U.S. ARMY ENGINEER DIVISION
HUNTSVILLE, ALABAMA

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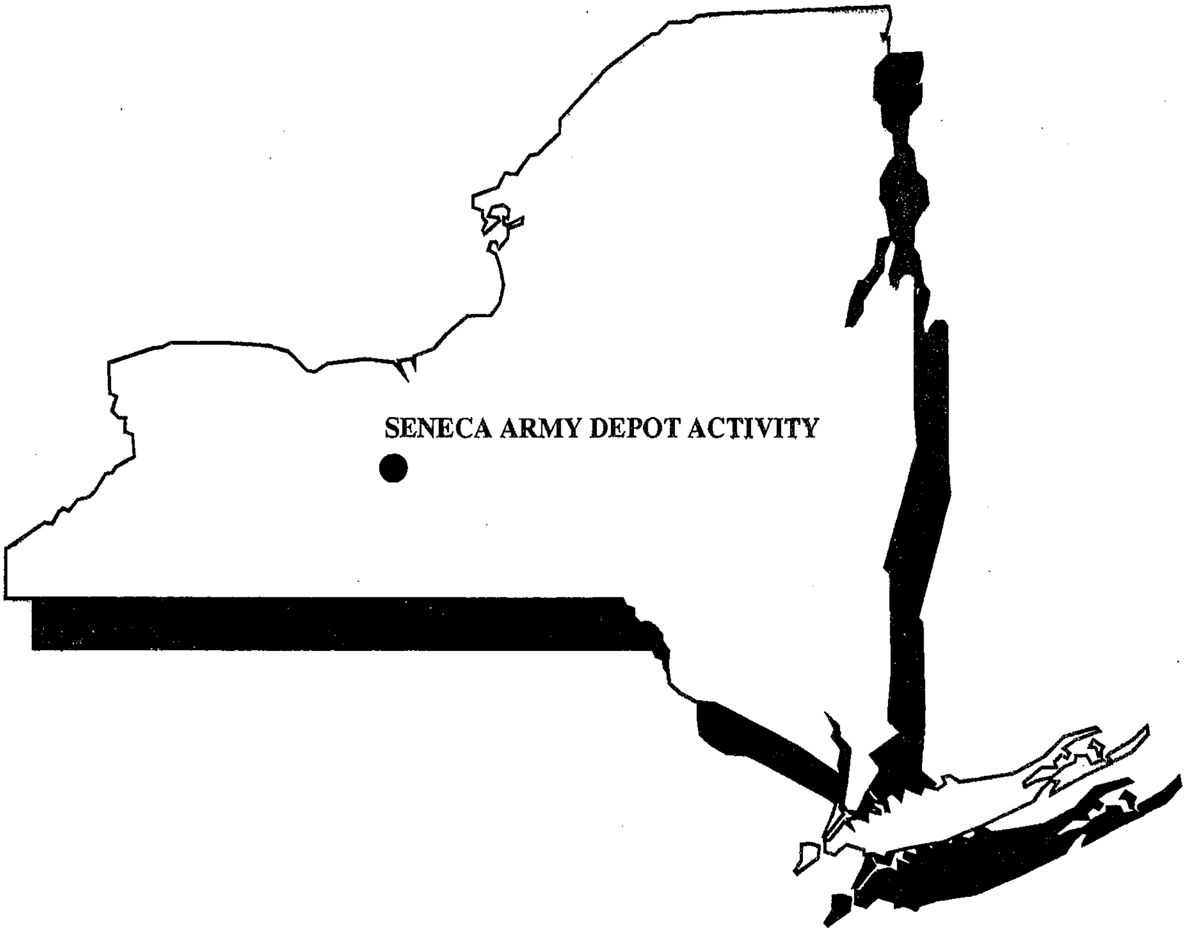

ASH LANDFILL

TREATABILITY STUDY WORK PLAN FOR ZERO VALENCE IRON CONTINUOUS REACTIVE WALL AT THE ASH LANDFILL

CONTRACT NO. DACA87-92-D-0022
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FEBRUARY 1999

GROUNDWATER TREATABILITY STUDY WORK PLAN FOR ZERO VALENCE IRON CONTINUOUS REACTIVE WALL AT THE ASH LANDFILL

SENECA ARMY DEPOT ACTIVITY
ROMULUS, NEW YORK

726209 February 1999

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APPENDICES

1.0 INTRODUCTION

This treatability study work plan presents the scope of the pilot-scale study for the Groundwater Treatability Study Using A Zero Valence Iron Continuous Reactive Wall at the Ash Landfill at Seneca Army Depot Activity. The primary objective of the study is to assess the effectiveness of zero valence iron in reducing the chlorinated solvents present in the groundwater at this site. If this technology is shown to be successful, the information gathered during this study will be used to support the Feasibility Study for the Ash Landfill site. This work plan is organized as follows:

Section 2 - Site Background
Section 3 - Rationale for Conducting a Treatability Study on the Continuous Reactive Wall
Section 4 - Continuous Reactive Wall Design for Treatability Study
Section 5 - Monitoring Plan
Section 6 - Investigation Derived Wastes
Section 7 - SEDA Support Requirements
Section 8 - Points of Contact
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2.0 SITE BACKGROUND

2.1 Site Location

SEDA is an active military facility constructed in 1941. The site is located approximately 40 miles south of Lake Ontario, near Romulus, New York as shown in Figure 1A. The facility is located in an uplands area, at an elevation of approximately 600 feet Mean Sea Level (MSL), that forms a divide separating two of the New York Finger Lakes, Cayuga Lake on the east and Seneca Lake on the west. Sparsely populated farmland covers most of the surrounding area. New York State Highways 96 and 96A adjoin SEDA on the east and west boundaries, respectively. Since its inception in 1941, SEDA's primary mission has been the receipt, storage, maintenance, and of military items. The Ash Landfill site encompasses approximately 130 acres of the 10,587 acre SEDA. Figure 1B presents a plan view of SEDA and identifies the location of the Ash Landfill site. The Ash Landfill site consists of an abandoned incinerator building and tower (Building 2207), a former cooling pond, an ash landfill, and a nearby Non-Combustible Fill Landfill (NCFL) as shown in Figure 1. The site is bounded on the north by Cemetery Road, on the east by a SEDA railroad line, on the south by undeveloped SEDA land, and on the west by the depot's boundary. Beyond the depot's western boundary are farmland and residences on Smith Farm Road and along Route 96A. Sampson State Park on the shore of Seneca Lake is located immediately to the west of Route 96A.

The Ash Landfill was previously used by the Army for disposal of ash generated from the incineration of solid waste (trash) produced at the depot. The NCFL is located east of the incinerator building on the south side of West Smith Farm Road. This landfill was the repository of materials that could not be burned in the incinerator.

2.2 Site History

SEDA was constructed in 1941 and has been owned by the United States Government and operated by the Department of the Army since this time. Prior to construction of the depot, the site was used for farming. From 1941 to 1974, uncontaminated trash was burned in a series of burn pits near the abandoned incinerator building (Building 2207). According to a U.S. Army Environmental Hygiene Agency (USAEHA) Interim Final Report, Groundwater Contamination Survey No. 38-26-0868-88 (July 1987), during approximately this same period of time (1941 until the late 1950's or early 1960's) the ash from the refuse burning pits was buried in the landfill.

The incinerator building was built in 1974. Between 1974 and 1979, materials intended for disposal were transported to the incinerator. The incinerator was a multiple chamber, batch-fed 2,000 pound per hour capacity unit which burned rubbish and garbage. The incinerator unit contained an automatic ram-type feeder, a refractory lined furnace with secondary combustion and settling chamber, a reciprocating stoker, a residue conveyor for ash removal, combustion air fans, a wet gas scrubber, an induced draft fan, and a refractory-lined stack (USAEHA, 1975). Nearly all of the approximately 18 tons of refuse generated per week on the depot were incinerated. The source for the refuse was domestic waste from depot activities and family housing. Large items which could not be burned were disposed of at the NCFL.

Ashes and other residues from the incinerator were temporarily disposed in an unlined cooling pond immediately north of the incinerator building. The cooling pond consisted of an unlined depression approximately 50 feet in diameter and approximately 6 to 8 feet deep. When the pond filled (approximately every 18 months), the fly ash and residues were removed, transported, and buried in the adjacent landfill east of the cooling pond. The refuse was dumped in piles and occasionally spread and compacted. No daily or final cover was applied. The active area of the Ash Landfill extended at least 500 feet north at the incinerator building, near a bend in a dirt road, based on an undated aerial photograph of the incinerator during operation. Parallel grooves at the northernmost extent of the filled area are visible in the aerial view of the incinerator and adjacent fill area during active operation and indicate that the fill was spread using a bulldozer or similar equipment. The incinerator was destroyed by a fire on May 8, 1979, and the landfill was subsequently closed. The landfill was apparently covered with native soils of various thicknesses but has not been closed with an engineered cover or cap.

A grease pit disposal area near the eastern boundary of the site was used for disposal of cooking grease. Evidence of burning of debris during the operation of the incinerator includes areas of blackened soil, charred debris and areas of stressed or dead vegetation.

The approximately 2-acre NCFL southeast of the incinerator building (immediately south of the SEDA railroad line) was used as a disposal site for non-combustible materials including construction debris from 1969 until 1977.

2.3 Site Geology

The site is underlain by a broad north-to-south trending series of rock terraces mantled by glacial till. As part of the Appalachian Plateau, the region is underlain by a tectonically undisturbed sequence of Paleozoic rocks consisting of shales, sandstones, conglomerates, limestones and dolostones.

The Hamilton Group, which underlies the site, is 600 to 1500 feet thick, and is divided into four formations. They are, from oldest to youngest, the Marcellus, Skaneateles, Ludlowville, and Moscow formations. The western portion of SEDA is generally located in the Ludlowville Formation while the eastern portion is located in the younger Moscow Formation. The Ludlowville and Moscow formations are characterized by gray, calcareous shales and mudstones and thin limestones with numerous zones of abundant invertebrate fossils that form geographically widespread encrinites, coral-rich layers, and complex shell beds. In contrast, the lower two formations (Skaneateles and Marcellus) consist largely of black and dark gray sparsely fossiliferous shales (Brett et al., 1991). Locally, the shale is soft, gray, and fissile.

Pleistocene age (Late Wisconsin age, 20,000 years bp) glacial till deposits overlie the shales. The till matrix, the result of glaciation, varies locally but generally consists of horizons of unsorted silt, clay, sand, and gravel. The soils at the site contain varying amounts of inorganic clays, inorganic silts, and silty sands. In the central and eastern portions of SEDA the till is thin and bedrock is exposed or within 3 feet of the surface in some locations. Thickness of the glacial till deposits at SEDA generally ranges from 1 to 15 feet. At the proposed location of the continuous reactive wall system, the thickness of the glacial till and weathered shale is approximately 10 feet.

Darien silt-loam soils, 0 to 18 inches thick, have developed over Wisconsin age glacial tills. These soils are developed on glacial till where they overlie the shale. In general, the topographic relief associated with these soils is 3 to 8 percent.

Regionally, four distinct hydrologic units have been identified within Seneca County (Mozola A.J., 1951). These include two distinct shale formations, a series of limestone units, and unconsolidated beds of Pleistocene glacial drift. Overall, the groundwater in the county is very hard, and therefore, the quality is minimally acceptable for use as potable water. The water table aquifer of the unconsolidated surficial glacial deposits of the region would be expected to flow in a direction consistent with the ground surface elevations. Geologic cross-sections from Seneca Lake and Cayuga Lake have been constructed by the State of New York, (Mozola, 1951, and Crain, 1974). This information suggests that a groundwater divide exists approximately halfway between the two finger lakes. SEDA is located on the western slope of this divide and therefore regional surficial groundwater flow is expected to be westward toward Seneca Lake.

The geologic information reviewed indicates that the upper portions of the shale formation would be expected to yield small, yet adequate, supplies of water for domestic use. For mid-Devonian shales such as those of the Hamilton group, the average yields, (which are less than 15 gpm), are consistent with what would be expected for shales (LaSala, 1968). The deeper portions of the bedrock, (at depths greater than 235 feet) have provided yields up to 150 gpm. At these depths, the high well-yields may be attributed to the effect of solution on the Onondaga limestone, which is at the base of the Hamilton Group. Based on well-yield data, the degree of solution is affected by the type and thickness of overlying material (Mozola, 1951). Solution effects on limestones (and on shales which contain gypsum) in the Erie-Niagara have been reported by LaSala (1968). This source of water is considered to comprise a separate source of groundwater for the area. Very few wells in the region adjacent to SEDA utilize the limestone as a source of water, which may be due to the drilling depths required to intercept this water.

2.4 Site Groundwater Contaminants

The primary impact to the groundwater is a plume of a chlorinated volatile organic solvents (trichloroethene, 1,2-dichloroethene and vinyl chloride) originating in the source area. The source of groundwater impacts is an area identified through a combination of soil gas and soil borings at the northwestern portion of the Ash Landfill. The source area was termed the "Bend in the Road" area as it was located at the bend in the unpaved access road. This area was eliminated in 1995 through an interim remedial measure (IRM) that treated approximately 34,000 CY of soil using Low Temperature Thermal Desorption (LTTD). Prior to the IRM, the maximum detected concentration at the site was 132,360 ug/L, which is the sum of TCE, 1,2-DCE, and VC in monitoring well MW-44 located within the source area prior to the IRM. (Note: This well was removed during the IRM and was replaced with MW-44A after completion of the IRM in the same location). After source removal, concentrations of chlorinated compounds dropped significantly. Figure 1 presents the VOC plume map for the Ash Landfill after the source was removed between September 1994 and June 1995. At the proposed location of the reactive wall, also shown in Figure 1, the concentration of total chlorinated VOCs ranges between 10 ug/L and 200 ug/L. Historic data for the wells in the area of the proposed continuous reactive wall are provided in Appendix A.

3.0 RATIONALE FOR CONDUCTING A TREATABILITY STUDY ON THE CONTINUOUS REACTIVE WALL

As part of the Feasibility Study for the Ash Landfill (Parsons ES, 1996), In-situ Treatment with Zero Valence Iron or Air Sparging was considered. In-situ treatment was determined to be a cost effective alternative, compared to extraction, treatment and discharge options, due to the minimal operation and maintenance (O&M) requirements associated with the in-situ alternative. With base closure as a consideration, in-situ treatment using a chemical reactant, such as zero valence iron, was determined to have advantages over other in-situ technologies, such as air sparging, since a chemical reactant does not require a mechanical system to operate and maintain.

The application of zero valence iron for groundwater pollution control is patented by researchers from the University of Waterloo, Ontario Canada. EnviroMetal Technologies, Inc. (ETI) holds the exclusive license for the application of zero valence iron for reactive walls. Parsons ES has contacted ETI regarding the application of zero valence iron at this site. ETI has provided a summary of similar in-situ field projects that have successfully utilized zero valence iron (personal communication). These reports have provided useful information pertaining to the design and construction of the continuous reactive wall system. Information such as expected residence times to achieve reduction of chlorinated solvents and constructability issues were presented in these reports. This technology has been recently installed at an industrial site in New York for removal of dissolved TCE in groundwater. Data from this installation indicates that the system has achieved the contaminant reduction goals. An article by Focht, et.al. (1996) documenting the reduction of chlorinated solvents at this site is provided in Appendix B.

Zero valence iron is an effective reducing agent for the chlorinated solvents. Chlorinated solvents such as trichloroethene, 1,2-dichloroethene, and vinyl chloride are degraded by reductive dechlorination as shown in Figure 2. The iron within the wall is subsequently oxidized. The half-reactions for the iron and TCE are shown below (Focht, et.al, 1996):

(1) $Fe^{\circ} \rightarrow Fe^{+2} + 2e^{-}$

(2) $C_2HCl_3 + 3H^{+} + 6e^{-} \rightarrow C_2H_4 + 3Cl^{-}$

Since this technology is considered innovative, a treatability study is appropriate prior to final selection and implementation of the alternative. As the first step in conducting the treatability study, modeling was conducted to determine the best configuration for an in situ treatment using zero valence iron. Parsons ES conducted this groundwater modeling study to determine design parameters which would be needed to effectively implement the in-situ treatment technology. Several reactive wall configurations were considered including the continuous reactive wall and various funnel and gate designs where water is "funneled" through the use of a barrier wall towards gates which are filled with zero valence iron. Modeling showed that either a 645-ft continuous reactive wall or a configuration consisting of a 645-ft funnel and four gates, each 30 feet wide, would capture the "toe" of the plume at the Ash Landfill. The continuous reactive wall would produce no mounding of the groundwater table upgradient of the system, while a funnel and gate system would produce some mounding upgradient. The results of the groundwater modeling are presented in Appendix C.

