorinated solvents in the direction of groundwater flow.

Concentrations of daughter products, particularly vinyl chloride, show a similar decreasing trend over time. The greatest decrease has been at well 38GS17, where VC concentrations have decreased from 3,700 $\mu\text{g/L}$ to non-detect in three years. Vinyl chloride concentrations at downgradient well 38GS32 have also decreased significantly, from 130 $\mu\text{g/L}$ to 14 $\mu\text{g/L}$, during this time. These decreases in VC concentrations over time strongly suggest that this critical daughter product is not accumulating in the aquifer.

Figure 5.9 Tetrachloroethene Building 604 Well Concentrations

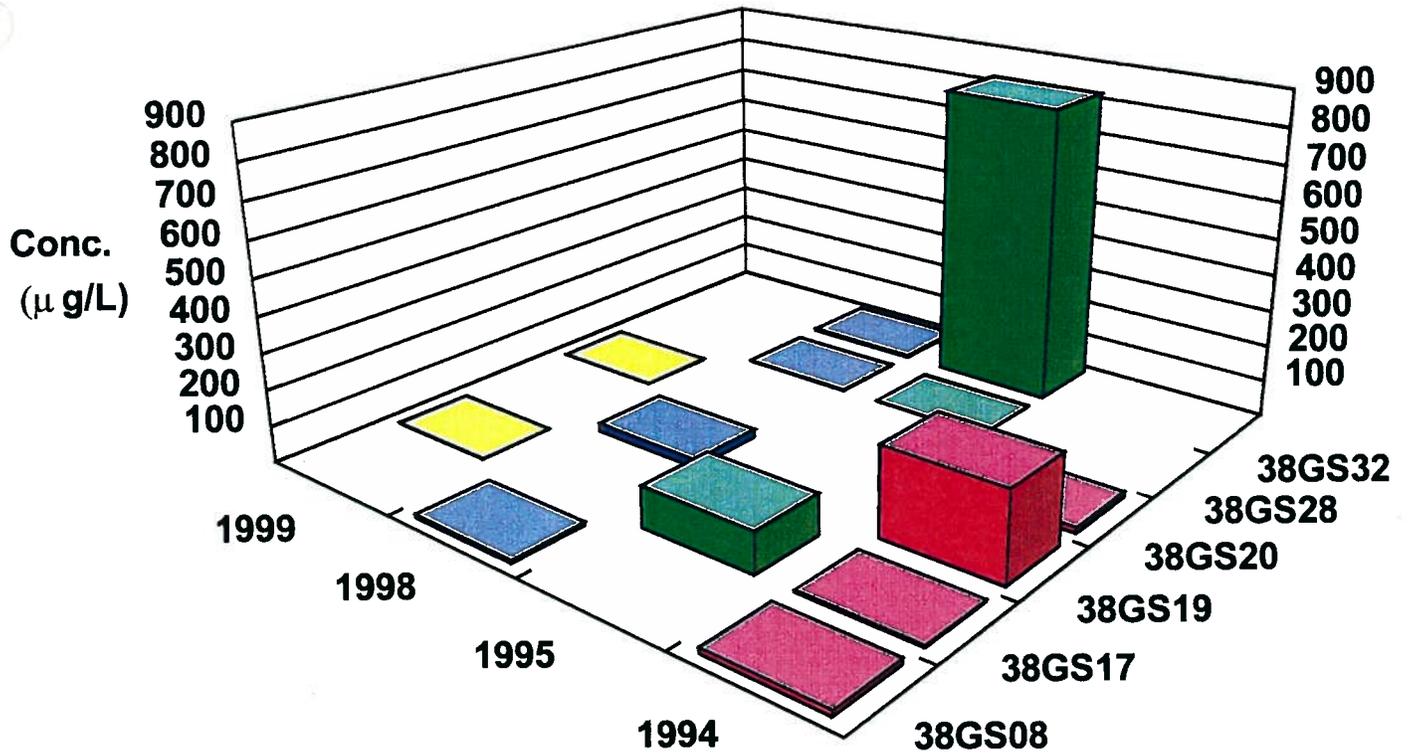


Figure 5.10 Trichloroethene Building 604 Well Concentrations

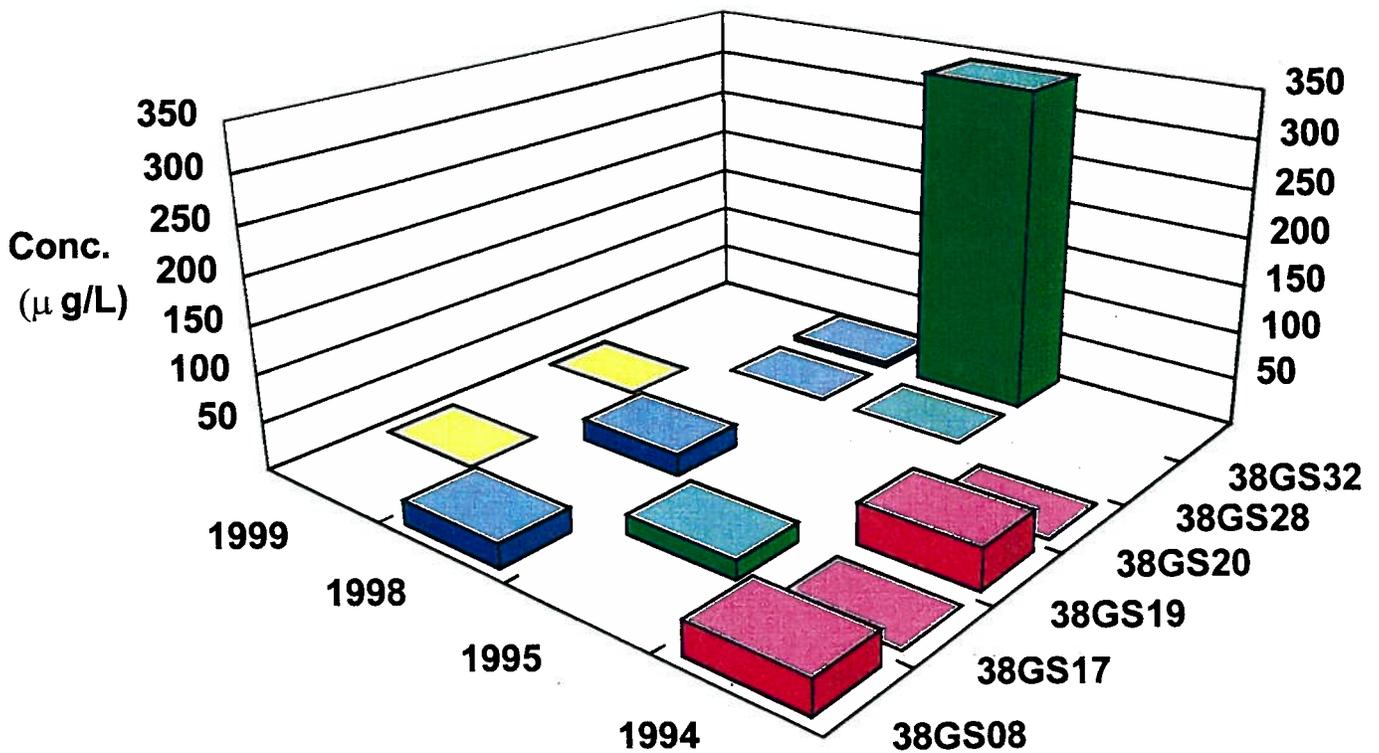


Figure 5.11 cis-1,2 -Dichloroethene Building 604 Well Concentrations

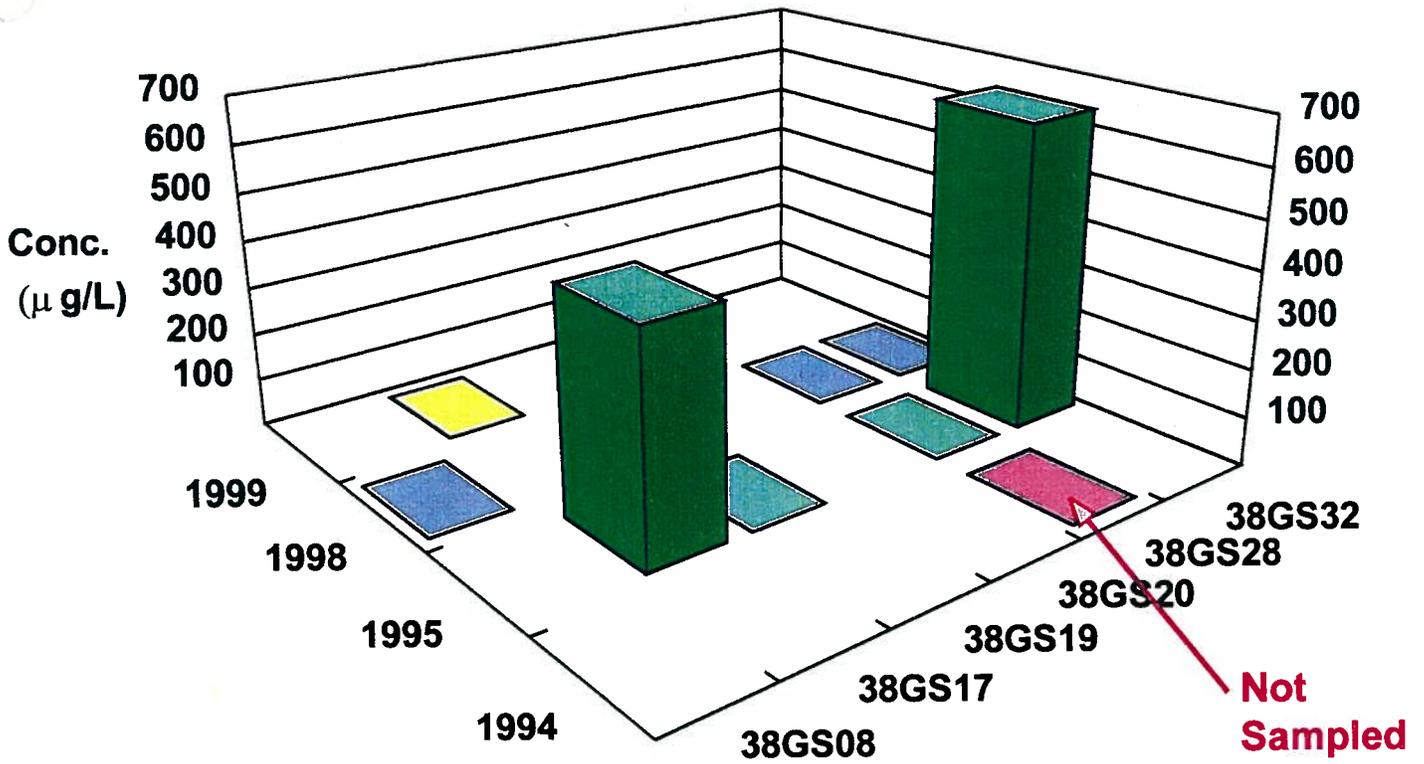


Figure 5.12 1,1-Dichloroethane Building 604 Well Concentrations

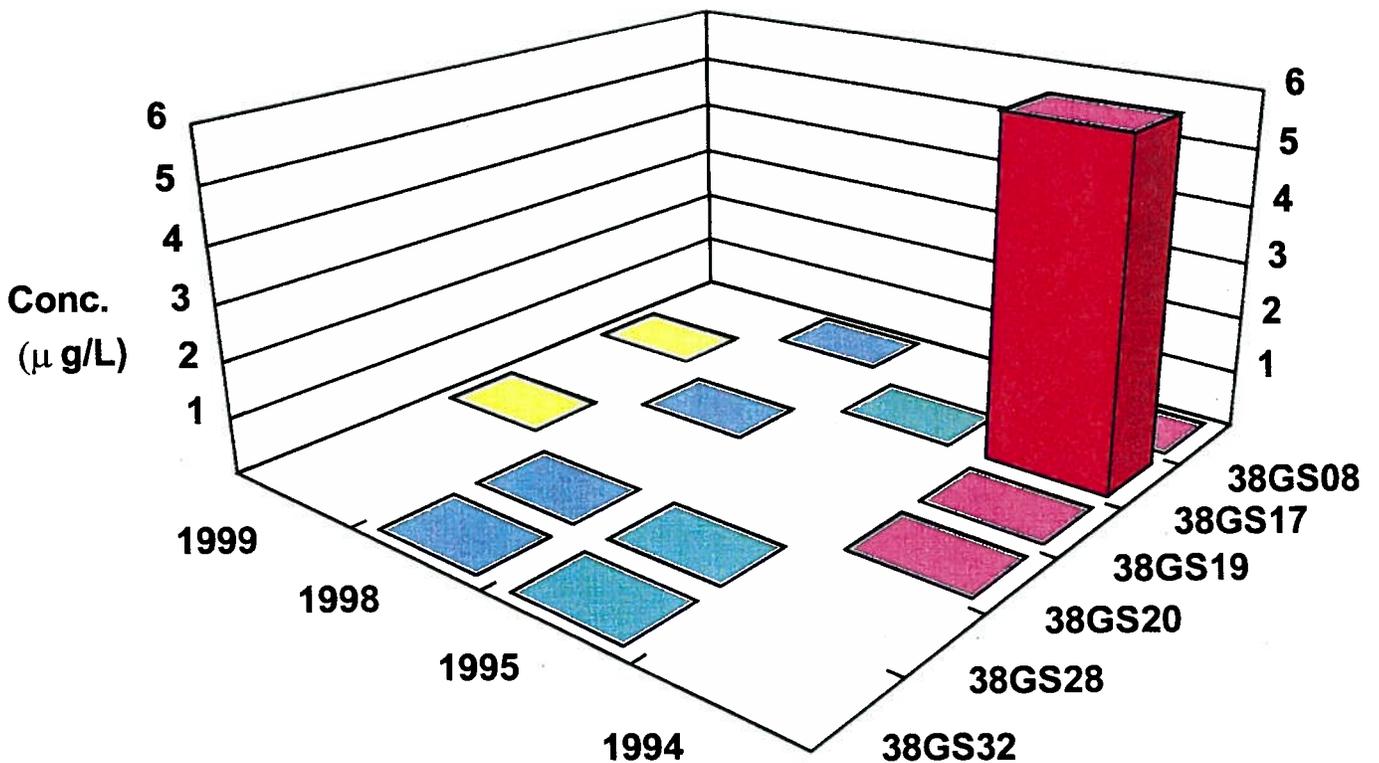


Figure 5.13 1994 Bldg. 604 Natural Attenuation of Chlorinated Solvents in Groundwater at NAS Pensacola

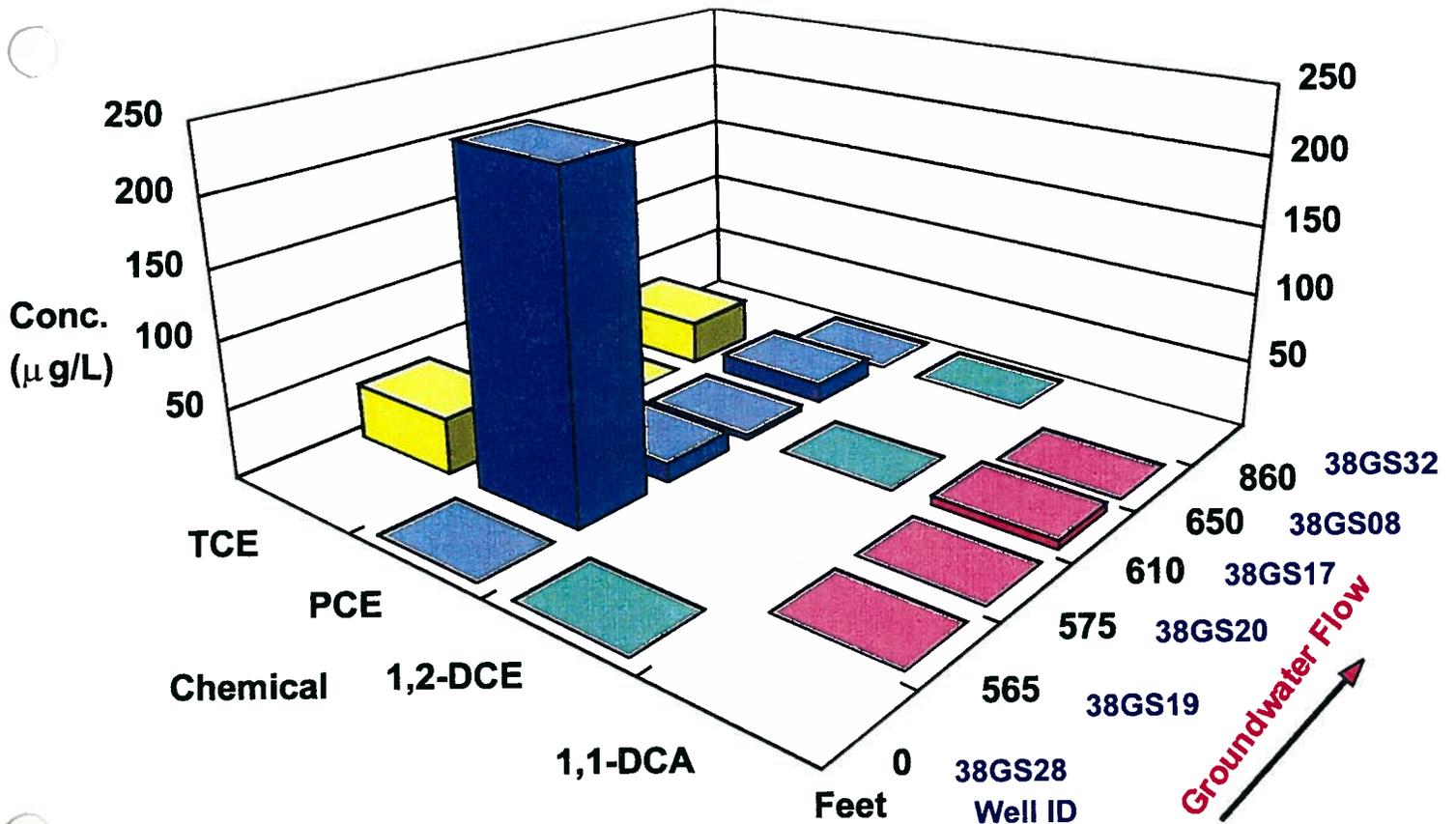


Figure 5.14 1995 Bldg. 604 Natural Attenuation Chlorinated Solvents in Groundwater at NAS Pensacola