Originally, a funnel and gate configuration appeared to offer several advantages over a continuous reaction wall. A funnel and gate configuration offers advantages over a continuous reaction wall in ease of change-out and greater ability to maintain saturated conditions in the zero valence iron during seasons where the groundwater level is low. However, after investigating the design of each system further, a continuous reaction wall was selected for the treatability study for the following reasons:

- A funnel and gate system raises hydraulic concerns. High water table conditions, combined with the low hydraulic conductivity soils, can lead to a large groundwater mound causing groundwater to be released at the ground surface or move around the confines of the collection trench. Although the modeling results concluded that the rise in the groundwater table for the funnel and four gate configuration was within an acceptable margin, a continuous reactive wall eliminates such hydraulic concerns.

- According to EnviroMetal Technologies, Inc. (ETI), iron which is subjected to unsaturated conditions shows negligible oxidation and therefore, does not appear to become ineffective under these conditions. ETI holds the exclusive license for the application of zero valence iron for reactive walls, and therefore, has been involved in all applications of this technology. Based on core samples taken of iron in reactive wall applications where the iron has been subjected to unsaturated conditions, ETI has found little evidence of oxidation of the iron. Therefore, since the necessity to change out the iron due to exposure to unsaturated conditions is minimal, the advantage of maintaining saturated conditions by using a funnel and gate system is no longer relevant.

- Design and implementation of a continuous reactive wall is simpler and more cost effective than that of a funnel and gate system.

4.0 CONTINUOUS REACTIVE WALL DESIGN FOR TREATABILITY STUDY

Technical specifications and drawings of the continuous reactive wall designed for the treatability study are included in Appendix D. A general description of the wall is provided below.

4.1 General Description

The continuous reactive wall will be installed approximately 350 feet downgradient of the source area and will have a total length of approximately 645 feet as shown in Figure 1. The length of the wall was determined based on groundwater modeling results described above. The wall will be approximately 1 foot wide and will be excavated to the top of competent shale bedrock (estimated to be between 8 and 10 feet below the ground surface). The trench will be backfilled with a mixture of coarse sand and iron filings. The upper one foot of the trench will be backfilled with soil from the excavation and a layer of top soil which will be revegetated. A geotextile will be placed between the iron/sand mixture and the backfill above the mixture.

4.2 Residence Time and Quantity of Iron

The maximum residence time required to treat the concentration of contaminants at the toe of the plume at the Ash Landfill is 1.25 days. This residence time was determined by ETI using a first-order degradation model which is described in greater detail in Appendix E. As shown in Appendix A, the only organics detected in the wells in the area where the reactive wall is to be located are trichloroethene, 1,2-dichloroethene, and vinyl chloride. Table 1 summarizes the maximum hits encountered in the most recent data available for wells located near the continuous reactive wall location. ETI's modeling results showed that the concentrations present in this area would be reduced to NYSDEC GA Standards if the water remained in contact with iron for 1.25 days.

Based on this residence time and the maximum velocity of the groundwater (60.5 ft/year, Groundwater Modeling Report at the Ash Landfill Site, Parsons ES, 1996), the quantity of iron necessary to treat the water was calculated to be 1,387 cubic feet (see Appendix E). A safety factor of 2 was applied to this quantity for a total of 2,774 cubic feet of iron. This quantity of iron will be mixed with a sand having a similar grain size to make up the total volume of the excavated trench. The specifications require that the iron be evenly distributed over the volume of the 1-foot thick trench to ensure adequate contact between the water and the iron. According to ETI, a minimum of 20% by volume of the trench contents must be iron to ensure adequate contact of groundwater and iron. The continuous reactive wall at the Ash Landfill will be approximately 48% iron.

5.0 MONITORING PLAN

The monitoring plan described below was created based on input from ETI and protocols described in "Regulatory Guidance for Permeable Barriers Design to Remediate Chlorinated Solvents", ITRC, 1997.

5.1 Location of Monitoring Wells

Figure 3 shows the location of the continuous reactive wall and monitoring wells which will be installed to monitor the effectiveness of its performance. Three sets of wells have been designed to monitor upgradient and downgradient VOC concentrations. Each set of monitoring wells consists of three wells: (1) an upgradient well (wells MW-T1, MW-T4, and MW-7), (2) a downgradient well point within the reactive iron (wells MW-T2, MW-T5, and MW-T8), and (3) a downgradient well within the aquifer (wells MW-T3, MW-T6, and MW-T9). The upgradient and downgradient wells will be located 2.5 feet from the respective edge of the reactive wall. By sampling upgradient and downgradient of the reactive wall, performance of the reactive wall may be monitored. However, as the treated groundwater exits the wall and re-enters the aquifer, VOC contaminants sorbed to the aquifer material may tend to desorb into the treated groundwater and make evaluation of the system's effectiveness difficult. Therefore, additional wells (MW-T2, -T5 and -T8) are located as close as possible to the downgradient iron/aquifer interface of the reactive wall so as to provide data representative of groundwater as it exists within the downgradient side of the trench.

Two additional wells, MW-T10 and MW-T11, will be located at each end of the trench to ensure that contaminated groundwater is not bypassing the reactive wall. In particular, data from MW-T11, located on the south end of the trench within West Smith Farm Road, will aid in verifying that the reactive wall is intercepting the southern edge of the groundwater plume.

5.2 Monitoring Well Construction

5.2.1 Monitoring Wells Within the Aquifer

Monitoring wells within the aquifer will be constructed in accordance with the Generic Installation RI/FS Work Plan (Parsons ES, 1995).

5.2.2 Well Points Within the Reactive Wall

Well points within the reactive wall will be constructed using a direct push method. The direct push method will be used to minimize the amount of disturbance of the reactive iron media. The Standard Operating Procedure for installation of well points is provided in Appendix F. The well points will be surrounded by the backfilled reactive media.

5.3 Sampling Plan

5.3.1 Analytical Parameters and Monitoring Frequency

Table 2 shows the sampling plan for the treatability study for the first year. Based on the monitoring data collected during the first year, it will be determined if additional monitoring is necessary. Such determination will be made in the treatability study report at the end of this study. VOCs will be monitored in all eleven wells initially after well installation, four months after installation, and nine months after installation. The sampling frequency is intended not only to evaluate the performance of the reactive wall over time, but also at different water levels which vary seasonally. Methane, ethane and ethene will also be analyzed during these events to assess the formation of reductive degradation products of chlorinated hydrocarbons. Other indicator parameters will also be analyzed during these sampling events to gauge the amount of mineral precipitation occurring in the reactive zone.

Field measurements (water level, pH, temperature, specific conductance, turbidity, redox potential, and dissolved oxygen) will be taken during each sampling event scheduled above, as well as immediately after well installation.

5.3.2 Sampling Procedures

Wells within the reactive wall require special consideration in order to obtain a representative sample. Typical well purging methods and volumes will not apply to these wells. In order to obtain a representative groundwater sample, the volume of groundwater removed and the rate at which it is removed must not greatly influence the residence time within the reactive wall. A very low flow purge rate and a small volume of groundwater should be purged to ensure that the groundwater being sampled has had sufficient time to react within the reactive wall. Low flow purging procedures outlined in the Generic Installation RI/FS Work Plan will be used to sample most wells. However, for the wells within the reactive iron (MW-T2, -T5, and -T8), a bailer or polyethylene tubing with a bottom check valve will be used and the well shall be purged until either a) one well volume has been removed, or b) field indicator parameters have stabilized, whichever occurs first. Samples will collected as described in the Generic Installation RI/FS Work Plan. If field indicator parameters have not stabilized prior to sample collection, the purging of the well using bailers or polyethylene tubing with bottom check valve (see Appendix F) will continue until field indicator parameters have stabilized. Field indicator parameters will be recorded to demonstrate that stabilization has occurred.

6.0 INVESTIGATION DERIVED WASTES

Soil, spent PPE and decontamination water are the only wastes that will be generated during installation of the treatability study reactive wall. Because this wall will be installed using a continuous trencher, there will be no need to dewater the trench, and therefore no potentially contaminated groundwater will be extracted during installation.

Soil from the excavation will be transported and stockpiled at the Abandoned Incinerator Building. One sample of soil will be collected for every 100 cubic yards of material that is transported over to the Abandoned Incinerator Building. This soil sample will be analyzed for VOCs. Each 100 cubic yards of material will be stockpiled separately until test results are returned. If the VOC concentration is acceptable, the soil will remain in the stockpile and will be contained and covered as described in the Specifications in Appendix D. This stockpile will be used as fill material at other locations at the site. If the concentrations of VOCs are not acceptable, the soil will either be treated or disposed off-site.

Spent PPE and decontamination water will be placed in drums for future testing and disposal by SEDA. Proper disposal of these wastes will occur promptly after installation of the continuous reactive wall.

7.0 SEDA SUPPORT REQUIREMENTS

The following SEDA support is needed prior to the arrival of the reactive iron, the excavation subcontractor and the Parsons ES test team:

- An area near the proposed location of the trench at the Ash Landfill to store approximately 100 cubic yards of reactive iron. This area must be dry and covered.
- Provision of any paperwork required to obtain gate passes and security badges for approximately two Parsons ES employees and 3 excavation subcontractor crew members. Vehicle passes will be needed for two trucks and one excavator.

During construction of the continuous reactive wall, the following base support is needed:

- Acceptance of the location of a decontamination pad where the subcontractor can clean equipment.
- Acceptance of responsibility by the base for excavated spoils from the trench and containerized decontamination water, including any drum sampling to determine hazardous waste status.

8.0 PROJECT SCHEDULE

The anticipated schedule for this Continuous Reactive Wall Treatability Study is shown below:

Action	Date
Construction of Continuous Reactive Wall	December 7, 1998 - December 18, 1998
Installation of Monitoring Wells	February 22, 1999 - March 1, 1999
MW Sampling Event #1	Initially after well installation (March 1999)
MW Sampling Event #2	4 months after well installation (July 1999)
MW Sampling Event #3	9 months after well installation (December, 1999)

9.0 POINTS OF CONTACT

Mr. Michael Duchesneau	Parsons Engineering Science	30 Dan Road Canton, MA 02021-2809	Ph: (781) 401-2492 Fx: (781) 401 2043
Mr. Steve Absolom SOISE-BEC BRAC Env. Coordinator	Seneca Army Depot Activity	Building 123 Romulus, NY 14541	Ph: (607) 869-1450 Fx: (607) 869-1362
Mr. Kevin Healy Engineering Support Center	U.S. Army Corps of Engineers Huntsville Division	2480 University Avenue Huntsville, AL 35816-1822	Ph: (256) 895-1627 Fx: (256) 895-1602
Ms. Carla Struble Project Manager	USEPA Region II	290 Broadway, 18th Floor, E-3 New York, NY 10007	Ph: (212) 637-4322 Fx: (212) 637-4360
Mr. James Quinn	NYSDEC	Room 208 50 Wolf Road Albany, NY 12233	Ph: (518) 457-6927 Fx: (518) 457-8990

10.0 REFERENCES

Focht, R., Vogan, J, and O'Hannesin, S., 1996. *Field Application of Reactive Iron Walls for In-Situ Degradation of Volatile Organic Compounds in Groundwater*, Remediation, John Wiley & Sons.

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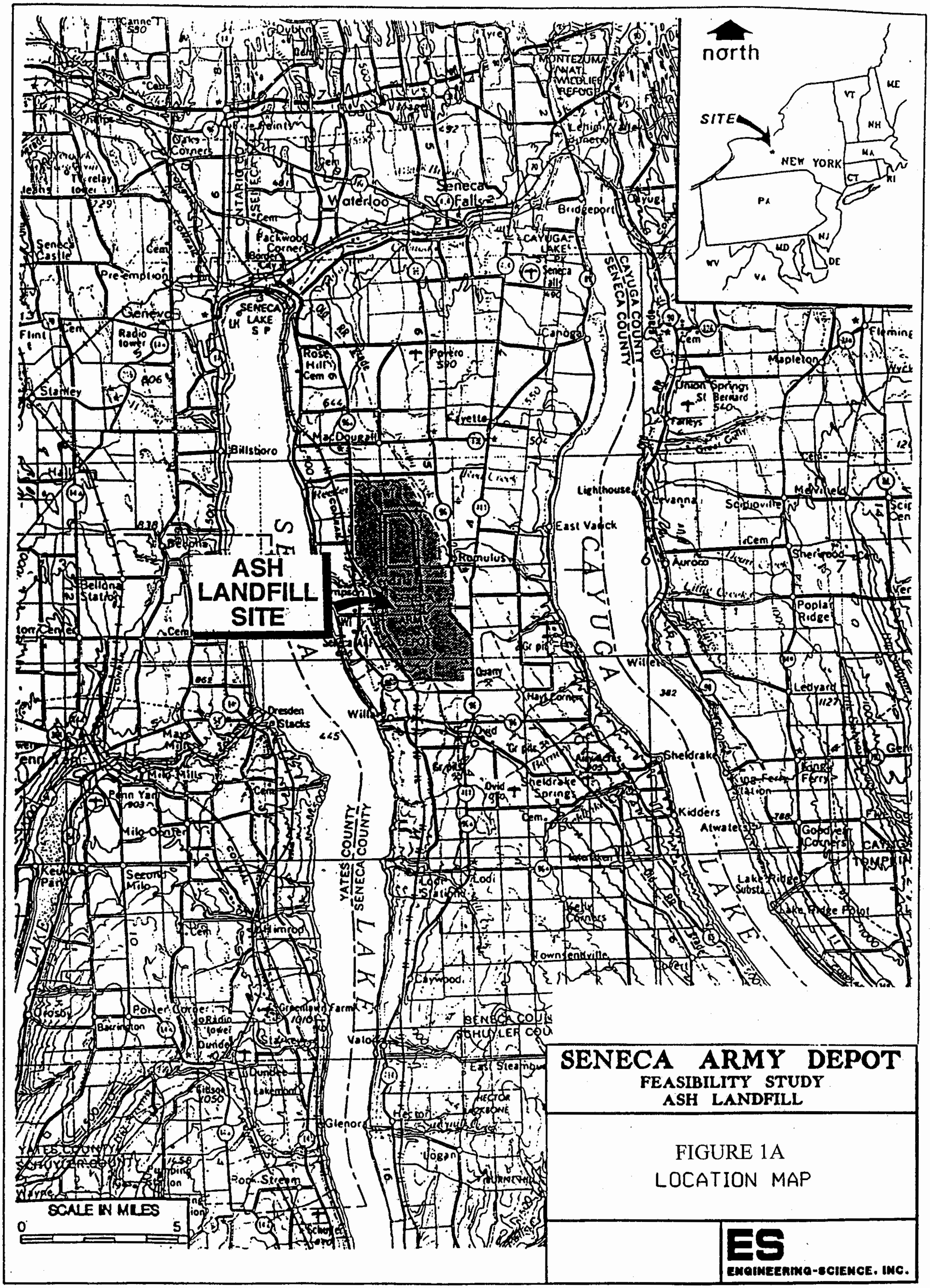
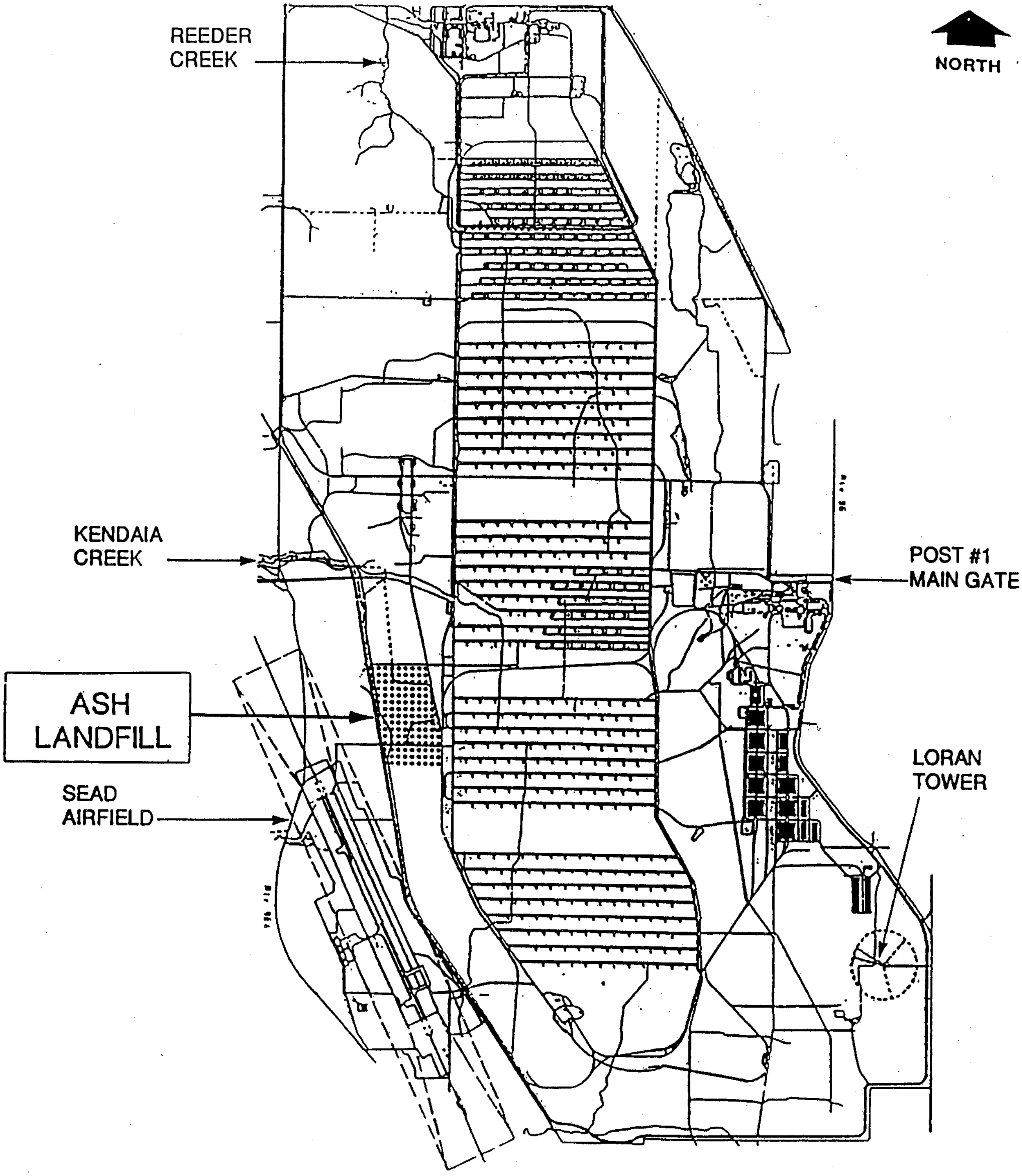
Figures and Tables



SENECA ARMY DEPOT
FEASIBILITY STUDY
ASH LANDFILL

FIGURE 1A
LOCATION MAP

ES
ENGINEERING-SCIENCE, INC.

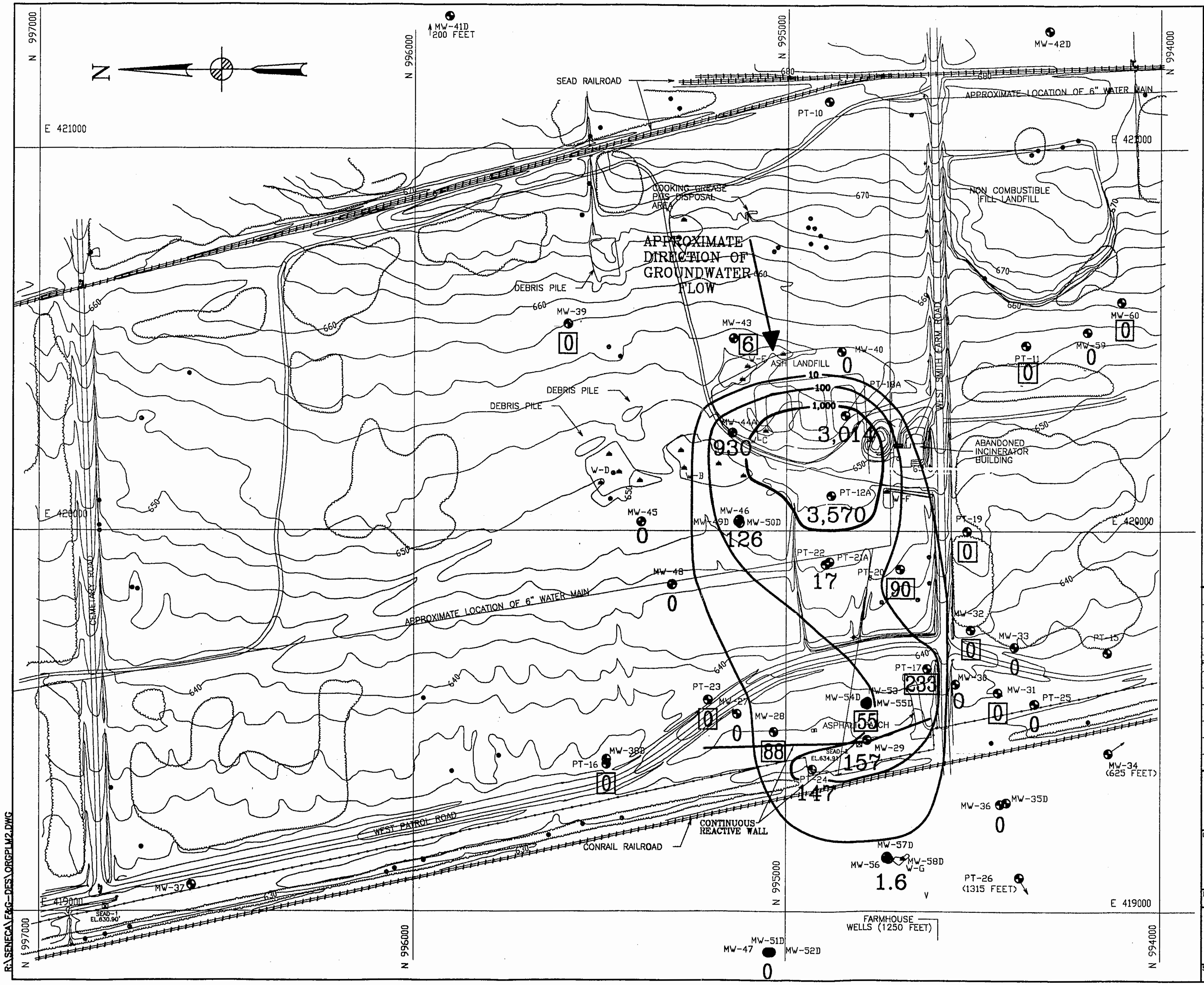


Source: Seneca Army Depot

SENECA ARMY DEPOT
FEASIBILITY STUDY
ASH LANDFILL

FIGURE 1B
LOCATION OF ASH LANDFILL
AT THE SENECA ARMY DEPOT
ACTIVITY

ES
ENGINEERING-SCIENCE, INC.



LEGEND:

PAVED ROAD
DIRT ROAD
GROUND CONTOUR AND ELEVATION
TREE
WETLAND & DESIGNATION
APPROXIMATE EXTENT OF FILL
OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
APPROXIMATE EXTENT OF DEBRIS PILE
BRUSH
CHAIN LINK FENCE
UTILITY POLE
APPROXIMATE LOCATION OF FIRE HYDRANT
FUEL OR UNDERGROUND STORAGE TANK
⊠ SEAD-1 EL.630.90' SURVEY MONUMENT
PT-22 MW-37 MONITORING WELL AND DESIGNATION
—1,000— GROUNDWATER ISOCONTOUR (ug/L)
17 TOTAL VOCs FROM SAMPLE COLLECTED IN JUNE 1997 DURING THE SECOND QUARTER 1997
90 TOTAL VOCs FROM SAMPLE COLLECTED IN JULY 1993 DURING THE RI

NOTE: THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILL/WEATHERED SHALE AQUIFER.

-250' 0 250'

SCALE: 1" = 250'

REV	DATE	DESCRIPTION
B	11/4/98	ISSUED FOR EPA REVIEW
A	8/20/98	ISSUED FOR REVIEW

DRAWN | CHECKED | DES.SUPV. | RESP.ENGR. | CH.DISC.ENG. | PROJ. MGR.

DRAWN BY C. DROWNE
CHECKED BY J. TRAVERS
DESIGN SUPV.
RESP. ENGR.
CHIEF DISC. ENGR.
MGR. OF ENGR.
PROJECT MANAGER M. DUCHESNEAU
MGR. OF PROJECTS J. P. CHAPLICK
IN CHARGE W. D. PATTERSON

PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY

ASH LANDFILL GROUNDWATER TREATABILITY STUDY USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL

DEPT. ENVIROMENTAL ENGINEERING
Dwg. No. 726209-01004

FIGURE 1

ASH LANDFILL SITE MAP WITH VOLATILE ORGANICS PLUME: POST-REMOVAL ACTION CONDITIONS

SCALE AS NOTED
DATE NOVEMBER 1998
REV B

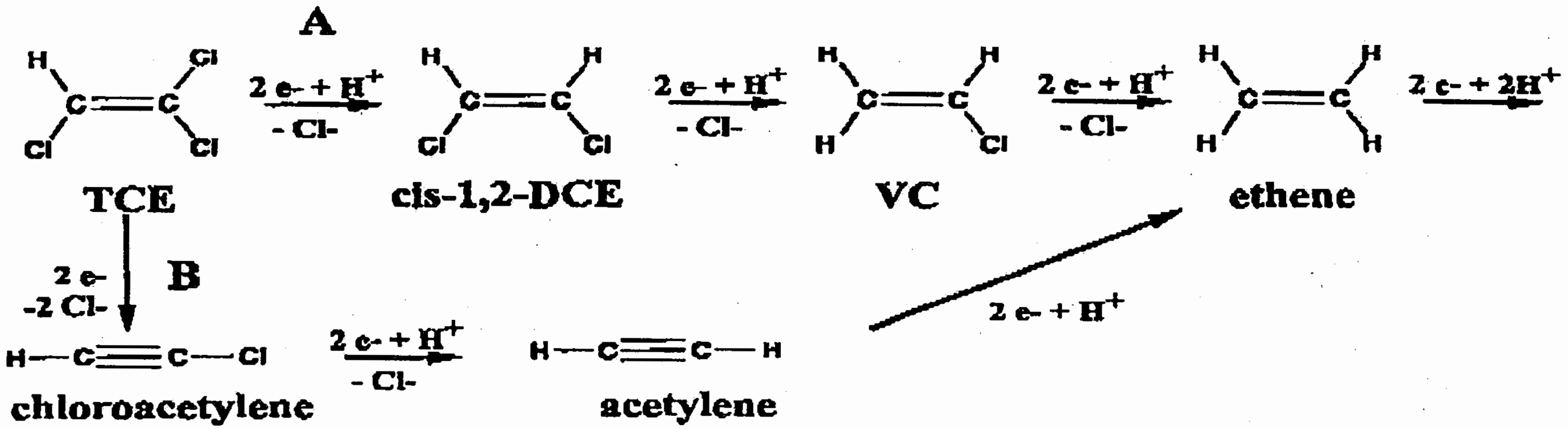
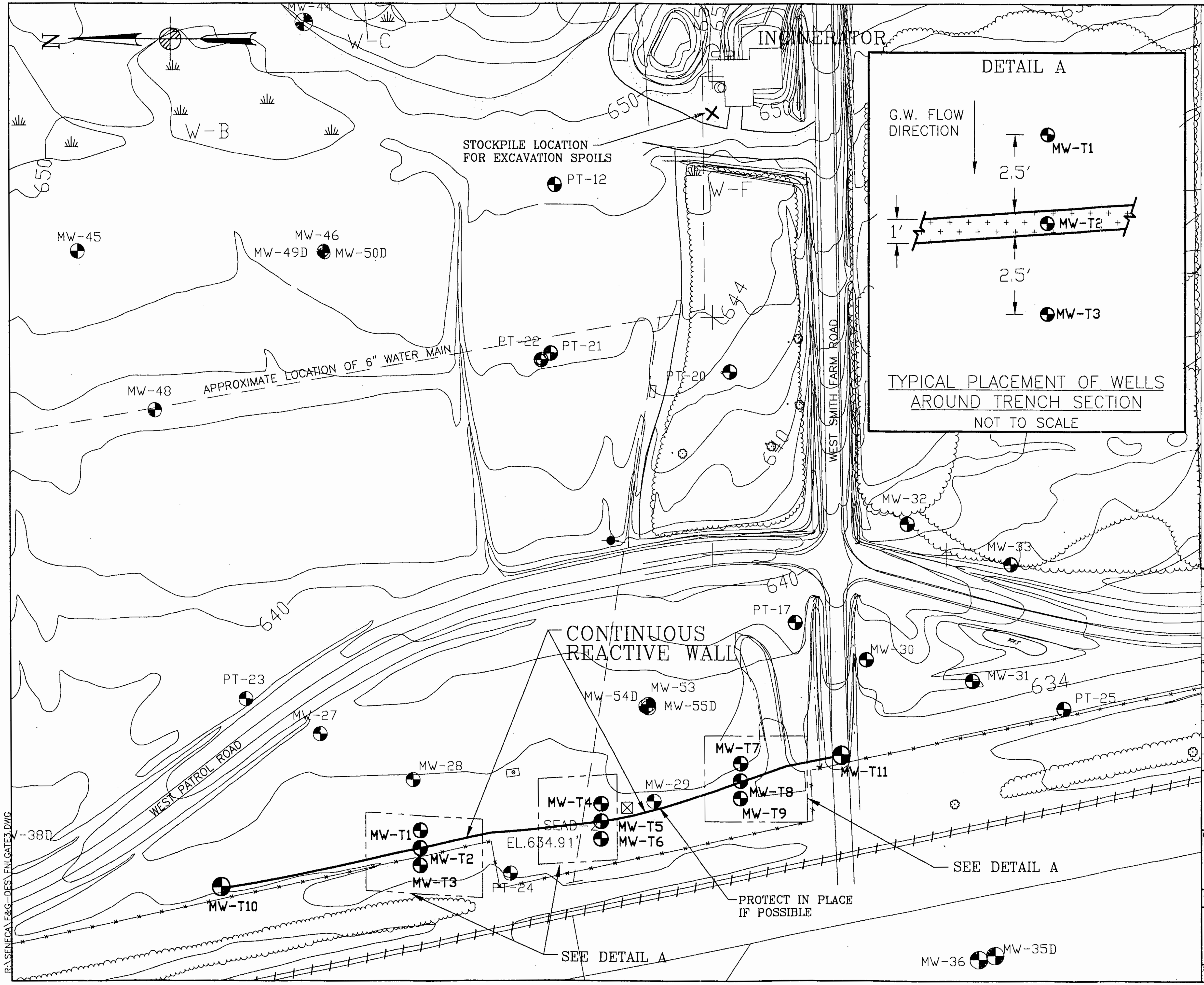


Figure 2 - Reductive Dechlorination of TCE to Ethene and Ethane

Source: EPA/600/F-97/008 July 1997



LEGEND:

PAVED ROAD
DIRT ROAD
GROUND CONTOUR AND ELEVATION (650)
TREE
WETLAND & DESIGNATION (W-B)
APPROXIMATE EXTENT OF FILL
OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
APPROXIMATE EXTENT OF DEBRIS PILE
BRUSH
CHAIN LINK FENCE
UTILITY POLE
APPROXIMATE LOCATION OF FIRE HYDRANT
FUEL OR UNDERGROUND STORAGE TANK
SURVEY MONUMENT (SEAD-1 EL.630.90')
MONITORING WELL AND DESIGNATION (PT-22, MW-37)
RAILROAD TRACKS
TREATMENT WALL
6" WATER MAIN

-100' 0 100'

SCALE: 1" = 100'

REV	DATE	DESCRIPTION
E	2/3/99	ISSUED FOR EPA REVIEW
D	11/4/98	ISSUED FOR EPA REVIEW
C	10/12/98	ISSUED FOR RE-BID
B	9/16/98	ISSUED FOR BID
A	8/20/98	ISSUED FOR REVIEW

DRAWN | CHECKED | DES.SUPV. | RESP.ENGR. | CH.DISC.ENG. | PROJ. MGR.