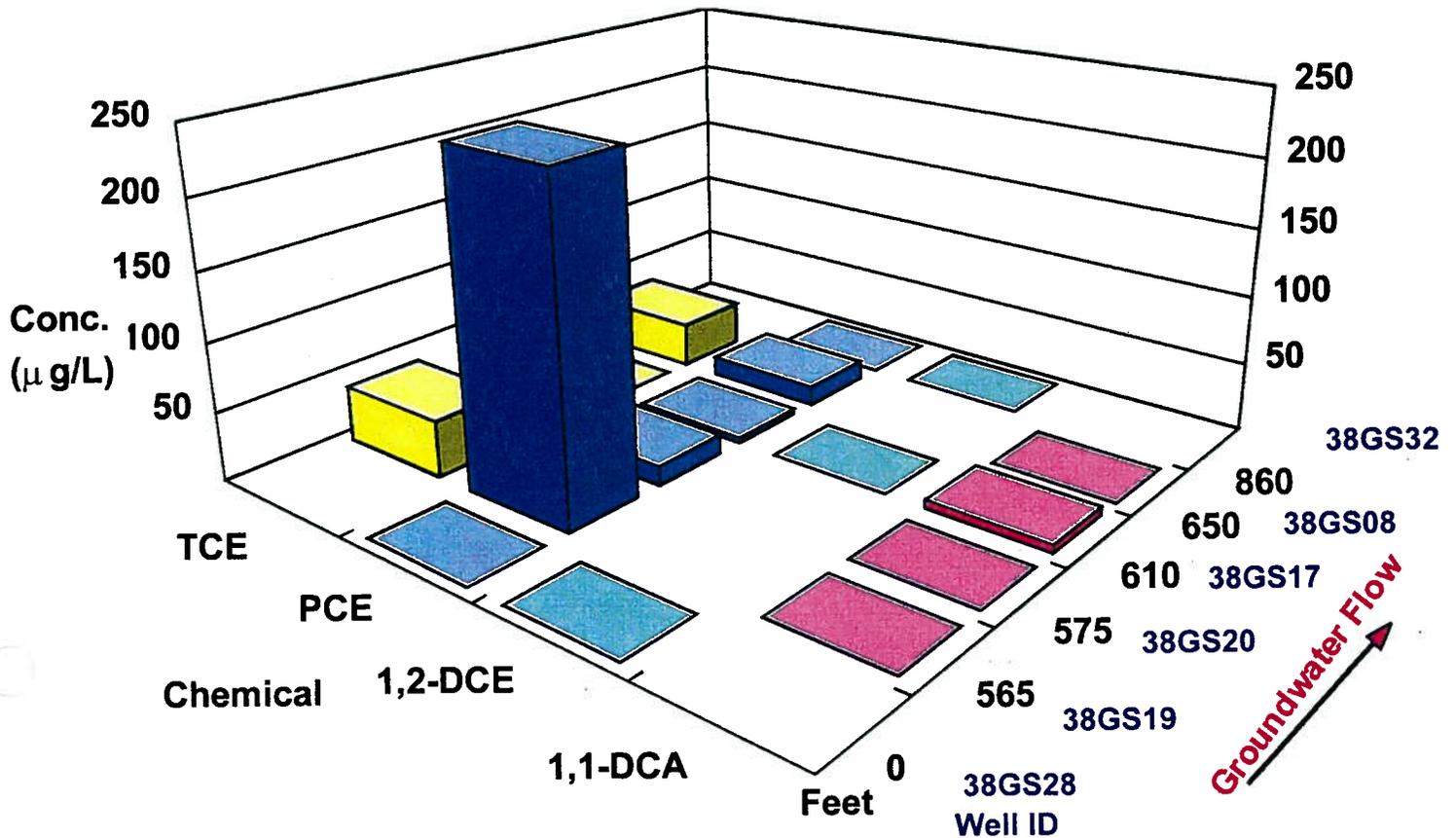


Figure 5.15 1998 Bldg. 604 Natural Attenuation of Chlorinated Solvents in Groundwater at NAS Pensacola

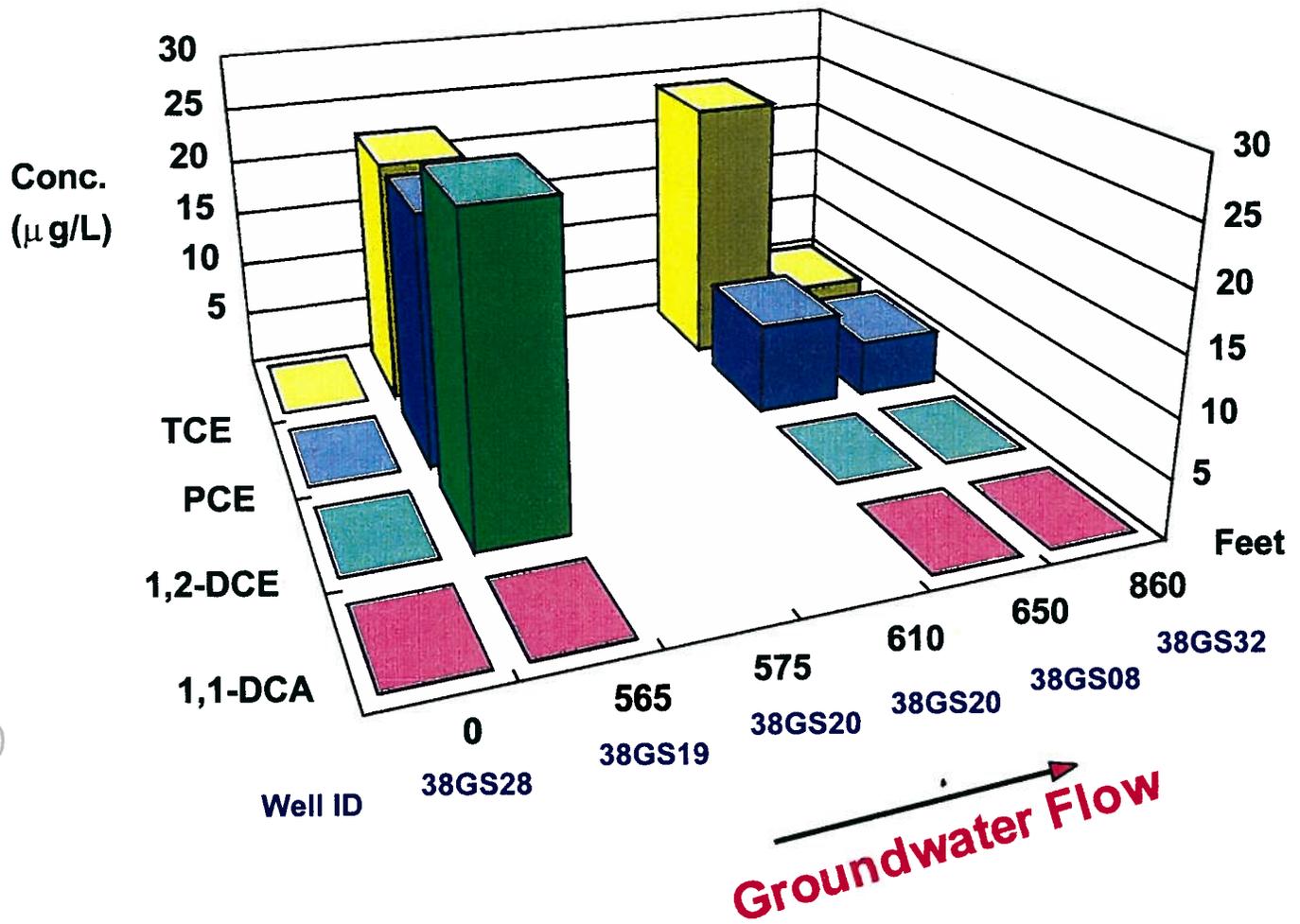


Table 5.4
 Site 38 -- 1994-1999
 Historical Data for Chlorinated Solvents
 Detected in Groundwater at Building 604

Parameter	Location	RI Samples (Jan 1994)	EPA Samples (Oct 1995)	Samples (Dec 1998)	Samples (May 1999)	Screening Concentration	Screening Source
Volatile Organic Compounds ($\mu\text{g/L}$)							
1,1-Dichloroethane	38GS08	ND	NS	ND	NS	700	FGCIC
	38GS17	6	ND	NS	ND		
	38GS19	ND	NS	ND	NS		
	38GS20	ND	NS	NS	ND		
	38GS28	NS	ND	ND	NS		
	38GS32	NS	ND	ND	NS		
cis-1,2-Dichloroethane	38GS08	NA	NS	25	NS	70	FPDWS
	38GS17	NA	460	NS	ND		
	38GS19	NA	NS	27	NS		
	38GS20	NA	NS	NS	ND		
	38GS28	NS	ND	ND	NS		
	38GS32	NS	640	25	NS		
Tetrachloroethene	38GS08	14	NS	8	NS	3	FPDWS
	38GS17	4	110	NS	ND		
	38GS19	240	NS	22	NS		
	38GS20	14	NS	NS	ND		
	38GS28	NS	ND	ND	NS		
	38GS32	NS	820	5	NS		
Trichloroethene	38GS08	33	NS	24	NS	3	FPDWS
	38GS17	ND	19	NS	ND		
	38GS19	41	NS	22	NS		
	38GS20	ND	NS	NS	ND		
	38GS28	NS	ND	ND	NS		
	38GS32	NS	340	5	NS		

Table 5.4
 Site 38 — 1994-1999
 Historical Data for Chlorinated Solvents
 Detected in Groundwater at Building 604

Parameter	Location	RI Samples (Jan 1994)	EPA Samples (Oct 1995)	Samples (Dec 1998)	Samples (May 1999)	Screening Concentration	Screening Source
Vinyl Chloride	38GS08	6	NS	ND	NS	1	FPDWS
	38GS17	1,600	3,700	NS	ND		
	38GS19	29	NS	3	NS		
	38GS26	1,100	NS	NS	15		
	38GS28	NS	NS	ND	NS		
	38GS32	NS	130	14	NS		

Notes:

- ND — Parameter not detected in this sample.
- NA — Parameter not analyzed for this sample.
- NS — Well not sampled during this event.