DRAWN BY C. DROWNE	CHECKED BY J. TRAVERS
DESIGN SUPV.	RESP. ENGR.
CHIEF DISC. ENGR.	MGR. OF ENGR.

PROJECT MANAGER
M. DUCHESNEAU
MGR. OF PROJECTS
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IN CHARGE
V. D. PATTERSON

PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE
SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER TREATABILITY STUDY
USING ZERO VALENT IRON CONTINUOUS REACTIVE WALL
TREATABILITY STUDY WORK PLAN

DEPT. ENVIRONMENTAL ENGINEERING
Dwg. No. 726209-01004

FIGURE 3
PROPOSED MONITORING WELL LOCATIONS FOR CONTINUOUS REACTIVE WALL

SCALE 1" = 100'
DATE FEBRUARY 1999
REV E

Table 1
Maximum Most Recent Concentrations Detected in Monitoring Wells in the Vicinity of the Continuous Reactive Wall
Ash Landfill Groundwater Treatability Study
Seneca Army Depot Activity, Romulus, NY

	Well Location and Concentration					
Well ID	PT-17	MW-28	MW-53	PT-24	MW-29	MW-27
Date of Data Collection	Jul-93	Jul-93	Nov-93	Jun-97	Jun-97	Jun-97
Post Removal Action?	No	No	No	Yes	Yes	Yes
VOC	**ug/L**					
Trichloroethene	190	35	4	7	5	ND
1,2-Dichloroethene	43	53	51	140	150	ND
Vinyl Chloride	ND	ND	ND	ND	ND	ND

Table 2
Sampling Plan for Ash Landfill Groundwater Treatability Study Using Zero Valence Iron Continuous Reactive Wall
Seneca Army Depot Activity, Romulus, NY

	Well ID:	MW-T1	MW-T2	MW-T3	MW-T4	MW-T5	MW-T6	MW-T7	MW-T8	MW-T9	MW-T10	MW-T11	QA/QC (2)		Total
Analysis	**Method No**	**Number of Samples Collected During First Year (1)**													
Volatiles and Degradation Products															
VOCs	EPA 8260	3	3	3	3	3	3	3	3	3	3	3	15	rb,tb,dup, MS/MSD	48
Methane	EPA Method RSKSOP-175	3	3	3	3	3	3	3	3	3	3	3	9	rb,tb,dup	42
Ethane		3	3	3	3	3	3	3	3	3	3	3	9	rb,tb,dup	42
Ethene		3	3	3	3	3	3	3	3	3	3	3	9	rb,tb,dup	42
Inorganic Parameters															
Sulfate	EPA 300.0	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Alkalinity	EPA 310.1	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Nitrate	EPA 300.0	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
TDS	EPA 160.2	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Phosphate	Std.M. 4110	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Chloride	EPA 300.0	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Calcium	EPA 200.7	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Magnesium	EPA 200.7	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Potassium	EPA 200.7	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Sodium	EPA 200.7	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Iron	EPA 200.7	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
Manganese	EPA 200.7	3	3	3	3	3	3	3	3	3	3	3	3	dup	36
pH	EPA 9040	3	3	3	3	3	3	3	3	3	3	3	3	dup	36

Note 1:
Samples will be collected initially after well installation, four months after well installation, and nine months after well ins

Note 2:
One set of QA/QC samples will be collected during each sampling event.
rb-rinse blank, tb - trip blank, dup - duplicate, MS - matrix spike, MSD - matrix spike duplicate

pH, conductivity, temperature, turbidity, redox potential, dissolved oxygen and water level will also be measured in field

Appendix A

Groundwater Results for Wells in the Vicinity of the Continuous Reactive Wall

Remedial Investigation Results for Wells PT-17, MW-28 and MW-53

TABLE 4-5

SUMMARY OF COMPOUNDS DETECTED-GROUNDWATER

SENECA ARMY DEPOT
ASH LANDFILL

	PERCENTAGE OF WELLS DETECTED IN	MAXIMUM DETECTED	MCL (µg/l)	DWQS (µg/l)	NUMBER OF SAMPLES ABOVE DWQS	NYSDEC CLASS GA AWQS (µg/l)	NUMBER OF SAMPLES ABOVE AWQS	BACKGROUND RANGE	PHASE I PT-17 01/16/92 PT-17	PHASE I PT-17 01/16/92 PT-17 (Filtered)	PHASE II PT-17 07/13/93 PT-17	PHASE I PT-18 01/09/92 PT-18	PHASE I PT-18 01/09/92 PT-18 (Filtered)	PHASE II PT-18 07/15/93 PT-18
VOCs (µg/l)														
Vinyl Chloride	6.4%	23000	2	2	6	2	6	ND	14 U	N	10 U	670 U	N	10
1,1-Dichloroethene	6.4%	200	7	5	2	5	2	ND	7 U	N	10 U	330 U	N	3 J
1,1-Dichloroethane	2.1%	160	-	5	2	5	2	ND	7 U	N	10 U	330 U	N	10 U
1,2-Dichloroethene (total)	31.9%	130000	-	5	27	5	27	ND	53	N	43	400	N	730 J
Chloroform	4.3%	210	100	100	2	7	2	ND	3 J	N	10 U	180 J	N	210 J
1,2-Dichloroethane	2.1%	6	5	5	1	5	1	ND	7 U	N	10 U	330 U	N	10 U
1,1,1-Trichloroethane	4.3%	72	200	5	1	5	1	ND	7 U	N	10 U	330 U	N	10 U
Trichloroethene	38.3%	51000	5	5	20	5	20	ND	260	N	190	11000	N	13000
Benzene	8.5%	170	5	5	4	0.7	5	ND	7 U	N	10 U	330 U	N	1 J
4-Methyl-2-Pentanone	2.1%	77	-	-	NA	-	NA	ND	14 U	N	10 U	670 U	N	10 U
Tetrachloroethene	2.1%	2	5	5	0	5	0	ND	7 U	N	10 U	330 U	N	10 U
Toluene	4.3%	900	1000	5	2	5	2	ND	7 U	N	10 U	330 U	N	10 U
Ethylbenzene	2.1%	130	700	5	2	5	2	ND	7 U	N	10 U	330 U	N	10 U
Xylene (total)	4.3%	590	10,000	5	2	5	2	ND	7 U	N	10 U	330 U	N	10 U
Semivolatiles (µg/l)														
Phenol	2.1%	5	-	50	0	1	1	ND	11 U	N	10 U	11 U	N	10 U
bis(2-Chloroethyl) ether	2.1%	0.6	-	50	0	1	0	ND	11 U	N	10 U	11 U	N	10 U
4-Methylphenol	4.3%	6	-	50	0	-	NA	ND	11 U	N	10 U	11 U	N	10 U
Naphthalene	2.1%	66	-	50	2	10	2	ND	11 U	N	10 U	11 U	N	10 U
2-Methylnaphthalene	2.1%	13	-	50	0	-	NA	ND	11 U	N	10 U	11 U	N	10 U
Diethylphthalate	2.1%	2	-	-	NA	50	0	ND	11 U	N	10 U	11 U	N	10 U
Pentachlorophenol	2.1%	74	1	50	2	1	2	ND	54 U	N	25 U	57 U	N	25 U
Di-n-butylphthalate	42.6%	18	-	50	0	50	0	ND - 18	11 U	N	3 J	11 U	N	10 U
Herbicides (µg/l)														
Dalapon	6.4%	6.4	200	50	0	50	0	ND	2.3 U	N	2.3 U	2.4 U	N	2.3 U
Dicamba	2.1%	0.18	-	0.44	0	0.44	0	ND	0.1 U	N	0.1 U	0.1 U	N	0.1 U
Metals (µg/l)														
Aluminum	100.0%	306000	-	-	NA	-	NA	ND -19100	14200	24.6 U	72.6 U	1510	24.4 U	318 J
Antimony	6.4%	191	6	-	NA	3	4	ND		53.4 U		55.5 U J	52.9 U	49.7 U
Arsenic	31.9%	8.6	50	50	0	50	0	ND	3.5 J	3.5 U	1.4 U	3.5 U	3.5 U	1.9 U
Barium	100.0%	1600	2000	2000	0	1000	4	ND-329	131 J		54.6 J	53.9 J		40 J
Beryllium	25.5%	11.7	4	-	NA	3	3	ND		1.1 U	0.9 U			0.9 U
Cadmium	29.8%	64.6	5	5	8	10	3	ND	3 U	3 U	2.8 U	2.9 U	3 U	2.8 U
Calcium	100.0%	1790000	-	-	NA	-	NA	39200-352000	115000	106000	114000	329000 J	271000	203000
Chromium	91.5%	418	100	10	43	50	14	ND-29.8	20	6.2 U	2.7 U	6.1 U	6.1 U	2.8 J
Cobalt	38.3%	201	-	-	NA	5	27	ND-28	20.3 U	20.5 U	5.5 U	19.8 U	20.3 U	5.9 J
Copper	76.6%	412	1300*	1300	0	200	2	ND-25.3	11.9 J	10.2 U	4.7 U	14.4 U	10.1 U	4.7 UJ
Iron	100.0%	610000	-	300	63	300	63	ND-27800	21500	7 U	105 J	2270	6.9 U	496 J
Lead	80.9%	147	15*	15	15	250	0	ND-8.2	6.3	1.2 U	0.6 U	17.8	1.2 U	0.8 U
Magnesium	100.0%	267000	-	-	NA	35000	20	14700-39600	15700	10700	11100	37000 J	39400	24900
Manganese	100.0%	11400	-	300	49	300	49	43.7-2200	520	4.8 U	5.1 J	1530	964	752
Mercury	19.1%	2.3	2	2	1	2	1	ND		0.03 U	0.09 UJ			0.09 U
Nickel	66.0%	622	100	-	NA	-	NA	ND-36.9	21.3 J	14.8 U	7.5 U	15.9 U	14.7 U	7.5 UJ
Potassium	100.0%	24800	-	-	NA	-	NA	1160-11200	3200 J	289 U	1080 J	2280 J	2010 J	1360 J
Selenium	19.1%	2.9	50	10	0	10	0	ND	1.3 U	1 U	1.5 U	1 U	1 U	0.99 UJ
Silver	6.4%	7.2	-	50	0	50	0	ND	3.4 U	3.4 U	5.5 U	9 U		5.5 U
Sodium	100.0%	149000	-	-	NA	20000	66	11200-91000	29400	27800	28300	114000 J	109000	93900
Vanadium	63.8%	358	-	-	NA	-	NA	ND	21.6 J	9.5 U	6.8 U	30.3 U	9.4 U	6.8 UJ
Zinc	93.6%	1750	-	5000	0	300	6	ND-58.8			2.8 U	496	120	
Cyanide	29.8%	11.2	200	-	NA	100	0	ND-11.2	10 U		3 J	10 U J		1.4 J

TABLE 4-5

SUMMARY OF COMPOUNDS
DETECTED-GROUNDWATER

SENECA ARMY DEPOT
ASH LANDFILL

	PERCENTAGE OF WELLS DETECTED IN	MAXIMUM DETECTED	MCL (µg/l)	DWQS (µg/l)	NUMBER OF SAMPLES ABOVE DWQS	NYSDEC CLASS GA AWQS (µg/l)	NUMBER OF SAMPLES ABOVE AWQS	BACKGROUND RANGE	PHASE I MW-28 01/15/92 MW-28 (Filtered)	PHASE I MW-28 01/15/92 PT-2(1)	PHASE I MW-28 01/15/92 PT-2(1)	PHASE II MW-28 07/10/93 MW-28 (Filtered)	PHASE I MW-29 01/15/92 MW-29	PHASE I MW-29 01/15/92 MW-29 (Filtered)
VOCs (µg/l)														
Vinyl Chloride	6.4%	23000	2	2	6	2	6	ND	N	10 U	N	10 U	10 U	N
1,1-Dichloroethene	6.4%	200	7	5	2	5	2	ND	N	5 U	N	10 U	5 U	N
1,1-Dichloroethane	2.1%	160	-	5	2	5	2	ND	N	5 U	N	10 U	5 U	N
1,2-Dichloroethene (total)	31.9%	130000	-	5	27	5	27	ND	N	62	N	53	71	N
Chloroform	4.3%	210	100	100	2	7	2	ND	N	5 U	N	10 U	5 U	N
1,2-Dichloroethane	2.1%	6	5	5	1	5	1	ND	N	5 U	N	10 U	5 U	N
1,1,1-Trichloroethane	4.3%	72	200	5	1	5	1	ND	N	5 U	N	10 U	5 U	N
Trichloroethene	38.3%	51000	5	5	20	5	20	ND	N	33	N	35	1 J	N
Benzene	8.5%	170	5	5	4	0.7	5	ND	N	5 U	N	10 U	5 U	N
4-Methyl-2-Pentanone	2.1%	77	-	-	NA	-	NA	ND	N	10 U	N	10 U	10 U	N
Tetrachloroethene	2.1%	2	5	5	0	5	0	ND	N	5 U	N	10 U	5 U	N
Toluene	4.3%	900	1000	5	2	5	2	ND	N	5 U	N	10 U	5 U	N
Ethylbenzene	2.1%	130	700	5	2	5	2	ND	N	5 U	N	10 U	5 U	N
Xylene (total)	4.3%	590	10,000	5	2	5	2	ND	N	5 U	N	10 U	5 U	N
Semivolatiles (µg/l)														
Phenol	2.1%	5	-	50	0	1	1	ND	N	11 U	N	10 U	11 U	N
bis(2-Chloroethyl) ether	2.1%	0.6	-	50	0	1	0	ND	N	11 U	N	10 U	11 U	N
4-Methylphenol	4.3%	6	-	50	0	-	NA	ND	N	11 U	N	10 U	11 U	N
Naphthalene	2.1%	66	-	50	2	10	2	ND	N	11 U	N	10 U	11 U	N
2-Methylnaphthalene	2.1%	13	-	50	0	-	NA	ND	N	11 U	N	10 U	11 U	N
Diethylphthalate	2.1%	2	-	-	NA	50	0	ND	N	11 U	N	10 U	11 U	N
Pentachlorophenol	2.1%	74	1	50	2	1	2	ND	N	55 U	N	25 U	55 U	N
Di-n-butylphthalate	42.6%	18	-	50	0	50	0	ND - 18	N	11 U	N	10 U	11 U	N
Herbicides (µg/l)														
Dalapon	6.4%	6.4	200	50	0	50	0	ND	N	2.5 U	N	2.3 U	N	N
Dicamba	2.1%	0.18	-	0.44	0	0.44	0	ND	N	0.1 U	N	0.1 U	N	N
Metals (µg/l)														
Aluminium	100.0%	306000	-	-	NA	-	NA	ND -19100	24.5 U	27000 J	24.5 U	6980	85700	24.4 U
Antimony	6.4%	191	6	-	NA	3	4	ND	53.3 U	53 U	53.3 U	49.5 UJ	53.3 U	53 U
Arsenic	31.9%	8.6	50	50	0	50	0	ND	3.5 U	3.5 U	3.5 U	1.4 UJ	3.5 U	3.5 U
Barium	100.0%	1600	2000	2000	0	1000	4	ND-329		154 J		76.9 J	418	
Beryllium	25.5%	11.7	4	-	NA	3	3	ND				0.89 U		
Cadmium	29.8%	64.6	5	5	8	10	3	ND	3 U	5.2	3 U	2.8 U	17	3 U
Calcium	100.0%	1790000	-	-	NA	-	NA	39200-352000	111000	152000 J	111000	121000	248000	124000
Chromium	91.5%	418	100	10	43	50	14	ND-29.8	6.2 U	34.6 J	6.2 U	9.6 J	122	6.2 U
Cobalt	38.3%	201	-	-	NA	5	27	ND-28	20.5 U	20.3 U	20.5 U	5.4 U	63.8	20.4 U
Copper	76.6%	412	1300*	1300	0	200	2	ND-25.3	10.2 U	27.6	10.2 U	6.1 J	111	10.1 U
Iron	100.0%	610000	-	300	63	300	63	ND-27800	7 U	46500 J	7 U	8530	159000	7 U
Lead	80.9%	147	15*	15	15	250	0	ND-8.2	1.2 U	8.9	1.2 U	2.2 J	39.4	1.2 U
Magnesium	100.0%	267000	-	-	NA	35000	20	14700-39600	123000	23400	11800	13900	59400	14700
Manganese	100.0%	11400	-	300	49	300	49	43.7-2200	4.8 U	1100 J	4.8 U	271	4110	4.8 U
Mercury	19.1%	2.3	2	2	1	2	1	ND				0.09 UJ		
Nickel	66.0%	622	100	-	NA	-	NA	ND-36.9	14.8 U	62.9	14.8 U	8.2 J	182 ✓	14.7 U
Potassium	100.0%	24800	-	-	NA	-	NA	1160-11200	347 J	4020 J	289 U	2570 J	10800	563 J
Selenium	19.1%	2.9	50	10	0	10	0	ND	1 U	1.3 U	1 U	1.5 UJ	13 U	1.4 J
Silver	6.4%	7.2	-	50	0	50	0	ND	3.4 U	3.4 U	3.4 U	5.4 U	3.4 U	
Sodium	100.0%	149000	-	-	NA	20000	66	11200-91000	8580	9250	8570	10100	26200	25000
Vanadium	63.8%	358	-	-	NA	-	NA	ND	9.5 U	32.7 J	9.5 U	12.6 J	98.3	9.4 U
Zinc	93.6%	1750	-	5000	0	300	6	ND-58.8	8.5 U	124 J	8.5 U		503	8.4 U
Cyanide	29.8%	11.2	200	-	NA	100	0	ND-11.2		10 U		1.7 UJ	10 U	

TABLE 4-5

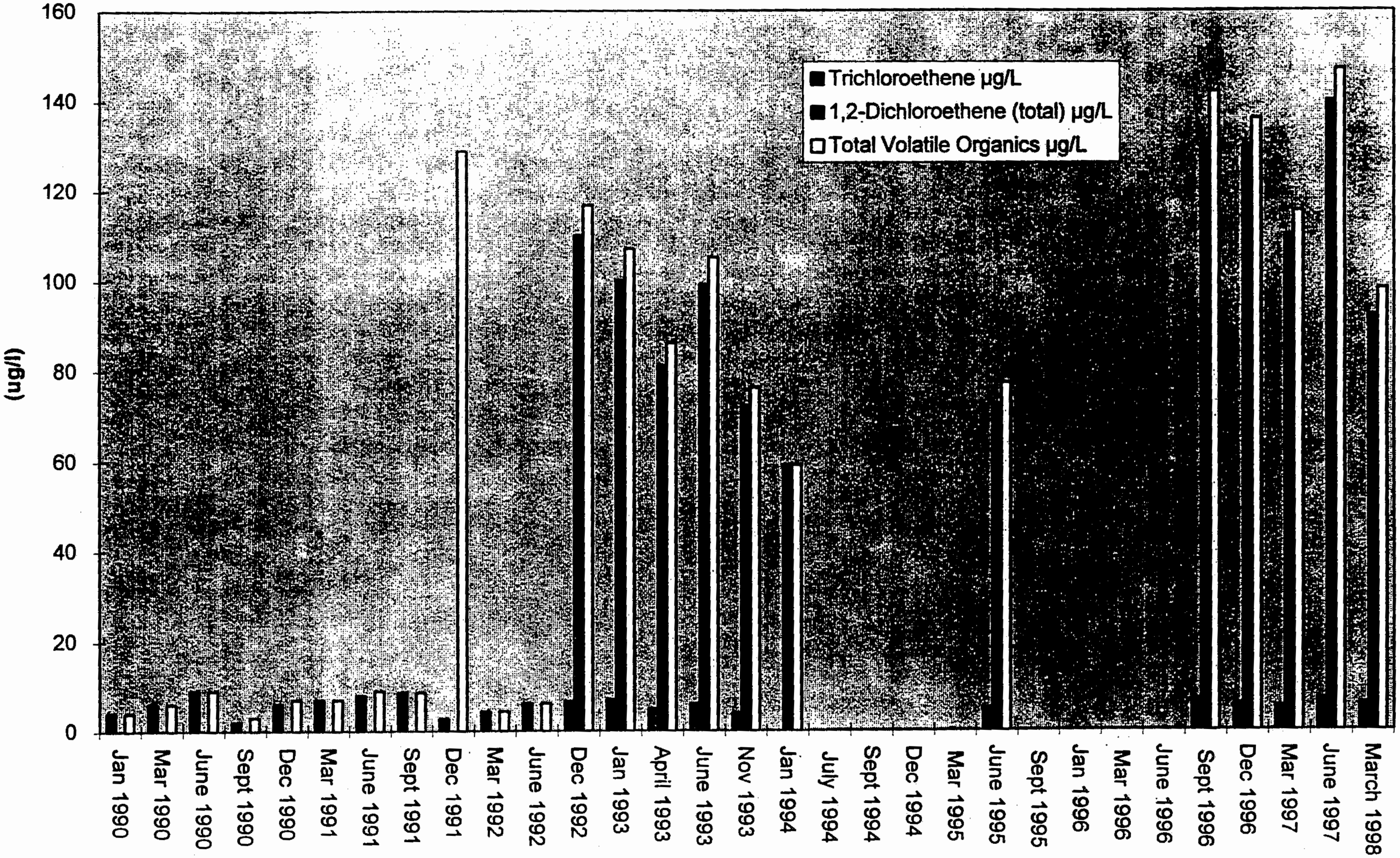
SUMMARY OF COMPOUNDS
DETECTED-GROUNDWATER

SENECA ARMY DEPOT
ASH LANDFILL

	PERCENTAGE OF WELLS DETECTED IN	MAXIMUM DETECTED	MCL (µg/l)	DWQS (µg/l)	NUMBER OF SAMPLES ABOVE DWQS	NYSDEC CLASS GA AWQS (µg/l)	NUMBER OF SAMPLES ABOVE AWQS	BACKGROUND RANGE	PHASE IIA MW-52D 11/07/93 MW-52D	PHASE II MW-53 07/13/93 MW-53	PHASE IIA MW-53 11/05/93 MW-53	PHASE II MW-54D 07/13/93 MW-54D	PHASE IIA MW-54D 11/05/93 MW-54D	PHASE II MW-55D 07/15/93 MW-55D
VOCs (µg/l)														
Vinyl Chloride	6.4%	23000	2	2	6	2	6	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
1,1-Dichloroethene	6.4%	200	7	5	2	5	2	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
1,1-Dichloroethane	2.1%	160	-	5	2	5	2	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
1,2-Dichloroethene (total)	31.9%	130000	-	5	27	5	27	ND	0.5 U	51	16.0	10 U	0.5 U	10 U
Chloroform	4.3%	210	100	100	2	7	2	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
1,2-Dichloroethane	2.1%	6	5	5	1	5	1	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
1,1,1-Trichloroethane	4.3%	72	200	5	1	5	1	ND	0.5 U	10 U	0.3 J	10 U	0.5 U	10 U
Trichloroethene	38.3%	51000	5	5	20	5	20	ND	0.5 U	4 J	1.0	10 U	0.5 U	10 U
Benzene	8.5%	170	5	5	4	0.7	5	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
4-Methyl-2-Pentanone	2.1%	77	-	-	NA	-	NA	ND	5.0 U	10 U	5.0 U	10 U	5.0 U	10 U
Tetrachloroethene	2.1%	2	5	5	0	5	0	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
Toluene	4.3%	900	1000	5	2	5	2	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
Ethylbenzene	2.1%	130	700	5	2	5	2	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
Xylene (total)	4.3%	590	10,000	5	2	5	2	ND	0.5 U	10 U	0.5 U	10 U	0.5 U	10 U
Semivolatiles (µg/l)														
Phenol	2.1%	5	-	50	0	1	1	ND	N	10 U	N	10 U	N	10 U
bis(2-Chloroethyl) ether	2.1%	0.6	-	50	0	1	0	ND	N	10 U	N	10 U	N	10 U
4-Methylphenol	4.3%	6	-	50	0		NA	ND	N	10 U	N	10 U	N	10 U
Naphthalene	2.1%	66	-	50	2	10	2	ND	N	10 U	N	10 U	N	10 U
2-Methylnaphthalene	2.1%	13	-	50	0	-	NA	ND	N	10 U	N	10 U	N	10 U
Diethylphthalate	2.1%	2	-	-	NA	50	0	ND	N	10 U	N	10 U	N	10 U
Pentachlorophenol	2.1%	74	1	50	2	1	2	ND	N	25 U	N	25 U	N	25 U
Di-n-butylphthalate	42.6%	18	-	50	0	50	0	ND - 18	N	1 J	N	1 J	N	9 J
Herbicides (µg/l)														
Dalapon	6.4%	6.4	200	50	0	50	0	ND	N	2.7 J	N	2.3 U	N	2.3 U
Dicamba	2.1%	0.18	-	0.44	0	0.44	0	ND	N		N	0.1 U	N	0.1 U
Metals (µg/l)														
Aluminum	100.0%	306000	-	-	NA	-	NA	ND -19100	N	47700	N	246	N	4140 J
Antimony	6.4%	191	6	-	NA	3	4	ND	N		N		N	49.5 U
Arsenic	31.9%	8.6	50	50	0	50	0	ND	N	5.3 J	N	1.4 U	N	1.9 U
Barium	100.0%	1600	2000	2000	0	1000	4	ND-329	N	325	N	151 J	N	117 J
Beryllium	25.5%	11.7	4	-	NA	3	3	ND	N	2.5 J	N	0.9 U	N	0.89 U
Cadmium	29.8%	64.6	5	5	8	10	3	ND	N	2.8 U	N	2.8 U	N	2.8 U
Calcium	100.0%	1790000	-	-	NA	-	NA	39200-352000	N	166000	N	64600	N	8580
Chromium	91.5%	418	100	10	43	50	14	ND-29.8	N	76.2	N	2.7 U	N	7.1 J
Cobalt	38.3%	201	-	-	NA	5	27	ND-28	N	54.5	N	5.5 U	N	5.4 U
Copper	76.6%	412	1300*	1300	0	200	2	ND-25.3	N	70.5	N	5.5 J	N	4.7 UJ
Iron	100.0%	610000	-	300	63	300	63	ND-27800	N	80900 J	N	507 J	N	5310 J
Lead	80.9%	147	15*	15	15	250	0	ND-8.2	N	25.8	N	0.59 U	N	1.3 J
Magnesium	100.0%	267000	-	-	NA	35000	20	14700-39600	N	34400	N	20700	N	2950 J
Manganese	100.0%	11400	-	300	49	300	49	43.7-2200	N	2930	N	145	N	86.2
Mercury	19.1%	2.3	2	2	1	2	1	ND	N	0.09 UJ	N	0.09 UJ	N	0.09 U
Nickel	66.0%	622	100	-	NA	-	NA	ND-36.9	N	107	N	7.5 U	N	7.4 UJ
Potassium	100.0%	24800	-	-	NA	-	NA	1160-11200	N	9280	N	2910 J	N	2670 J
Selenium	19.1%	2.9	50	10	0	10	0	ND	N	1.5 U	N	1.5 U	N	1 UJ
Silver	6.4%	7.2	-	50	0	50	0	ND	N	5.5 U	N	5.5 U	N	5.4 U
Sodium	100.0%	149000	-	-	NA	20000	66	11200-91000	N	33000	N	29500	N	114000
Vanadium	63.8%	358	-	-	NA	-	NA	ND	N	71.2	N	6.8 U	N	6.7 UJ
Zinc	93.6%	1750	-	5000	0	300	6	ND-58.8	N	284	N	8 J	N	
Cyanide	29.8%	11.2	200	-	NA	100	0	ND-11.2	N	1.8 J	N	2.1 J	N	1.2 U

Recent Quarterly Monitoring Data through First Quarter 1998 for Wells PT-24, MW-27, and MW-29

PT-24

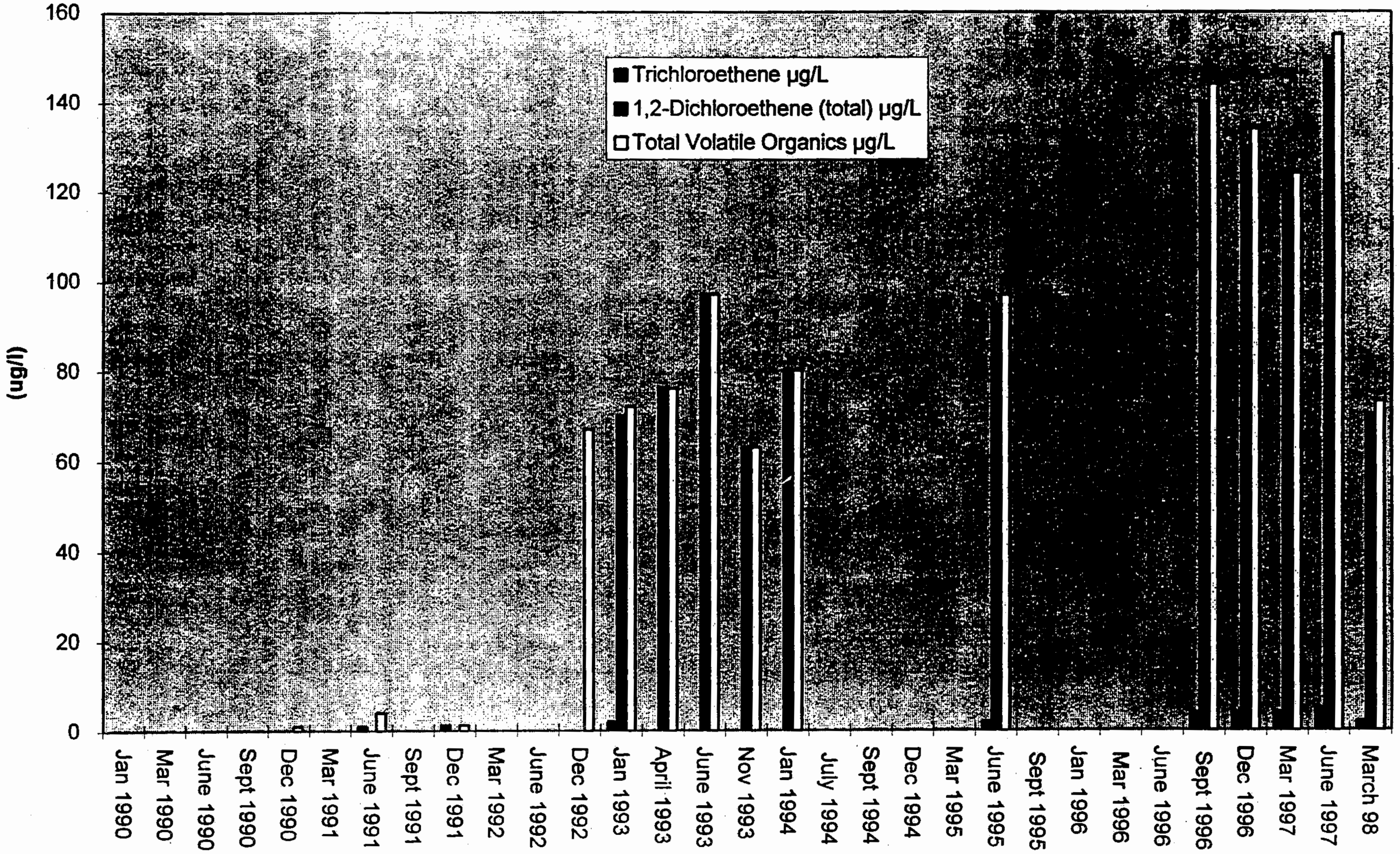


Note: Well was not sampled July 1994-Mar 1995 and Sept 1995-June 1996.