Concentrations exceeding screening values are in bold.

5.2 Effect of Geochemistry on Lead Concentrations

5.2.1 Building 71 Area

Lead concentrations have decreased over the entire site since sampling began in 1994 (see Table 5.5 below). All three downgradient wells (38GS02, 38GS03, and 38GS10) are now at non-detect concentrations. Furthermore, the concentration of lead in 38GS12, the most contaminated well, has also decreased from 280 $\mu\text{g/L}$ to 128 $\mu\text{g/L}$ in three years.

Table 5.5
Lead Concentrations ($\mu\text{g/L}$) in Groundwater
Buildings 71 and 604
1994-1998

Bldg 71	RI Samples	EPA Samples	Addendum Samples
Location	(Jan 1994)	(Oct 1995)	(December 1998)
38GS01	276	NS	117
38GS02	362	NS	ND
38GS03	388.5	NS	ND
38GS10	54	NS	ND
38GS12	280	NS	128

Bldg 604	RI Samples	EPA Samples	Addendum Samples
Location	(Jan 1994)	(Oct 1995)	(December 1998)
38GS28		ND	4
38GS08	79.2	NS	116
38GS17	65.2	ND	NS
38GS19	180	NS	58
38GS20	110	NS	NS
38GS32	ND	NS	24

The decrease in Area 71 lead concentrations can be linked to site geochemistry and the presence of sulfate, sulfide, and the overwhelming evidence of sulfate-reducing conditions in the aquifer. The presence of sulfide in sufficient quantities results in the ready precipitation of lead to form lead sulfide (PbS). This precipitation immobilizes the metal and is an effective natural mechanism for remediation.

5.2.2 Building 604 Area

Lead concentrations have decreased at locations 38GS17 and 38GS19 (see Table 5.5). Concentrations are now at non-detect at 38GS17. This is most likely due to the sulfate present in the groundwater and the conversion of sulfates to sulfide under anaerobic conditions, as indicated by hydrogen measurements, ORP values, and sulfide concentrations.

Though concentrations of lead have increased temporarily at downgradient wells 38GS08 and 38GS32, it is likely that they will decrease over time. Hydraulically upgradient groundwater wells now exhibit sulfate-reducing conditions that are likely to immobilize the lead. With increasing immobilization of lead and reduced concentrations in the upgradient locations, lead in the downgradient groundwater is likely to gradually follow the same pattern of decreasing concentrations over time. This hypothesis is supported by the general anaerobic nature of the aquifer and the presence of sufficient amounts of sulfate to provide the sulfide required for lead precipitation. However, this hypothesis will have to be verified through monitoring.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- Geochemical analysis and interpretation of groundwater results at Site 38 show that both Building 71 and 604 Areas are highly conducive to natural biological degradation of chlorinated solvents.

- Measurements of DO, ORP, hydrogen, and other geochemical parameters have established anaerobic or reducing conditions in the aquifer, which are critical for reductive dechlorination of chlorinated solvents.

- Geochemical analysis has shown evidence to suggest the continuing degradation of PCE and TCE.

- Low concentrations of vinyl chloride at Site 38 suggest that this critical biological daughter breakdown product is not accumulating in the aquifer.

- Historical trends show an overall decrease in concentrations of PCE and TCE across these two areas and an overall decrease along the direction of groundwater flow.

- Lead concentrations at the site have decreased over time in critical locations in both areas, which is attributed to favorable geochemical conditions in the aquifer. Although lead concentrations have temporarily increased at two downgradient locations in the Building 604 Area, conditions are still favorable for an overall decrease in lead via precipitation before it is transported to downgradient locations.

6.2 Recommendations

Based on overwhelming evidence of natural biological degradation of chlorinated solvents in the aquifer and the decrease in contaminant concentrations observed over time, it is recommended that MNA be considered as the potential remedial alternative for Site 38. This would necessitate implementing a groundwater monitoring program or a performance monitoring program to verify natural attenuation is occurring (US EPA, November, 1997). The purpose of the monitoring program will be to:

- Demonstrate continuing natural biological degradation in the aquifer.
- Document continued decreases in concentrations over time.
- Ensure that downgradient receptors are not unduly impacted.
- Ensure that daughter products are not accumulating in the aquifer.
- Verify the attainment of cleanup objectives.
- Trigger the implementation of alternate active (engineered) remedies, if MNA does not fulfill the cleanup objectives.

Performance monitoring during remedial design will initially include collection of two more rounds of groundwater samples to complete the evaluation of seasonal effects (four different quarters) on site geochemistry and MNA feasibility. Following this final evaluation, the frequency and duration of long-term monitoring will be determined during remedial implementation.

Performance monitoring would continue as long as contamination remains above cleanup goals. It is performed at a specified frequency, usually annually. Monitoring is typically performed for a specified period of time after cleanup objectives are attained (one to three years). The data collected during performance monitoring will be used to update contaminant trend graphs and confirm continued decreases in concentration in the direction of groundwater flow. When sufficient data are available, the feasibility and reliability of estimating degradation rates and cleanup times will be examined. Wells in the monitoring program would include those located where contamination still exists and locations downgradient of the contaminated areas. Cleanup goals and the monitoring plan are outlined in the Site 38 FS Report. If MNA is accepted as the remedy for Site 38, a detailed monitoring plan will be submitted for approval and implementation during remedial design.

7.0 REFERENCES

USEPA. *Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents*. November 1997.

USEPA. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. Directive 92000.4-17*. November, 1997.

USEPA. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*. EPA 600/R/R-98/128, Office of Research and Development, Washington DC. September 1998.

Appendix A
Glossary of Terms

This glossary has been taken from *Natural Attenuation of Chlorinated Solvents in Groundwater: Principles And Practices*, Version 3.0 May 1997, prepared by the Bioremediation of Chlorinated Solvents Consortium of the Remediation Technologies Development Forum (RTDF).

Abiotic: Occurring without the involvement of microorganisms.

Advection: Transport of molecules dissolved in water along the groundwater flow path at an average expected velocity.

Aerobic Respiration: Process whereby microorganisms use oxygen as an electron acceptor to generate energy.

Aliphatic Hydrocarbon: A compound built from carbon and hydrogen atoms joined in a linear chain. Petroleum products are composed primarily of aliphatic hydrocarbons.

Anaerobic Respiration: Process whereby microorganisms use a chemical other than oxygen as an electron acceptor. Common "substitutes" for oxygen are nitrate, sulfate, iron, carbon dioxide, and other organic compounds (fermentation).

Aquifer: An underground geological formation that stores groundwater.

Aquitard: An underground geological formation of low permeability that does not readily transmit groundwater.

Aromatic Hydrocarbon: A compound built from carbon and hydrogen atoms joined in an unsaturated ring (e.g., benzene ring).

Bacterium: A single cell organism of microscopic size. Bacteria are ubiquitous in the environment, inhabiting water, soil, organic matter and the bodies of plants and animals.

Biodegradation: Biologically mediated conversion of one compound to another.

Biomass: Total mass of microorganisms present in a given amount of water or soil.

Bioremediation: Use of microorganisms to control and destroy contaminants.

Biotransformation: Microbiologically catalyzed transformation of a chemical to some other product.

Chlorinated Solvent: A hydrocarbon in which chlorine atoms substitute for one or more hydrogen atoms in the compounds structure. Chlorinated solvents commonly are used for grease removal in manufacturing, dry cleaning, and other operations.

Cometabolism: A reaction in which microbes transform a contaminant even though the contaminant cannot serve as an energy source for the organisms. To degrade the contaminant, the microbes require the presence of other compounds (primary substrates) that can support their growth.

Degradation: Destruction of a compound through biological or abiotic reactions.

Dechlorination: The removal of chlorine atoms from a compound.

Desorption: Opposite of sorption; the release of chemicals attached to solid surfaces.

Diffusion: Dispersive process that results from the movement of molecules along a concentration gradient. Molecules move from areas of high concentration to low concentration.

Dilution: The combined processes of advection and dispersion result in a net dilution of the molecules in the groundwater.

Dispersion: The spreading of molecules along and away from the expected groundwater flow path during advection as a result of mixing of groundwater in individual pores and channels.

Electron: A negatively charged subatomic particle that may be transferred between chemical species in chemical reactions. Every chemical molecule contains electrons and protons (positively charged particles).

Electron Acceptor: Compound that gains electrons (and therefore is reduced) in oxidation – reduction reactions that are essential for the growth of microorganisms. Common electron acceptors are oxygen, nitrate, sulfate, iron and carbon dioxide. Highly chlorinated solvents (e.g., TCE) can act as electron acceptors.

Electron Donor: Compound that loses electrons (and therefore is oxidized) in oxidation - reduction reactions that are essential for the growth of microorganisms. In bioremediation organic compounds serve as electron donors. Less chlorinated solvents (e.g., VC) can act as electron donors.

Hydraulic Conductivity: A measure of the rate at which water moves through a unit area of the subsurface under a unit hydraulic gradient.

Hydraulic Gradient: Change in head (i.e., water pressure) per unit distance in a given direction, typically in the principal flow direction.

Inorganic Compound: A chemical that is not based on covalent carbon bonds. Important examples are metals, nutrients such as nitrogen and phosphorus, minerals, and carbon dioxide.

Intrinsic Bioremediation: A type of in situ bioremediation that uses the innate capabilities of naturally occurring microbes to degrade contaminants without taking any engineering steps to enhance the process.

Metabolic Intermediate: A chemical produced by one step in a multistep biotransformation.

Metabolism: The chemical reactions in living cells that convert food sources to energy and new cell mass.

Methanogen: A microorganism that exists in anaerobic environments and produces methane as the end product of its metabolism. Methanogens use carbon dioxide or simple carbon compounds such as methanol as an electron acceptor.

Microcosm: A laboratory vessel set up to resemble as closely as possible the conditions of a natural environment.

Microorganism: An organism of microscopic or submicroscopic size. Bacteria are microorganisms.

Mineralization: The complete degradation of an organic chemical to carbon dioxide, water, and in some cases inorganic ions.

Oxidization: Loss of electrons from a compound, such as an organic contaminant. The oxidation can supply energy that microorganisms use for growth. Often (but not always), oxidation results in the addition of an oxygen atom and/or the loss of a hydrogen atom.

Petroleum Hydrocarbon: A chemical derived from petroleum by various refining processes. Examples include gasoline, fuel oil and a wide range of chemicals used in manufacturing and industry.

Plume: A zone of dissolved contaminants. A plume usually originates from a source and extends for some distance in the direction of ground water flow.

Primary Substrates: The electron donor and electron acceptor that are essential to ensure the growth of microorganisms. These compounds can be viewed as analogous to the food and oxygen that are required for human growth.

Reduction: Transfer of electrons to a compound such as oxygen. It occurs when another compound is oxidized.

Reductive Dehalogenation: A variation on biodegradation in which microbially catalyzed reactions cause the replacement of a halogen atom (e.g., chlorine) on an organic compound with a hydrogen atom. The reactions result in the net addition of two electrons to the organic compound.

Saturated Zone: Subsurface environments where pore spaces are filled with water.

Sorption: Attachment of a substance on the surface of a solid by physical or chemical attraction.

Stabilization: Process whereby chemical molecules become chemically bound by a stabilizing agent (e.g., clay, humic materials), reducing the mobility of the molecule in the groundwater.

Substrate: A compound that microorganisms can use in the chemical reactions catalyzed by their enzymes.

Sulfate reducer: A microorganism that exists in anaerobic environments and reduces sulfate to hydrogen sulfide.

Surface to Volume Ratio: The surface area of an object relative to its volume.

Unsaturated Zone: Soil above the water table, where pores are partially or largely filled with air.

Vadose Zone: See "Unsaturated Zone."

Volatilization: Transfer of a chemical from the liquid to the gas phase (as in evaporation).

Appendix B
USEPA MNA Protocol

Table 2.1 Soil, Soil Gas, and Ground-water Analytical Methods to Evaluate the Potential for Natural Attenuation of Chlorinated Solvents or Fuel Hydrocarbons in Ground Water. Analyses other than those listed in this table may be required for regulatory compliance.

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Soil	Aromatic and Chlorinated hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]); Chlorinated Compounds	SW8260A		Data are used to determine the extent of soil contamination, the contamination mass present, and the potential for source removal.	Each soil sampling round	Sample volume approximately 100 ml; subsample and extract in the field using methanol or appropriate solvent; cool to 4°C.	Fixed-base Laboratory
Soil	Biologically Available Iron (III)	Under development	HCl extraction followed by quantification of released iron (III)	Optional method that should be used when fuel hydrocarbons or vinyl chloride are present in the ground water to predict the possible extent of removal of fuel hydrocarbons and vinyl chloride via iron reduction.	One round of sampling in five borings, five cores from each boring	Minimum 1 inch diameter core samples collected into plastic liner. Cap and prevent aeration.	Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	Procedure must be accurate over the range of 0.1 to 5 percent TOC	The rate of migration of petroleum contaminants in ground water is dependent upon the amount of TOC in the aquifer matrix.	At initial sampling	Collect 100 g of soil in a glass container with Teflon-lined cap; cool to 4°C.	Fixed-base
Soil Gas	Fuel and Chlorinated VOCs	EPA Method TO-14		Useful for determining chlorinated and BTEX compounds in soil	At initial sampling	1-liter Summa Canister	Fixed-base
Soil Gas	Methane, Oxygen, Carbon dioxide	Field Soil Gas Analyzer		Useful for determining bioactivity in vadose zone.	At initial sampling and respiration testing	3-liters in a Tedlar bag, bags are reusable for analysis of methane, oxygen, or carbon dioxide.	Field

Table 2.1 (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Alkalinity	Hach Alkalinity test kit model AL AP MG-L	Phenolphthalein method	General water quality parameter used (1) as a marker to verify that all site samples are obtained from the same ground-water system and (2) to measure the buffering capacity of ground water.	Each sampling round	Collect 100 mL of water in glass container.	Field
Water	Aromatic and chlorinated hydrocarbons (BTEX, trimethylbenzene isomers, chlorinated compounds)	SW8260A	Analysis may be extended to higher molecular weight alkyl benzenes	Method of analysis for BTEX and chlorinated solvents/byproducts, which are the primary target analytes for monitoring natural attenuation; method can be extended to higher molecular weight alkyl benzenes; trimethylbenzenes are used to monitor plume dilution if degradation is primarily anaerobic.	Each sampling round	Collect water samples in a 40 mL VOA vial; cool to 4°C; add hydrochloric acid to pH 2.	Fixed-base
Water	Arsenic	EPA 200.7 or EPA 200.9		To determine if anaerobic biological activity is solubilizing arsenic from the aquifer matrix material.	One round of sampling	Collect 100 ml in a glass or plastic container that is rinsed in the field with the ground water to be sampled. Unfiltered samples obtained using low flow sampling methods are preferred for analysis of dissolved metals. Adjust pH to 2 with nitric acid. Do not insert pH paper or an electrode into the sample.	Laboratory
Water	Chloride (optional, see data use)	Hach Chloride test kit model 8-P	Silver nitrate titration	As above, and to guide selection of additional data points in real time while in the field.	Each sampling round	Collect 100 mL of water in a glass container.	Field

Table 2.1 (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Chloride	Mercuric nitrate titration A4500-Cl ⁻ C	Ion chromatography (IC) method E300 or method SW9050 may also be used	General water quality parameter used as a marker to verify that site samples are obtained from the same ground-water system. Final product of chlorinated solvent reduction.	Each sampling round	Collect 250 mL of water in a glass container.	Fixed-base Laboratory
Water	Chloride (optional, see data use)	Hach Chloride test kit model 8-P	Silver nitrate titration	As above, and to guide selection of additional data points in real time while in the field.	Each sampling round	Collect 100 mL of water in a glass container.	Field
Water	Conductivity	E120.1/SW9050, direct reading meter		General water quality parameter used as a marker to verify that site samples are obtained from the same ground-water system.	Each sampling round	Collect 100 to 250 mL of water in a glass or plastic container.	Field
Water	Iron (II) (Fe ⁺²)	Colorimetric Hach Method # 8146	Filter if turbid.	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Each sampling round	Collect from a flow-through or over-flow cell / analyze at the well head.	Field
Water	Hydrogen (H ₂)	Equilibration with gas in the field. Determined with a reducing gas detector.	Optional specialized analysis	Determined terminal electron accepting process. Predicts the possibility for reductive dechlorination.	One round of sampling on selected wells.	Sampled at well head requires the production of 300 mL per minute of water for 30 minutes.	Field
Water	Manganese	EPA 200.7 or EPA 200.9		To determine if anaerobic biological activity is solubilizing manganese from the aquifer matrix material.	One round of sampling	Collect 100 ml in a glass or plastic container that is rinsed in the field with the ground water to be sampled. Unfiltered samples obtained using low flow sampling methods are preferred for analysis of dissolved metals. Adjust pH to 2 with nitric acid. Do not insert pH paper or an electrode into the sample.	Laboratory

Table 2.1 (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Methane, ethane, and ethene	Kampbell <i>et al.</i> , 1989 and 1998 or SW3810 Modified	Method published by researchers at the U.S. Environmental Protection Agency. Limited to few commercial labs.	The presence of CH ₄ suggests BTEX degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing biological transformation.	Each sampling round	Collect water samples in 50 mL glass serum bottles with gray butyl Teflon-faced septa and crimp caps; add H ₂ SO ₄ to pH less than 2, cool to 4°C.	Fixed-base Laboratory
Water	Nitrate	IC method E300		Substrate for microbial respiration if oxygen is depleted.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; add H ₂ SO ₄ to pH less than 2, cool to 4°C.	Fixed-base
Water	Oxidation-reduction potential	A2580B	Measurements made with electrodes; results are displayed on a meter; protect samples from exposure to oxygen. Report results against a silver/silver chloride reference electrode. (Eh) is calculated by adding a correction factor specific to the electrode used.	The ORP of ground water influences and is influenced by the nature of the biologically mediated degradation of contaminants; the ORP (expressed as Eh) of ground water may range from more than 800 mV to less than -400 mV.	Each sampling round	Measure in a flow through cell or an over-flowing container filled from the bottom to prevent exposure of the ground water to the atmosphere.	Field
Water	Oxygen	Dissolved oxygen meter calibrated between each well according to the supplier's specifications	Refer to method A4500 for a comparable laboratory procedure.	The oxygen concentration is a data input to the Bioplume model; concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Each sampling round	Measure dissolved oxygen on site using a flow-through cell or over-flow cell.	Field
Water	pH	Field probe with direct reading meter calibrated in the field according to the supplier's specifications.	Field	Aerobic and anaerobic biological processes are pH-sensitive.	Each sampling round	Measure dissolved oxygen on site using a flow-through cell or over-flow cell.	Field

Table 2.1 (Continued)

Matrix	Analysis	Method/Reference	Comments	Data Use	Recommended Frequency of Analysis	Sample Volume, Sample Container, Sample Preservation	Field or Fixed-Base Laboratory
Water	Sulfate (SO ₄ ²⁻)	IC method E300	If this method is used for sulfate analysis, do not use the field method.	Substrate for anaerobic microbial respiration.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C.	Fixed-base
Water	Sulfate (SO ₄ ²⁻)	Hach method # 8051	Colorimetric, if this method is used for sulfate analysis, do not use the fixed-base laboratory method.	Same as above.	Each sampling round	Collect up to 40 mL of water in a glass or plastic container; cool to 4°C.	Field
Water	Temperature	Field probe with direct reading meter.	Field only	To determine if a well is adequately purged for sampling.	Each sampling round	Read from oxygen meter.	Field
Water	Total Organic Carbon also called DOC	SW9060	Laboratory	Used to classify plume and to determine if reductive dechlorination is possible in the absence of anthropogenic carbon.	Each sampling round	Measure using a flow-through cell or over-flow cell.	Laboratory

NOTES:

1. "Hach" refers to the Hach Company catalog, 1990.
2. "A" refers to *Standard Methods for the Examination of Water and Wastewater*, 18th edition, 1992.
3. "E" refers to *Methods for Chemical Analysis of Water and Wastes*, U.S. EPA, 1983.
4. "SW" refers to the *Test Methods for Evaluating Solid Waste, Physical, and Chemical Methods*, SW-846, U.S. EPA, 3rd edition, 1986.