PT-24
Ash Landfill

Parameters	Source: Units	PES Nov 1993 4	PES Jan 1994 1	PES July 1994 2	PES Sept 1994 3	PES Dec 1994 4	PES Mar 1995 1	PES June 1995 2	PES Sept 1995 3	PES Jan 1996 4	PES Mar 1996 1	PES June 1996 2	PES Sept 1996 3	PES Dec 1996 4	PES Mar 1997 1	PES June 1997 2	PES March 1998 1
VOLATILE ORGANICS		NYSCLP	NYSCLP					NYSCLP					524.2	NYSCLP	NYSCLP	NYSCLP	NYSCLP
Chloromethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Bromomethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Vinyl Chloride	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Chloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Methylene Chloride	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1-Dichloroethene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1-Dichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Chloroform	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,2-Dichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Carbon Tetrachloride	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Bromodichloromethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,2-Dichloropropane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
cis-1,3-Dirchloropropene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Trichloroethene	µg/L	4	ND	-	-	-	-	5	-	-	-	-	7	6	5.4	7	6
Dibromochloromethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Benzene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Bromoform	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Tetrachloroethene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Toluene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Chlorobenzene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Ethylbenzene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
2-Chloroethylvinyl Ether	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,3-Dichlorobenzene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,2-Dichlorobenzene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,4-Dichlorobenzene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,2-Dichloroethene (total)	µg/L	72	59	-	-	-	-	72	-	-	-	-	130	130	110	140	92
cis-1,2-Dichloroethene	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
trans-1,2-Dichloroethene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
Trichlorofluoromethane	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
Acetone	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	5	ND	ND	ND	ND
Carbon Disulfide	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
4-Methyl-2 Pentanone	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
2-Hexanone	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Styrene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Xylenes (total)	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Total Volatile Organics	µg/L	76	59	0	0	0	0	77	0	0	0	0	142	136	115.4	147	98

MW-29



Note: Well was not sampled Sept 1990, Sept 1991, July 1994-Mar 1995 and Sept 1995-June 1996.

MW-29
Ash Landfill

Parameters	Source: Units	PES Nov 1993 4	PES Jan 1994 1	PES July 1994 2	PES Sept 1994 3	PES Dec 1994 4	PES Mar 1995 1	PES June 1995 2	PES Sept 1995 3	PES Jan 1996 4	PES Mar 1996 1	PES June 1996 2	PES Sept 1996 3	PES Dec 1996 4	PES Mar 1997 1	PES June 1997 2	PES March 98 1
VOLATILE ORGANICS		NYSCLP	NYSCLP					NYSCLP					524.2	NYSCLP	NYSCLP	NYSCLP	NYSCLP
Chloromethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Bromomethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Vinyl Chloride	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Chloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Methylene Chloride	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1-Dichloroethene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1-Dichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Chloroform	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,2-Dichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	µg/L	ND	ND	-	-	-	-	1	-	-	-	-	ND	ND	ND	ND	1
Carbon Tetrachloride	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Bromodichloromethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,2-Dichloropropane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
cis-1,3-Dirchloropropene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Trichloroethene	µg/L	ND	ND	-	-	-	-	2	-	-	-	-	4	4	4.1	5	2
Dibromochloromethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Benzene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Bromoform	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Tetrachloroethene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Toluene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Chlorobenzene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Ethylbenzene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
2-Chloroethylvinyl Ether	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,3-Dichlorobenzene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,2-Dichlorobenzene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,4-Dichlorobenzene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
1,2-Dichloroethene (total)	µg/L	63	80	-	-	-	-	94	-	-	-	-	140	130	120	150	70
cis-1,2-Dichloroethene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
trans-1,2-Dichloroethene	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
Trichlorofluoromethane	µg/L	-	-	-	-	-	-	-	-	-	-	-	ND	-	-	-	-
Acetone	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Carbon Disulfide	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
4-Methyl-2 Pentanone	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
2-Hexanone	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Styrene	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Xylenes (total)	µg/L	ND	ND	-	-	-	-	ND	-	-	-	-	ND	ND	ND	ND	ND
Total Volatile Organics	µg/L	63	80	0	0	0	0	97	0	0	0	0	144	134	124.1	155	73

MW-27
Ash Landfill

Parameters	Source: Units	PES Nov 1993 4	PES Jan 1994 1	PES July 1994 2	PES Sept 1994 3	PES 1994 4	PES Mar 1995 1	PES June 1995 2	PES Sept 1995 3	PES Jan 1996 4	PES Mar 1996 1	PES June 1996 2	PES Sept 1996 3	PES Dec 1996 4	PES Mar 1997 1	PES June 1997 2	PES March 1998 1
VOLATILE ORGANICS		NYSCLP	NYSCLP	NYSCLP				524.2	524.2	524.2	524.2	524.2	524.2	524.2	524.2	524.2	524.2
Chloromethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromomethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl Chloride	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene Chloride	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Tetrachloride	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloromethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloropropane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,3-Dirchloropropene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibromochloromethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,2-Trichloroethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,3-Dichloropropene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromoform	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dioxane	µg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
1,1,2,2-Tetrachloroethane	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Chloroethylvinyl Ether	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dichlorobenzene	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-Dichlorobenzene	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichloroethene (total)	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichlorofluoromethane	µg/L	-	-	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetone	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methyl-2 Pentanone	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Hexanone	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Styrene	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes (total)	µg/L	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Volatile Organics	µg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50

Appendix B

Literature from Envirometal Technologies, Inc.

Field Application of Reactive Iron Walls for In-Situ Degradation of Volatile Organic Compounds in Groundwater

Robert Focht • John Vogan • Stephanie O'Hannesin

Robert Focht is a project manager with EnviroMetal Technologies Inc. (ETI). He joined ETI in 1995 and has served as ETI's field engineer on several of the installations completed to date. John Vogan is Manager of ETI and has been involved in the planning and design of all of the commercial installations implemented by the firm. Mr. Vogan joined the firm in 1993 after several years of consulting in Ontario. Stephanie O'Hannesin is a research project manager at the University of Waterloo. In 1991 she undertook the initial in-situ field trial of the granular iron reactive wall technology. She has assisted ETI with various stages of technology application at commercial sites since the company was founded in 1992.

Reactive walls containing metallic iron have been installed at several commercial sites in the United States to degrade chlorinated organic compounds in groundwater. Although the results of laboratory studies conducted to determine reaction mechanisms have been widely disseminated, little information has been published on the full-scale application of this technology. This article describes the construction, implementation, and cost of in-situ reactive walls at three commercial sites.

In-situ permeable treatment zones containing granular iron are currently in use to remediate groundwater contaminated with dissolved chlorinated solvents at many private and government facilities in the United States. This method of treatment, developed from research initiated at the Institute for Groundwater Research, University of Waterloo, involves placing granular iron in in-situ permeable zones, across the path of groundwater containing VOCs. As the contaminated groundwater flows through the permeable zones, the chlorinated solvent reacts with the granular iron. Although the iron does not have to be replaced because of the reaction rate, it may have to be replaced because of hydraulics.

This passive treatment system offers many advantages over conventional pump-and-treat systems. In particular, the contaminants degrade to nontoxic chemicals, and with proper placement, only contaminated water is treated. Because the process is fully passive, substantial reductions in operation and maintenance costs are anticipated.

EnviroMetal Technologies Inc. (ETI) was founded in 1992 to implement this patented technology on a commercial scale. More than 40 treatability studies of the technology have been initiated in the past two years at private and government sites in the United States and Canada. Many of these have now reached various stages of field implementation. Full-scale in-situ treatment zones have been installed at two private industrial facilities in California and one in Belfast, Northern Ireland. Three

CCC 1051-5658/96/060381-14

pilot-scale in-situ treatment zones were installed in 1995 and 1996, and several others are planned over the next 12 months. These three case studies applying the technology in the past 18 months illustrate the technical and economic considerations involved in construction of these in-situ treatment systems.

REACTION CHEMISTRY

Considerable research during the past five years has focused on the degradation of chlorinated solvents, such as trichloroethylene and perchloroethylene, by reactions with granular iron. Although faced with considerable initial skepticism, it is now widely accepted that the process is an abiotic reductive dehalogenation with psuedo-first order kinetics. Although details of the reaction chemistry remain unknown, the process involves the simultaneous oxidative corrosion of the reactive iron metal by both water and the chlorinated organic compounds (Matheson and Tratnyek, 1994; Orth and Gillham, 1996). The two half-reactions involving iron and TCE can be shown as:

$$Fe^{o} \rightarrow Fe^{+2} + 2e^{-} \qquad (1)$$

$$C_2HCl_3 + 3H^{+} + 6^{-}_{e} \rightarrow C_2H_4 + 3Cl^{-} \qquad (2)$$

The process involves the simultaneous oxidative corrosion of the reactive iron metal by both water and the chlorinated organic compounds.

These are accompanied by the hydrolysis of water and subsequent formation of hydrogen gas:

$$2H_2O + 2^{-}_{e} \rightarrow H_{2(g)} + 2OH^{-} \qquad (3)$$

As suggested by equation (2), TCE degrades spontaneously in the presence of iron, requiring no additives or application of energy, and the products are chloride and nontoxic hydrocarbons.

In bench-scale studies using contaminated water from commercial sites, 10 to 20 percent of the original TCE appears as cis-1,2-dichloroethene (cDCE) and less than 1 percent as vinyl chloride (VC). However, these breakdown products also degrade in the presence of granular iron given sufficient contact time. For chlorinated methanes and ethanes such as carbon tetrachloride and 1,1,1-trichloroethane (1,1,1-TCA), the percentage of chlorinated breakdown products (e.g., trichloromethane from carbon tetrachloride and 1,1-dichloroethane from 1,1,1-TCA) is higher. **Exhibit 1** lists the chlorinated volatile organic compounds (VOCs) that have been successfully degraded by the process in commercial applications, as well as those that do not appear to degrade.

The dissociation of water, as shown in equation (3), has important consequences with respect to the potential operation and maintenance (O&M) associated with the technology. As a result of the increase in pH, carbonate minerals, including calcium carbonate ($CaCO_3$) and siderite (Fe_3CO), may precipitate in the reactive material. With exhaustion of the carbonate buffering capacity, further pH increases can result in the precipitation of ferrous hydroxides ($Fe(OH)_2$). This precipitation process

Exhibit 1. Compounds Evaluated during Treatability Studies

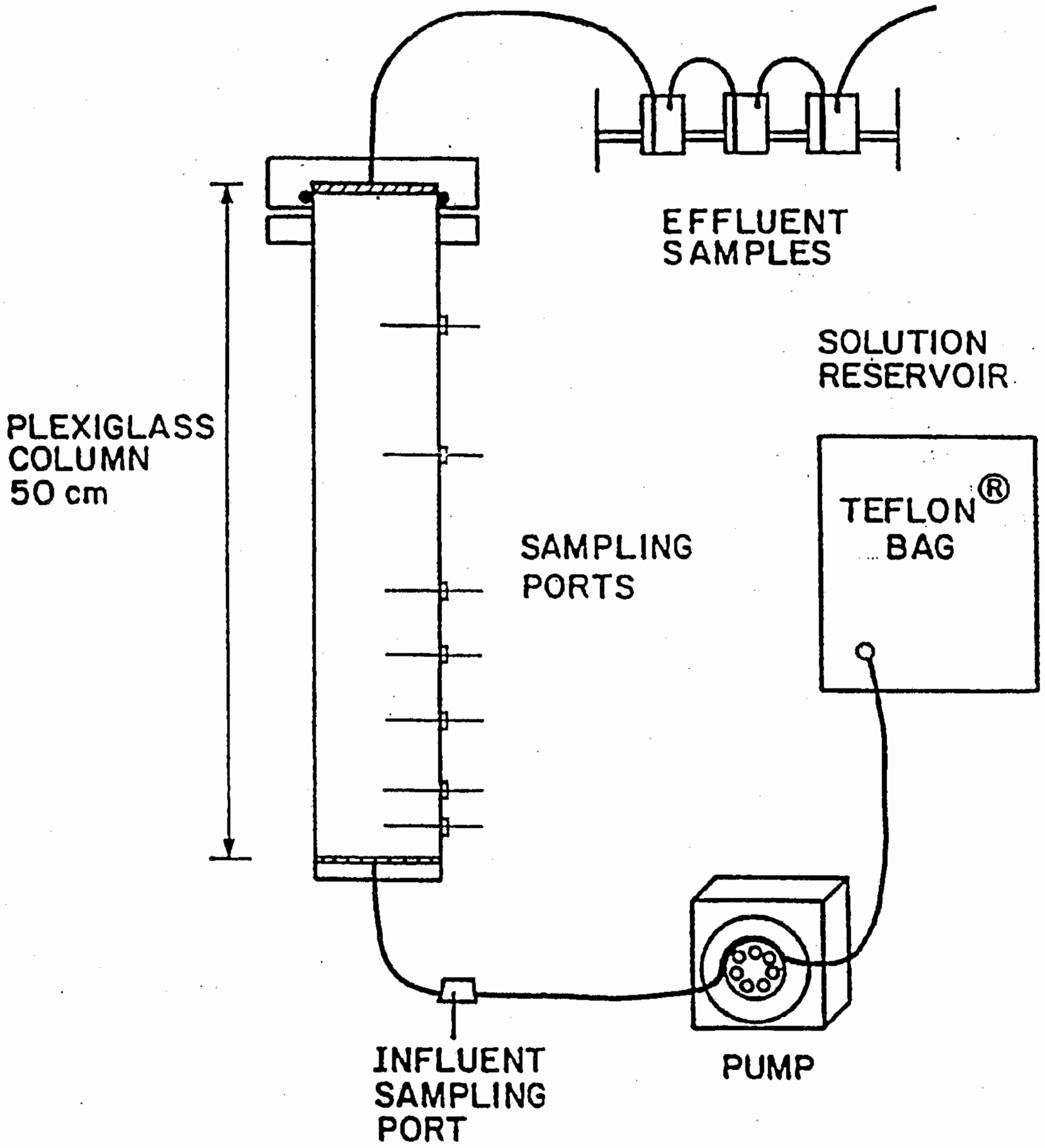
Compound	Successfully Degraded	
	Yes	No
Methanes		
tetrachloromethane	✓	
trichloromethane	✓	
dichloromethane		✓
Ethanes		
hexachloroethane	✓	
1,1,1-trichloroethane	✓	
1,1,2-trichloroethane	✓	
1,1-dichloroethane	✓	
1,2-dichloroethane		✓
chloroethane		✓
Ethenes		
tetrachloroethene	✓	
trichloroethene	✓	
cis-1,2-dichloroethene	✓	
trans-1,2-dichloroethene	✓	
1,1-dichloroethene	✓	
vinyl chloride	✓	
Propanes		
1,2,3-trichloropropane	✓	
1,2-dichloropropane	✓	
Other		
hexachlorobutadiene	✓	
1,2-dibromoethane	✓	
freon 113	✓	

results in clogging of the system and, possibly, coating of the granular iron surface. Clogging or coating inhibits the performance of the system, necessitating replacement or flushing of the granular iron every few years in areas where groundwater may have a high mineral content.

IMPLEMENTATION PROCEDURE

The initial phase in applying the technology at a site involves bench-scale tests, where groundwater from the site is pumped through a column containing granular iron (**Exhibit 2**). These tests determine the degradation rate of the VOCs in the site groundwater under flowing conditions. Data on the initial VOC concentrations and the degradation rate can be used to calculate the amount of time the contaminated groundwater must

Exhibit 2. Schematic of the Apparatus Used in the Bench-Scale Testing



remain in contact with the granular iron (residence time) to enable sufficient degradation to meet treatment objectives. Degradation rates are typically expressed in terms of half-life, or the time needed to lower the concentration by 50 percent.

With this information, and knowing the groundwater velocity, the thickness of the reactive zone (the flow-through distance) can be calculated. For example, **Exhibits 3, 4,** and **5** present results of column tests conducted on groundwater from an industrial facility in New Jersey. **Exhibit 6** shows how the degradation rates were used to calculate the residence times required to meet the objectives for each compound. In this case, though cDCE had a much lower initial concentration than PCE, cDCE was the limiting parameter in the design of the reactor because of its larger half-life and because degradation of PCE resulted in an increase in the cDCE concentration. A small aboveground reactor designed from these data has been operating since November 1994.