Table 2.2 Objectives for Sensitivity and Precision to Implement the Natural Attenuation Protocol. Analyses other than those listed in this table may be required for regulatory compliance.

Matrix	Analysis	Method/Reference	Minimum Limit of Quantification	Precision	Availability	Potential Data Quality Problems
Soil	Aromatic and chlorinated hydrocarbons (benzene, toluene, ethylbenzene, and xylene [BTEX]; chlorinated compounds)	SW8260A	1 mg/Kg	Coefficient of Variation of 20 percent.	Common laboratory analysis.	Volatiles lost during shipment to laboratory; prefer extraction in the field.
Soil	Biologically Available Iron (III)	Under development	50 mg/Kg	Coefficient of Variation of 40 percent.	Specialized laboratory analysis.	Sample must not be allowed to oxidize.
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	0.1 percent	Coefficient of Variation of 20 percent.	Common laboratory analysis.	Samples must be collected from contaminant-transporting (i.e., transmissive) intervals.
Soil Gas	Fuel and Chlorinated VOCs	EPA Method TO-14	1 ppm (volume/volume)	Coefficient of Variation of 20 percent.	Common laboratory analysis.	Potential for atmospheric dilution during sampling.
Soil Gas	Methane, O ₂ , CO ₂	Field Soil Gas Analyzer	1 percent (volume/volume)	Coefficient of Variation of 20 percent.	Readily available field instrument.	Instrument must be properly calibrated.
Water	Alkalinity	Hach alkalinity test kit model AL AP MG-L	50 mg/L	Standard deviation of 20 mg/L.	Common field analysis.	Analyze sample within 1 hour of collection.
Water	Aromatic and chlorinated hydrocarbons (BTEX, trimethylbenzene isomers, chlorinated compounds)	SW8260A	MCLs	Coefficient of Variation of 10 percent.	Common laboratory analysis.	Volatilization during shipment and biodegradation due to improper preservation.
Water	Chloride	IC method E300	1 mg/L	Coefficient of Variation of 20 percent.	Common laboratory analysis.	----
Water	Chloride (optional, see data use)	Hach Chloride test kit model 8-P	1 mg/L	Coefficient of Variation of 20 percent.	Common field analysis.	Possible interference from turbidity.
Water	Conductivity	E120.1/SW9050, direct reading meter	50 μ S/cm ²	Standard deviation of 50 μ S/cm ² .	Common field probe.	Improperly calibrated instrument.

Table 2.2 (Continued)

Matrix	Analysis	Method/Reference	Minimum Limit of Quantification	Precision	Availability	Potential Data Quality Problems
Water	Hydrogen (H ₂) ^v	See Appendix A	0.1 nM	Standard deviation of 0.1nM.	Specialized field analysis.	Numerous, see Appendix A.
Water	Iron (II) (Fe ²⁺) XX	Colorimetric Hach Method # 8146	0.5 mg/L	Coefficient of Variation of 20 percent.	Common field analysis.	Possible interference from turbidity (must filter if turbid). Keep out of sunlight and analyze within minutes of collection.
Water	Major Cations	SW6010	1 mg/L	Coefficient of Variation of 20 percent.	Common laboratory analysis.	Possible colloidal interferences.
Water	Methane, ethane, and ethene	Kampbell <i>et al.</i> , 1989 or SW3810 Modified	1 µg/L	Coefficient of Variation of 20 percent.	Specialized laboratory analysis.	Sample must be preserved against biodegradation and collected without headspace (to minimize volatilization). Must be preserved.
Water	Nitrate	IC method E300	0.1 mg/L	Standard deviation of 0.1 mg/L	Common laboratory analysis.	Must be preserved.
Water	Oxidation-reduction potential (ORP)	A2580B	plus or minus 300 mV	plus or minus 50 mV.	Common field probe.	Improperly calibrated electrodes or introduction of atmospheric oxygen during sampling.
Water	Oxygen	Dissolved oxygen meter	0.2 mg/L	Standard deviation of 0.2 mg/L.	Common field instrument.	Improperly calibrated electrodes or bubbles behind the membrane or a fouled membrane or introduction of atmospheric oxygen during sampling.
Water	Sulfate (SO ₄ ²⁻)	IC method E300	5 mg/L	Coefficient of Variation of 20 percent.	Common laboratory.	Fixed-base.
Water	Sulfate (SO ₄ ²⁻) XX	Hach method # 8051	5 mg/L	Coefficient of Variation of 20 percent.	Common field analysis.	Possible interference from turbidity (must filter if turbid). Keep sample cool.
Water	pH	Field probe with direct reading meter.	0.1 standard units	0.1 standard units.	Common field meter.	Improperly calibrated instrument; time sensitive.
Water	Temperature	Field probe with direct reading meter.	0 degrees Celsius	Standard deviation of 1 degrees Celsius.	Common field probe.	Improperly calibrated instrument; time sensitive.
Water	Total Organic Carbon	SW9060	0.1 mg/L	Coefficient of Variation of 20 percent.	Common laboratory analysis.	

Notes:

** Filter if turbidity gives a response from the photometer before addition of the reagents that is as large or larger than the specified minimum quantification limit.

Table 2.3 Analytical Parameters and Weighting for Preliminary Screening for Anaerobic Biodegradation Processes^{a/}

Analysis	Concentration in Most Contaminated Zone	Interpretation	Value
Oxygen*	<0.5 mg/L	Tolerated, suppresses the reductive pathway at higher concentrations	3
Oxygen*	>5 mg/L	Not tolerated; however, VC may be oxidized aerobically	-3
Nitrate*	<1 mg/L	At higher concentrations may compete with reductive pathway	2
Iron II*	>1 mg/L	Reductive pathway possible; VC may be oxidized under Fe(III)-reducing conditions	3
Sulfate*	<20 mg/L	At higher concentrations may compete with reductive pathway	2
Sulfide*	>1 mg/L	Reductive pathway possible	3
Methane*	<0.5 mg/L	VC oxidizes	0
	>0.5 mg/L	Ultimate reductive daughter product, VC Accumulates	3
Oxidation Reduction Potential* (ORP) against Ag/AgCl electrode	<50 millivolts (mV)	Reductive pathway possible	1
	<-100mV	Reductive pathway likely	2
pH*	5 < pH < 9	Optimal range for reductive pathway	0
	5 > pH >9	Outside optimal range for reductive pathway	-2
TOC	> 20 mg/L	Carbon and energy source; drives dechlorination; can be natural or anthropogenic	2
Temperature*	> 20°C	At T >20°C biochemical process is accelerated	1
Carbon Dioxide	>2x background	Ultimate oxidative daughter product	1
Alkalinity	>2x background	Results from interaction between CO ₂ and aquifer minerals	1
Chloride*	>2x background	Daughter product of organic chlorine	2
Hydrogen	>1 nM	Reductive pathway possible, VC may accumulate	3
Hydrogen	<1 nM	VC oxidized	0
Volatile Fatty Acids	> 0.1 mg/L	Intermediates resulting from biodegradation of more complex compounds; carbon and energy source	2
BTEX*	> 0.1 mg/L	Carbon and energy source; drives dechlorination	2
Tetrachloroethene		Material released	0
Trichloroethene*		Material released	0
		Daughter product of PCE	2 ^{a/}
DCE*		Material released	0
		Daughter product of TCE	2 ^{a/}
		If cis is > 80% of total DCE it is likely a daughter product	
		1,1-DCE can be chemical reaction product of TCA	
VC*		Material released	0
		Daughter product of DCE	2 ^{a/}
1,1,1-Trichloroethane*		Material released	0
DCA		Daughter product of TCA under reducing conditions	2
Carbon Tetrachloride		Material released	0
Chloroethane*		Daughter product of DCA or VC under reducing conditions	2
Ethene/Ethane	>0.01mg/L	Daughter product of VC/ethene	2
	>0.1 mg/L		3
Chloroform		Material released	0
		Daughter product of Carbon Tetrachloride	2
Dichloromethane		Material released	0
		Daughter product of Chloroform	2

* Required analysis. a/ Points awarded only if it can be shown that the compound is a daughter product (i.e., not a constituent of the source NAPL).

Table 2.4 Interpretation of Points Awarded During Screening Step 1

Score	Interpretation
0 to 5	Inadequate evidence for anaerobic biodegradation* of chlorinated organics
6 to 14	Limited evidence for anaerobic biodegradation* of chlorinated organics
15 to 20	Adequate evidence for anaerobic biodegradation* of chlorinated organics
> 20	Strong evidence for anaerobic biodegradation* of chlorinated organics

**reductive dechlorination*

The following two examples illustrate how Step 1 of the screening process is implemented. The site used in the first example is a former fire training area contaminated with chlorinated solvents mixed with fuel hydrocarbons. The presence of the fuel hydrocarbons appears to reduce the ORP of the ground water to the extent that reductive dechlorination is favorable. The second example contains data from a dry cleaning site contaminated only with chlorinated solvents. This site was contaminated with spent cleaning solvents that were dumped into a shallow dry well situated just above a well-oxygenated, unconfined aquifer with low organic carbon concentrations of dissolved organic carbon.

Example 1: Strong Evidence for Anaerobic Biodegradation (Reductive Dechlorination) of Chlorinated Organics

Analyte	Concentration in Most Contaminated Zone	Points Awarded
Dissolved Oxygen	0.1 mg/L	3
Nitrate	0.3 mg/L	2
Iron (II)	10 mg/L	3
Sulfate	2 mg/L	2
Methane	5 mg/L	3
ORP	-190 mV	2
Chloride	3 times background	2
PCE (released)	1,000 µg/L	0
TCE (none released)	1,200 µg/L	2
cis-DCE (none released)	500 µg/L	2
VC (none released)	50 µg/L	2
Total Points Awarded		23 Points

In this example, the investigator can infer that biodegradation is likely occurring at the time of sampling and may proceed to Step 2.

Example 2: Anaerobic Biodegradation (Reductive Dechlorination) Unlikely

Analyte	Concentration in Most Contaminated Zone	Points Awarded
Dissolved Oxygen	3 mg/L	-3
Nitrate	0.3 mg/L	2
Iron (II)	Not Detected (ND)	0
Sulfate	10 mg/L	2
Methane	ND	0
ORP	+ 100 mV	0
Chloride	background	0
TCE (released)	1,200 µg/L	0
cis-DCE (none released)	ND	0
VC (none released)	ND	0
Total Points Awarded		1 Point

Appendix C
Field Geochemistry Data
Lab Geochemical Analysis

Field Geochemistry Data

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID:

386510

Site:

38

Date:

6 May 99

Field Personnel:

Phil Hardy, Barbara Afbrecht

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1100	0.31	YSI
DO (titration)	1110	0.17	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1100	⊖ 327.2	Orion
Redox Meter #2	1100	out of range	ORP Testr
Redox Meter #3	1100	⊖ 200	Hanna

Temperature (from GW Quality) =

Hach 210 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1155	0.01	
Total Iron	1140	0.008	
Sulfide	1205	average / 5mls = 0.218	
Sulfate	1227	⊖ 10	under range

450-4655

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1135	120	
Alkalinity	1220	120	

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID:
384502

Site:
38

Date:
6 May 99

Field Personnel:
Phil Hardy, Barbara Adcock

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1115	0.11	YSI
DO (titration)	1130	0.00	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1115	⊖ 345.7	Orion
Redox Meter #2	1115	out of Range	ORP Testr
Redox Meter #3	1115	⊖ 256	Hanna

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1157	0.10	
Total Iron	1147	0.085	
Sulfide	1210	average / Sulf = 0.283	
Sulfate	1229	1.0	

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1140	30+ Drops + sample would not titrate to orange.	
Alkalinity	1225	160	

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID:

38 65 28

Site:

38

Date:

6 May 99

Field Personnel:

Phil Hardy, Barbara Albrecht

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	0915	0.47	VSE
DO (titration)	1042	0.22	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	0915	148.4	ORion
Redox Meter #2	0915	80	ORP Tester
Redox Meter #3	0915	45	Hanna

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1036	0.06	
Total Iron	1102	0.050	
Sulfide	1046	0.001	
Sulfate	1052	45	

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1035	70	
Alkalinity	1041	120	

**FIELD DATA RECORDING FORM
 NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59**

Sample ID:
38GS19

Site: Site 38
Bldg 604

Date: 5/5/99

Field Personnel: RB,
BA,
PH

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	11:30	2.40	YSE
DO (titration)	11:50	1.39	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1		+209.5	anom
Redox Meter #2		+114	Hanna
Redox Meter #3		+5.	meter not reading accurately

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1145	0.01	
Total Iron	1205	0.003	Under range.
Sulfide	1150	0.001	
Sulfate	1158	25	Cloudy

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1142	20	
Alkalinity	1155	100	

**FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
NAS Pensacola
Site 38 - CTO 59**

Sample ID:
38 GS20

Site: 38
Bldg 604

Date: 5/5/99

Field Personnel:

RB
BA
PH

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1200	0.45	YSZ
DO (titration)	1215	0.00	winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1200	⊖ 305	Orian
Redox Meter #2	1205	⊖ 213	Hanna
Redox Meter #3			

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1218	0.12	
Total Iron	1214	0.145	
Sulfide	1226	over range / 0.088	retested w/ 5ml sample
Sulfate	1235	15	

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1210	25	
Alkalinity	1225	80	

FIELD DATA RECORDING FORM
 NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

DT. 3.73

Sample ID: 38-6512 Site: 38 Date: 5 May 99 Field Personnel: Phil Hardy, Ronnie Britto, Barbara Amrocht

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	0830	0.49 mg/L	YSZ-
DO (titration)	0855	0.00	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	0830	-291.8	YSZ Orion
Redox Meter #2	0835	-217	Hanna
Redox Meter #3	0835	off limits	ORP

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	0845	0.06	
Total Iron		0.039	
Sulfide	0850	over-range / 0.306	1st sample, over range - ve ran 1w/ 5 mls + 20 mls DT
Sulfate	0900	21	

Individual Tests

	Time	Reading (mg/L)	Remarks
Chloride	0950	75	
Alkalinity	0955	160	

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID:

38-6503

Site:

38

Date:

5 May 99

Field Personnel:

PH, RB, BA

Dissolved Oxygen (DO) Measurement

	Time	Reading (mg/L)	Remarks
DO (direct)	0850	0.28	YSE
DO (titration)	0900	0.00	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement

	Time	Reading (mV)	Remarks
Redox Meter #1	0850	-262	Orion
Redox Meter #2	0850	-176	Hanna
Redox Meter #3		out of range	ORP

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests

	Time	Reading (mg/L)	Remarks
Ferrous Iron	1010	0.11	
Total Iron	1000	0.111	
Sulfide	1015	0.282	
Sulfate	1020	23	cloudy

Individual Tests

	Time	Reading (mg/L)	Remarks
Chloride	0955	150	
Alkalinity	1000	120	

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Observers R. Joiner, BK +
 P. Hill

Sample ID:
 0386-9501-03

Site:
 38

Date:
 4 May 99

Field Personnel:
 Phil Hardy, Barbara Albrecht,
 Ronnie Brito

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1050 1145	0.71 0.84	YSP
DO (titration)	1150	0.38	W. wheel

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1050	Ⓢ 715 +79	Orion 290A
Redox Meter #2	1100	+5.0	ORP Tester
Redox Meter #3	1103	+83	Hanna

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1220	0.00	
Total Iron	1415 1445	0.00 0.000 PA	
Sulfide	1415	0.000	
Sulfate	1430	9	

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1200	35	
Alkalinity	1205	100	

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID:
 038G-6506-204

Site:
 38

Date:
 May 4, 1999

Field Personnel:
 Phil Herdy, Ronnie Ritho
 Bob Albrecht

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1110	0.60 6.9 → 5.6	Y81
DO (titration)	1155	0.78	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1110	+277 +74.9	Olium 290 K
Redox Meter #2		+100	
Redox Meter #3		+83	

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1400	0.01	
Total Iron	1425 1445	0.01 0.004	
Sulfide	1425	0.1	
Sulfate	1435	22.0	Cloudy

Individual Tests

	Time	Reading (mg/L)	Remarks
Chloride	1205	40	
Alkalinity		120	

**FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
NAS Pensacola
Site 38 - CTO 59**

Sample ID: 38GS17 Site: ³⁸Bldg 604 Date: 5/5/99 Field Personnel: RBS, B.A, PH

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1440	0.36	YSZ
DO (titration)	1440	0.32 0.00	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1440	⊖ 324.8	
Redox Meter #2	1440	out of range	ORP Testr
Redox Meter #3	1440	⊖ 218	Hanna

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1455	0.03	
Total Iron	1535	0.011	
Sulfide	1515	1st Sample over range, 2nd Sample over range. 1st = 25 mL, 2nd = 5 mL, 3rd = 2 mL = 0.443	
Sulfate	1520	16	

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1455	55	
Alkalinity	1508	220	

* Note H₂S odor present

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID: **38G508** Site: **38** Date: **5/5/99** Field Personnel: **RB**
Bldg 604 **BA**
PH

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1530	0.36	YSZ
DO (titration)	1555	0.51	winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1530	⊕ 157.3	Orion
Redox Meter #2	1515	-30	ORP Tester
Redox Meter #3	1516	-001	Hanna

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1557	0.00	
Total Iron	1550	0.010	
Sulfide	1604	0.000	
Sulfate	1610	22	

Individual Tests

	Time	Reading (mg/L)	Remarks
Chloride	1545	55	
Alkalinity	1600	100	

FIELD DATA RECORDING FORM
NATURAL ATTENUATION FIELD PARAMETER EVALUATION
 NAS Pensacola
 Site 38 - CTO 59

Sample ID: 38GS32 Site: 38 Date: 6 May 29 Field Personnel: Phil Hardy, Barbara Atwood