Exhibit 3. Degradation of PCE, 100-Percent Iron

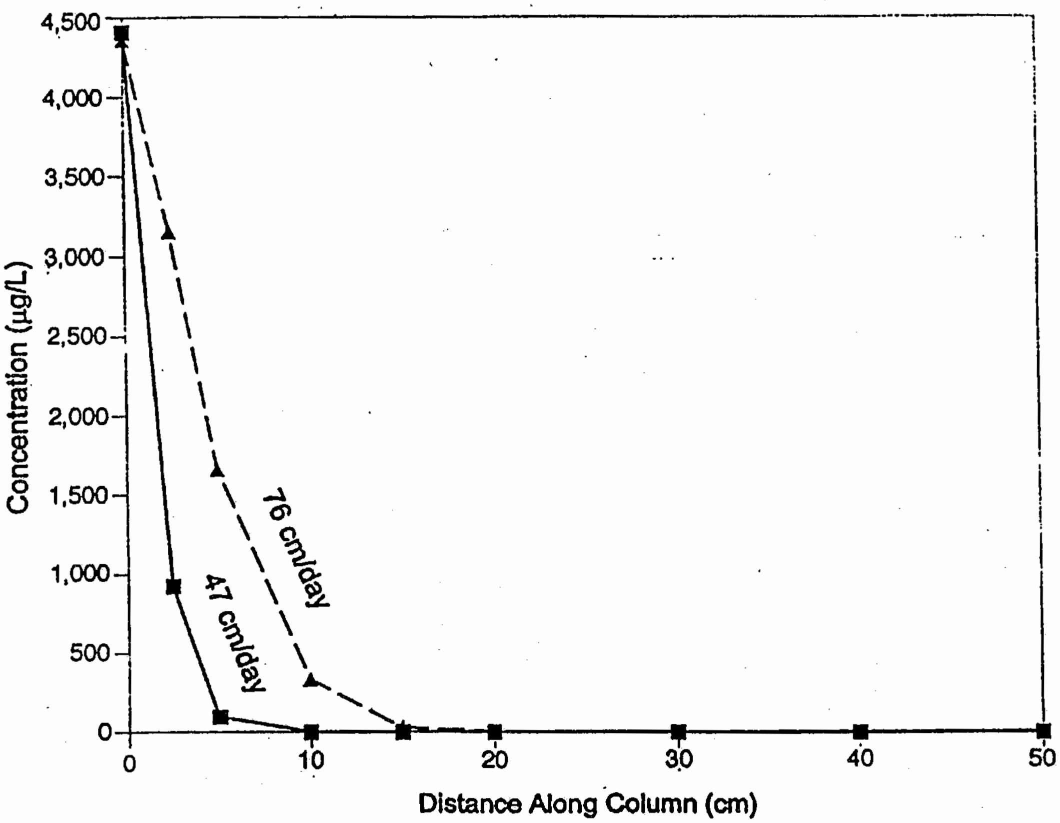
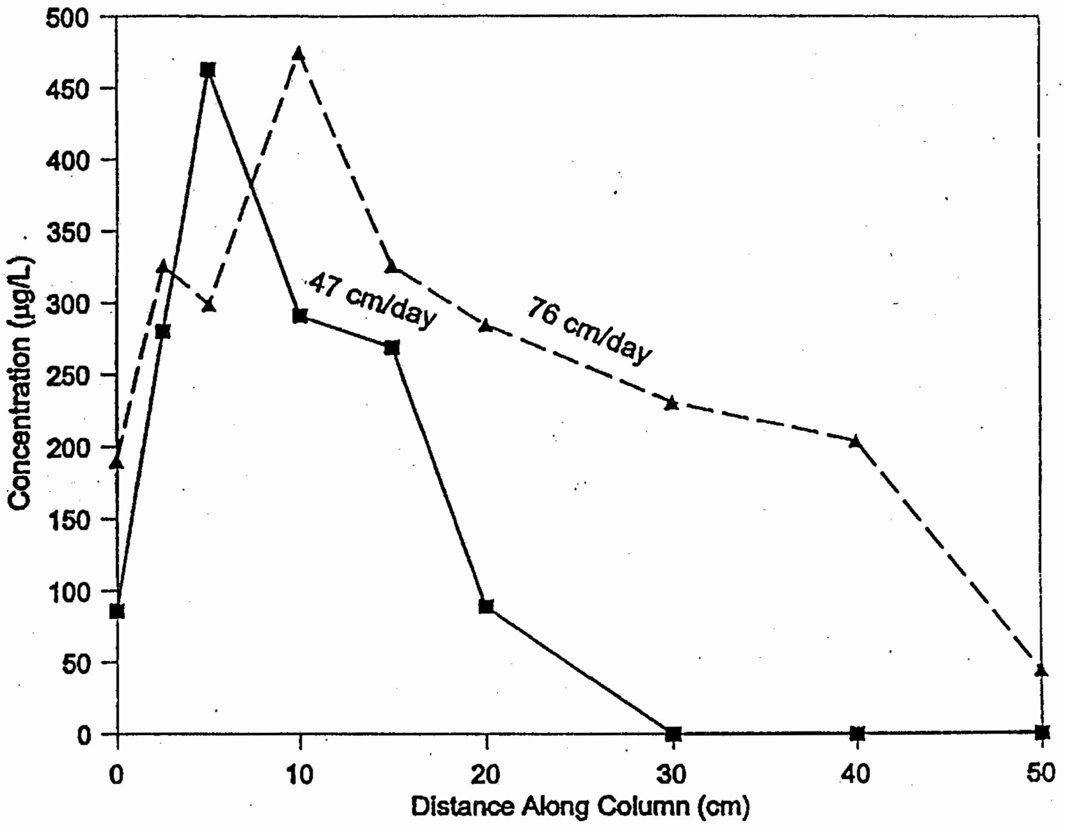


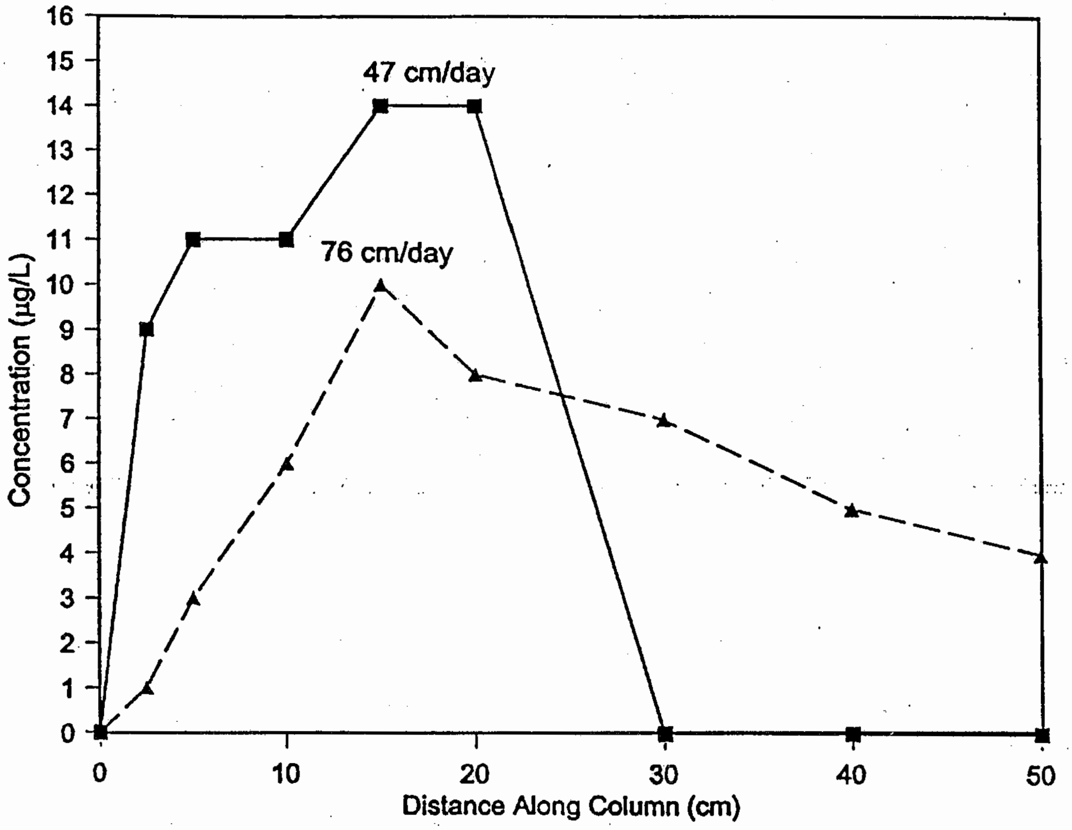
Exhibit 4. Degradation of cDCE, 100-Percent Iron



Inorganic parameters measured in the column influent and effluent during bench-scale tests are used to evaluate the potential for mineral precipitation in the reactive material. The measured parameters include calcium, magnesium, iron, and alkalinity. Another factor that affects the rate at which the degradation of chlorinated VOCs occurs in the presence of granular iron is temperature (the reaction increases with increasing temperature). In the design of a full-scale system, the degradation rates determined by bench-scale tests conducted in the laboratory are often adjusted to take into account groundwater temperature and possible effects of field variations in inorganic geochemistry.

Concurrently or following bench-scale testing, groundwater modeling of the in-situ treatment system is performed to determine the permeable treatment zone dimensions required to create the desired residence time, and the size system required to capture the plume. Two-dimensional or

Exhibit 5. Degradation of VC, 100-Percent Iron



three-dimensional models are used, depending on aquifer characteristics and the configuration of the proposed system (Shikaze et al., 1995). Particle tracking routines in the groundwater model are used to determine residence times in a treatment zone (**Exhibit** 7) and the width of the upgradient aquifer captured by a treatment zone of given dimensions (**Exhibit** 8). Configurations of treatment systems containing granular iron may consist of a continuous permeable wall placed across the contaminant plume, or a "funnel and gate" system where impermeable funnel sections are used to direct groundwater toward permeable treatment zones. The choice of system configuration is based on several factors, including plume configuration and depth, construction costs and the potential for underflow of contaminated groundwater. Because the residence time determined in these models is highly sensitive to the groundwater velocity, the reliability of the modeling results depends on the accuracy of the measurements used to determine the hydrogeologic parameters. Thus, a thorough understand-

Exhibit 6. Design Calculations

Compound	Assumed Initial Concentration (µg/L)	MCL (µg/L)	Laboratory Half-Life (hrs)	Required Residence Time (hrs)
PCE	30,000	1	0.6	8.9
cDCE	3,000	10	1.5	12.3
VC	300	5	1.0	5.9

- cDCE and VC result from PCE degradation
- Required residence time: 8.9 + 12.3 + 5.9 = 27.1 hrs
- Conservative approach
- Adjustments for field conditions

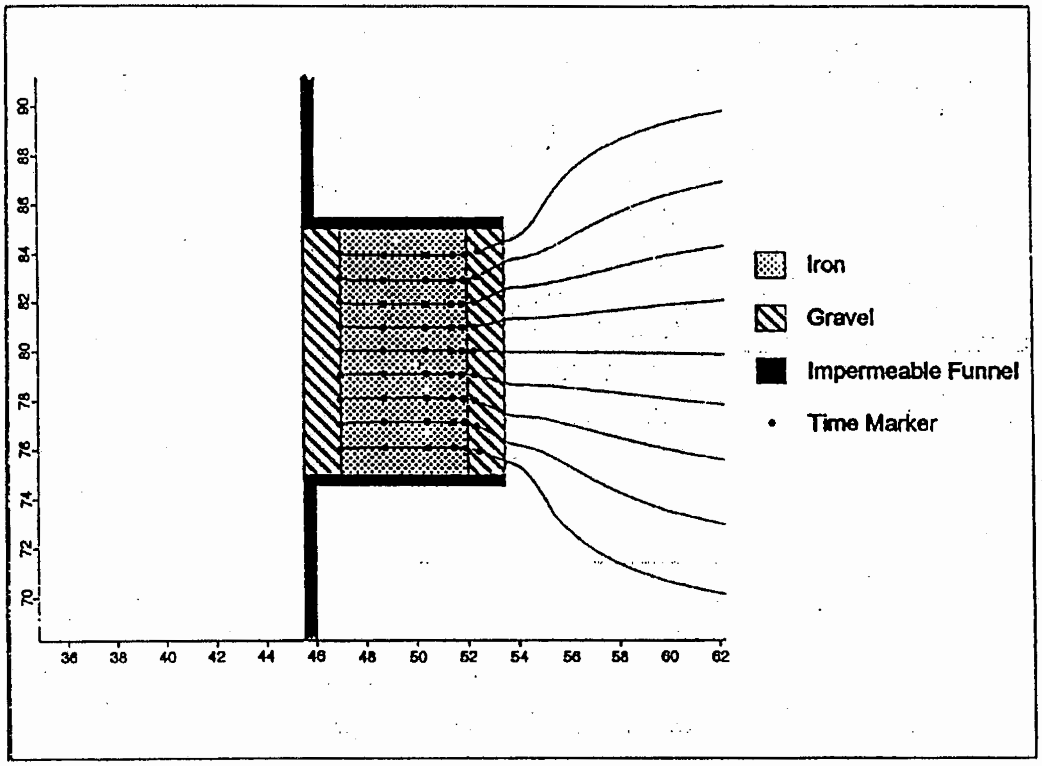
ing of the hydrogeology of the site is essential in developing a treatment system design.

FIELD APPLICATION

The primary factors affecting the installation cost of a reactive iron wall are plume dimensions, upgradient VOC concentrations, and groundwater velocity. These parameters affect the size of the system and treatment zone dimensions, particularly the "flow-through" thickness of the reactive zone required for the necessary residence time. Reactive iron represents a significant component of the installation costs. The unit cost of the original iron source used in the first field applications (in 1994) was approximately $650/ton. This cost has since dropped to between $400 and $450/ton as additional sources of granular iron have been identified and tested.

As mentioned above, either a continuous permeable wall or a funnel-and-gate-system may be employed, based on site-specific characteristics. In either case, the iron is placed deep enough to intercept the saturated thickness of the plume in a treatment zone. Treatment zones to date have been constructed using the following procedure. A rectangular box is built by driving sheet piling. Native material is excavated and replaced with granular iron. The piling on the long axis of the box is then removed to create a flow through the reactive section (Exhibit 7). A layer of pea gravel is placed on either side of the iron, which serves several purposes: (1) to minimize the effects of high velocity layers in the aquifer by spreading flow vertically across the reactive zone; (2) to serve as locations for monitoring well placement; and (3) to facilitate "closed-loop" flushing of the iron

Exhibit 7. Groundwater Model Particle Tracking Routines Used To Determine Residence Time in the Treatment Zone

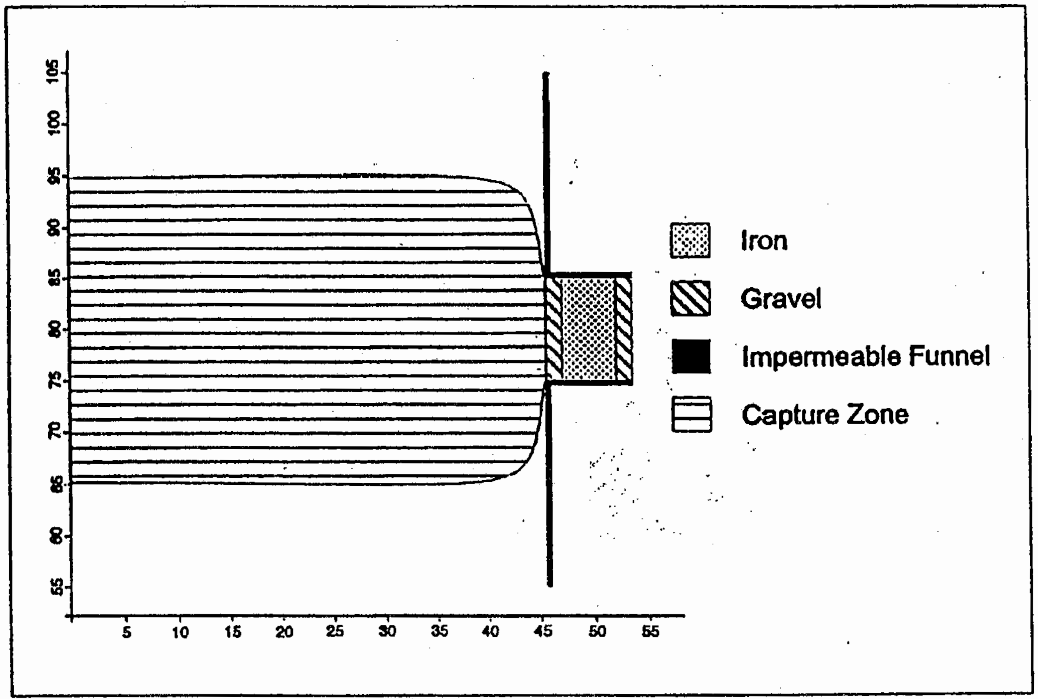


material to remove precipitate build-up, should the need arise. Continuous permeable wall systems involve placing the treatment zone perpendicular to the groundwater flow in a location that intercepts the downgradient edge of the plume. In funnel-and-gate systems, slurry walls or sheet piling is installed to direct groundwater flow through the treatment zone.