Dissolved Oxygen (DO) Measurement			
	Time	Reading (mg/L)	Remarks
DO (direct)	1500	0.12	YSI
DO (titration)	1610	0.17	Winkler

pH (from GW Quality) =

Oxidation-Reduction Potential Measurement			
	Time	Reading (mV)	Remarks
Redox Meter #1	1500	⊖ 114.5	Orion
Redox Meter #2	1500	⊖ 080	Hanna
Redox Meter #3	1500	Out of Range	ORP Tester

Temperature (from GW Quality) =

Hach 2010 Spectrophotometer Tests			
	Time	Reading (mg/L)	Remarks
Ferrous Iron	1602	0.15	
Total Iron		0.510	
Sulfide	1610	0.004	
Sulfate	1618	25	

Individual Tests			
	Time	Reading (mg/L)	Remarks
Chloride	1600	60	
Alkalinity	1605	140	

ENS1-992650

----- ENSAFE -----

Sample Names	Carbon Dioxide mg/l	Hydrogen nM	Lab ID	Date Sampled	Date Received	Date Analyzed	Analyst
38GS17-03	60.76	5.60	T20 100	05/05/99	05/10/99	05/17/99	BC
38GS03-03	34.40	2.50	T20 101	05/05/99	05/10/99	05/17/99	BC
38GS19-03	---	0.50	T20 102	05/05/99	05/10/99	05/17/99	BC
38GS20-03	5.86	3.11	T20 103	05/05/99	05/10/99	05/17/99	BC
38GS12-03	23.06	1.94	T20 104	05/05/99	05/10/99	05/17/99	BC
38GS28-03	43.55	0.67	T20 105	05/06/99	05/10/99	05/17/99	BC
38GS02-03	---	1.34	T20 106	05/06/99	05/10/99	05/17/99	BC
38GS06-03	---	0.75	T20 107	05/06/99	05/10/99	05/17/99	BC
38GS32-03	9.52	0.73	T20 108	05/06/99	05/10/99	05/17/99	BC
38GS10-03	---	1.34	T20 109	05/06/99	05/10/99	05/17/99	BC
38GS08-03	---	0.90	T20 110	05/05/99	05/10/99	05/17/99	BC

DETECTION LIMITS 0.60mg/l 0.03nM

ANALYST *JK*

REVIEW *mb*

Microseeps

***** QUALITY CONTROL *****

ENS1-992650

--- ENSAFE ---

CONTINUING CALIBRATION STANDARDS 05/17/99

HE IN LOOP 05/17/99

COMPOUND	FILE ID	TRUE CONC.	MEASURED	% DIFF.
CARBON DIOXIDE	T20 94	7.50	6.84	8.80
HYDROGEN	T20 92	12.25	11.66	4.82

COMPOUND	FILE ID	DET. LIMIT	MEASURED
CARBON DIOXIDE	T20 96	0.60mg/l	ND
HYDROGEN	T20 96	0.03nM	ND

ANALYST INITIALS AB

REVIEW slg.

992650- EPS-1

MICROSEEPS, Inc.

220 William Pitt Way, Pittsburgh, PA 15238

Phone: (412) 826-5245 Fax: (412) 826-3433

CHAIN-OF-CUSTODY RECORD

Analysis Options Note: Enter proper letters in Requested Analytes columns below.
 Note: If analysis D,E, or K is selected, scratch (option) NOT wanted.

* A	C1 - C4	G	Chlorinated HC
* B	Hydrogen & Helium	H	BTEX
* C	Permanent Gases (CH4, CO, CO2, N2, O2)	J	BTEX & C5 - C10
D	Mercury (Soil) or (Air **)	K	TPH (C5 - C10) or (C4 - C12)
E	TO-14 by GC/MS (Ambient) or (Source **)	L	C11 - C18
F	601 & 602 Compounds	Other	Specify below.

* An additional 22 ml vial of sample is required when requested in combination with another analysis.
 ** Available upon request.

Company Name: ENSURE
 Address: _____
 Proj. Manager: Allison Danner-Harris / Ronnie Britto
 Proj. Location: _____
 Proj. Number: _____
 Phone #: 901-372-7962 Fax #: 901-372-2454
 Sampler's signature: [Signature]

Collection Date	Time	Number of Containers	"Summa" # if Can. used	Sample Type	Sample Identification	Requested Analytes (Other)		Remarks
						CO2	H2	
5 May 99	1510	1			38GS17-03	CO2	H2	
5 May 99	-	1			38GS03-03	CO2	H2	
5 May 99	1135	1			38GS19-03	-	H2	
5 May 99	1200	1			38GS20-03	CO2	H2	
5 May 99	0920	1			38GS12-03	CO2	H2	
6 May 99	0945	1			38GS28-03	CO2	H2	
6 May 99	-	1			38GS02-03	-	H2	
6 May 99	1630	1			38GS06-03	-	H2	
6 May 99	1510	1			38GS032-03	CO2	H2	
6 May 99	-	1			38GS10-03	-	H2	
5 May 99	-	1			38GS08-03	-	H2	

Invoice to:

Results to: Allison Danner-Harris + Ronnie Britto
ENSURE 5724 Summer Trees Drive, Memphis, TN 38134

Relinquished by:	Company:	Date:	Time:
<u>Barbara Albrecht</u>	<u>ENSURE</u>	<u>7 May 99</u>	
Relinquished by:	Company:	Date:	Time:
Relinquished by:	Company:	Date:	Time:

Lab Geochemical Analysis

PENSACOLA, SITE 38
PENSACOLA, SITE 38 NATURAL ATTENUATION

METHANE	SAMPLE ID ORIGINAL ID LAB SAMPLE ID ID FROM REPORT SAMPLE DATE DATE ANALYZED MATRIX UNITS	038-G-GS01-03 038GG0103 S912852*1 038GG0103 05/04/99 05/18/99 Water UG/L	038-G-GS02-03 038GG0203 S912939*3 038GG0203 05/07/99 05/18/99 Water UG/L	038-G-GS03-03 038GG0303 S912892*2 038GG0303 05/05/99 05/18/99 Water UG/L	038-G-GS06-03 038GG0603 S912852*2 038GG0603 05/04/99 05/18/99 Water UG/L	038-G-GS08-03 038GG0803 S912892*5 038GG0803 05/05/99 05/19/99 Water UG/L	038-G-GS10-03 038GG1003 S912939*2 038GG1003 05/07/99 05/18/99 Water UG/L
CAS #	Parameter	NASPO3	NASPO3	NASPO3	NASPO3	NASPO3	NASPO3
74-82-8	METHANE	47. U	360.	330.	47. U	47. U	580.

PENSACOLA, SITE 38
PENSACOLA, SITE 38 NATURAL ATTENUATION

METHANE	SAMPLE ID ORIGINAL ID LAB SAMPLE ID ID FROM REPORT SAMPLE DATE DATE ANALYZED MATRIX UNITS	038-G-GS12-03 038GGG1203 S912892*1 038GGG1203 05/05/99 05/18/99 Water UG/L	038-G-GS17-03 038GGG1703 S912892*6 038GGG1703 05/05/99 05/19/99 Water UG/L	038-G-GS19-03 038GGG1903 S912892*3 038GGG1903 05/05/99 05/18/99 Water UG/L	038-G-GS20-03 038GGG2003 S912892*4 038GGG2003 05/05/99 05/19/99 Water UG/L	038-G-GS28-03 038GGG2803 S912939*1 038GGG2803 05/06/99 05/18/99 Water UG/L	038-G-GS32-03 038GGG3203 S912939*4 038GGG3203 05/06/99 05/18/99 Water UG/L
			5300.	47. U	1700.	460.	210.
CAS #	Parameter						
74-82-8	METHANE						

PENSACOLA, SITE 38
PENSACOLA, SITE 38 NATURAL ATTENUATION

PARAMETER	SAMPLE ID ORIGINAL ID LAB SAMPLE ID ID FROM REPORT SAMPLE DATE DATE ANALYZED MATRIX UNITS	BLK-0-SP03-02 MBLANK1 S9NASP03*1 MBLANK1 05/19/99 Water UG/L	BLK-0-SP03-04 MBLANK2 S9NASP03*4 MBLANK2 05/18/99 Water UG/L				
CAS #	Parameter	NASPO3	NASPO3				
74-82-8	METHANE	47. U	47. U				

PENSACOLA, SITE 38
PENSACOLA, SITE 38 NATURAL ATTENUATION

TOC	SAMPLE ID -----> ORIGINAL ID -----> LAB SAMPLE ID -----> ID FROM REPORT -----> SAMPLE DATE -----> DATE EXTRACTED -----> DATE ANALYZED -----> MATRIX -----> UNITS ----->	038-G-GS02-03 038GGS0203 S912977*4 038GGS0203 05/07/99 05/12/99 05/12/99 Water MG/L	038-G-GS10-03 038GGS1003 S912977*3 038GGS1003 05/07/99 05/12/99 05/12/99 Water MG/L	038-G-GS17-03 038GGS1703 S912977*1 038GGS1703 05/07/99 05/12/99 05/12/99 Water MG/L	038-G-GS20-03 038GGS2003 S912977*2 038GGS2003 05/07/99 05/12/99 05/12/99 Water MG/L	BLK-D-SP03-02 MBLANK1 S9NASP03*1 MBLANK1 05/12/99 05/12/99 Water MG/L	CAS # Parameter 9999900-01-4 Total Organic Carbon (TOC)				
		NASPO3	NASPO3	NASPO3	NASPO3	NASPO3	1.6	2.3	29.	3.9	1. U