Five funnel-and-gate systems have been constructed and are currently operating in the United States. Although no full-scale continuous permeable wall systems have been constructed, one is planned at a site in North Carolina in 1996.

A system to monitor the performance of the system generally consists of long-screened wells placed across the vertical thickness of the iron on the downgradient side of the treatment zone gate. In addition, wells may be placed at various locations within the iron itself. VOC results from these wells, combined with the groundwater velocity, can be used to determine VOC degradation rates in the field. These data are extremely useful when results from a pilot-scale system, placed in a small part of the plume, are

Exhibit 8. Capture Zone Upgradient of a Funnel and Gate



used to "scale up" during the design of a full-scale system.

The three field installations described below include one full-scale installation and two recent pilot-scale installations. It is of some importance to note that health and safety issues played a significant role during these field-scale applications. The iron itself is nonhazardous, with only nuisance dust concerns, but preparing the excavation and placing the reactive material represent a variety of confined-space health and safety requirements.

CASE STUDIES

Industrial Facility, Sunnyvale, California

The first full-scale in-situ treatment wall was installed at a former semiconductor manufacturing facility in Sunnyvale, California, to replace an existing pump-and-treat system. VOCs in the groundwater beneath this facility, including TCE, cDCE, and VC, were degraded rapidly in bench-scale tests. Degradation rates were further evaluated in a field-test reactor (a large fibreglass canister) containing 50-percent iron and 50-percent sand by weight at a flow velocity of 4 ft/day for nine months. Influent concentrations, half-lives, and required residence times are presented in **Exhibit 9**. Measured degradation rates in Exhibit 9 are expressed in terms of half-life.

Following regulatory approval, a full-scale in-situ wall was installed in December 1994. The reactive zone is four feet wide, 40 feet long, and about 20 feet deep, and contains 100-percent granular iron. The permeable wall is flanked by slurry walls on either side, one 225 feet long and one 250 feet long, to direct groundwater flow toward the permeable section. Approximately 220 tons of iron were placed in the reactive zone. The total capital costs for the system, including the slurry walls, were about $720,000. Since the system was installed, no VOC concentrations exceeding maximum contaminant levels (MCLs) have been detected from downgradient monitoring wells.

As part of this design, hydrogen gas generation rates measured in the laboratory (Reardon, 1995) were used to evaluate the need for a hydrogen gas collection system. Based on an evaluation of microbial hydrogen gas consumption rates, no need for a gas collection system was indicated. Groundwater from within the field test canister was sampled for phospholipid fatty acid (PLFA) analysis to evaluate the potential for microbial growth in the reactive material. These results indicated that the reactive material did not encourage the development of a microbial population beyond the population observed in "background" groundwater. This has also been observed in groundwater samples taken from other in-situ installations.

Industrial Facility, New York

Following successful bench-scale studies, a pilot-scale in-situ funnel and gate was installed in May 1995 to treat up to 300 ppb of TCE, up to 500 ppb of cDCE, and up to 80 ppb of VC present in a shallow aquifer at an industrial facility in New York. A 12-foot-wide, 3.5-foot-thick central

Exhibit 9. Field Canister Test Results Using 50-Percent Iron and 50-Percent Sand by Weight

VOC	Influent Concentration (ppb)	Half-Life (hrs)	Time to Reach MCLs (hrs)
TCE	210	1.7	10
cDCE	1.415	0.9	7
VC	540	4.0	43

reactive section is flanked by 15 feet of sheet piling extending laterally on either side. The installation, which was keyed into a clay layer located approximately 14 to 15 feet below the ground surface, took about ten days to complete. This trial was monitored through the EPA Superfund Innovative Technology Evaluation (SITE) Program for six months, through the summer and fall of 1995. VOC concentrations have been reduced to MCLs within 1.5 feet of travel through the reactive media (**Exhibit 10**). Based on water level data, the velocity through the zone is about 1 foot/day, and a portion of the plume about 24 feet wide is being captured and treated. Costs for the installation of this system, about $250,000, included $30,000 for approximately 45 tons of iron. Preliminary microbial analyses on groundwater samples from the site show a significant decrease in microbial population in the iron relative to the population present in the aquifer, either upgradient or downgradient of the reactive zone. This indicates that the sysem operation should not be significantly inhibited by biofouling.

Industrial Facility, Kansas

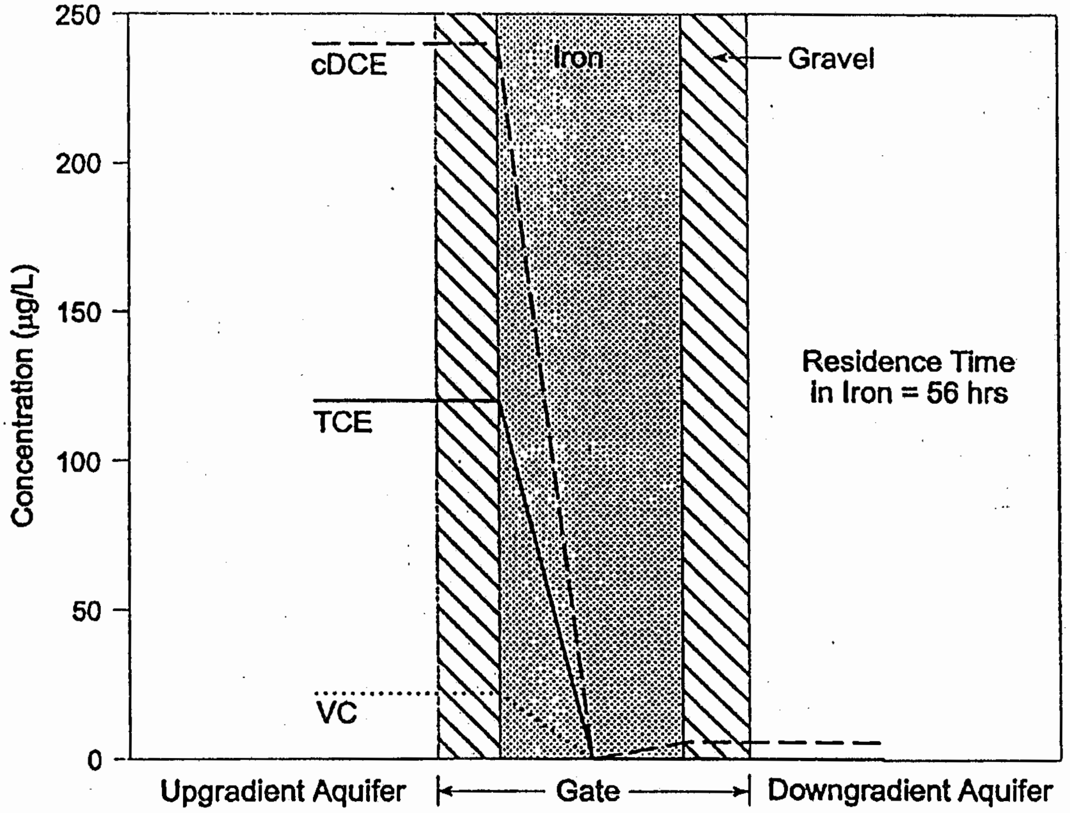
A 1,000-foot-long funnel-and-gate system was installed at the property boundary of an industrial facility in Kansas in January 1996 to treat about 100 to 400 ppb of TCE in groundwater migrating across the property boundary. The TCE occurs in a basal alluvial sand and gravel zone overlying the local bedrock, at a depth of about 30 feet. Low natural groundwater velocity permitted the use of a high funnel-to-gate ratio (490 feet of funnel on either side of a 20-foot-long gate). That is, the velocity increase due to the funneling action still permitted a reasonably sized treatment zone to be built. The reactive zone was placed from about 30 feet to 17 feet below ground surface and had a flow-through thickness of three feet. Excavated soil was placed from the top of the zone to the ground surface. The "funnel" sections of this system consisted of a soil-bentonite slurry wall. The gate section was excavated in the center of the slurry wall after the slurry was allowed to set. Inclement weather and the Christmas holiday season extended the construction period; however, the contractor estimated that under optimum conditions, the soil-bentonite slurry wall could have been built in one to two weeks, and the gate section in one week. The installation costs, including slurry walls and gate, and 70 tons of granular iron, were about $400,000.

The major factor affecting operation and maintenance costs is the possibility of periodic removal of precipitates from the reactive material.

OPERATION AND MAINTENANCE REQUIREMENTS

Other than groundwater monitoring, the major factor affecting operation and maintenance costs is the possibility of periodic removal of precipitates from the reactive material, perhaps by "closed-loop" flushing, or periodic replacement of the affected sections of the material if the precipitates cannot otherwise be removed. Before implementation it is difficult to judge the extent to which inorganic precipitates may occur; however, porosity losses due to inorganic mineral precipitates from 2 to 15 percent per year have been predicted based on laboratory column results. It has been suggested that the amount of precipitation that will

Exhibit 10. Field VOC Concentrations Through 100-Percent Iron



occur in-situ will be significantly less than predicted from laboratory studies, due to the condition of groundwater used in the laboratory. Groundwater sampling and transport can shift the carbonate equilibrium, causing groundwater used in the laboratory tests to be supersaturated with calcium carbonate before it enters the reactive iron column. No significant precipitates were observed in the in-situ reactive wall at the University of Waterloo Borden test site almost four years after it was installed. This wall has now been performing consistently for 4.5 years. Data from in-situ systems installed in California and from other in-situ field trials will generate further inorganic data to better evaluate this issue.

Although the need for rehabilitation or replacement has yet to be demonstrated, the possibility should be recognized when evaluating the economic viability of a treatment system. Rehabilitation or replacement costs can be calculated by assuming that a percentage of the original iron costs will need to be spent every five to ten years. The percentage and frequency are site-specific; for example, for very high TDS (carbonate) groundwaters, 75 percent of the iron costs might be expended at five-year intervals; for lower TDS groundwater, one might assume expenditures of only 25 percent of the iron costs every ten years.

TECHNOLOGY ADVANCEMENT

There are several areas where the commercial application of reactive iron walls can possibly be enhanced. One is to extend the depth of the treatment zone. Contractors indicate that the "sheet pile box" method for constructing permeable treatment zones is most cost-effective with depths up to 45 feet. A number of techniques for deeper placement of reactive material are being evaluated. Another significant area of potential improvement is the integration of this technology with others to treat groundwater plumes containing a mixture of contaminants. ETI is providing technical review and design support to the Advanced Applied Technology Demonstration Facility for Environmental Technology (AATDF), a Rice University/ Department of Defense project at the University of Waterloo Borden test site, where granular iron will be used in combination with other in-situ technologies to treat mixed plumes of chlorinated and nonchlorinated VOCs. In addition, a permeable wall containing granular iron will be installed in 1996 to treat a combined TCE and chromium plume emanating from a source area beneath a former machine shop at a facility in North Carolina. Also, considerable interest has been expressed at DOE sites where the technology may be used to treat combined plumes of chlorinated VOCs and trace radionuclides. A variety of methods of enhancing the iron degradation rates are being investigated. Should these be successful, the technology may be more applicable to aboveground treatment systems. Field trials of these enhancements will be initiated in mid-1996.

There are several areas where the commercial application of reactive iron walls can possibly be enhanced.

ACKNOWLEDGMENTS

We wish to thank the firms of Geomatrix Consultants (California site), Stearns and Wheler (New York site) and SECOR (Kansas site) for provision of construction information and cost data on these projects. The support of the owners of these installations is also appreciated. ■

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Appendix C

Groundwater Modeling Study

GROUNDWATER MODELING FOR CONTINUOUS AND FUNNEL AND GATE SYSTEM

Ash Landfill, SEDA, Romulus, NY

1.0 BACKGROUND

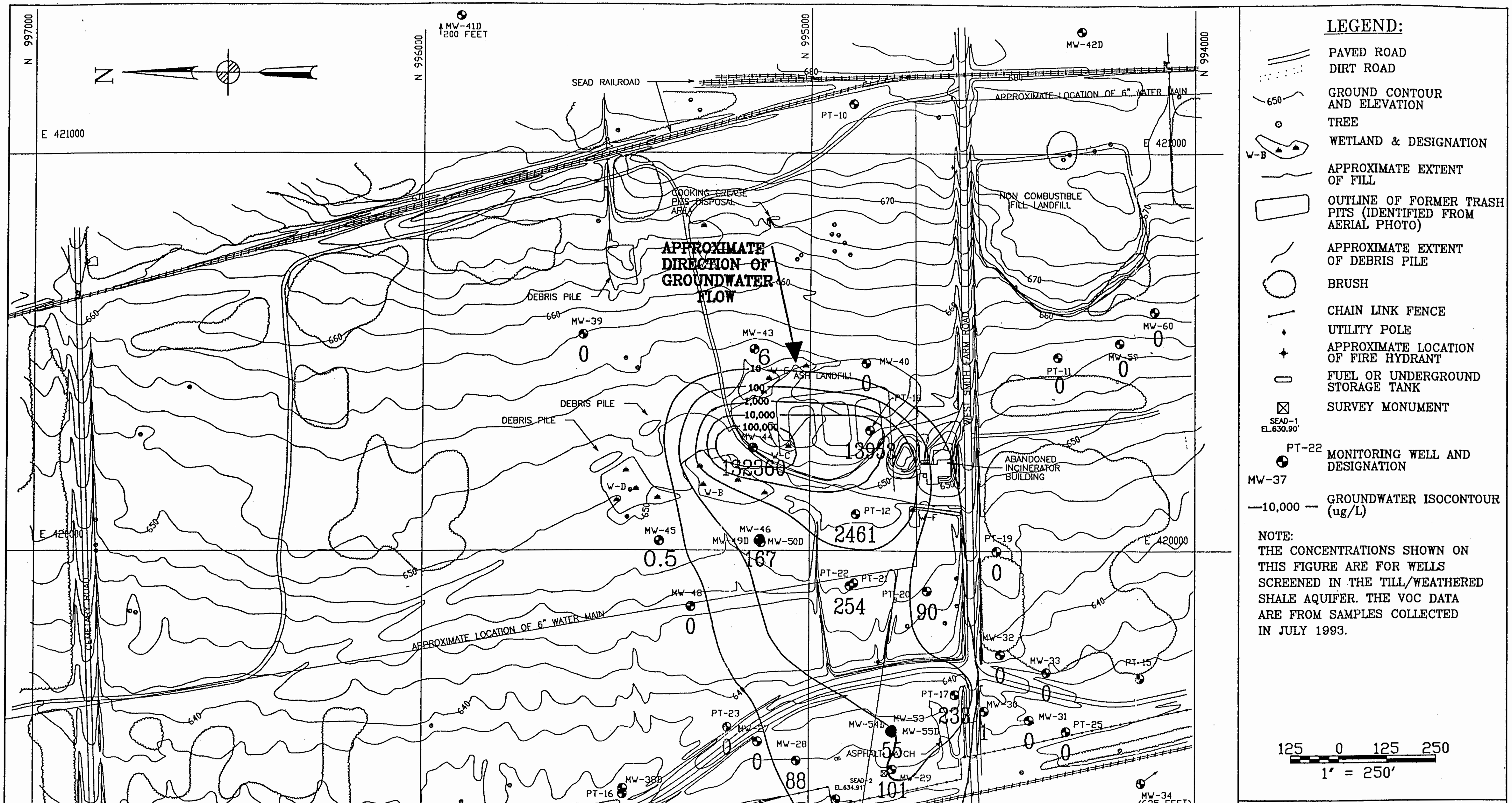
A groundwater plume, consisting primarily of dissolved trichloroethene (TCE) and dichloroethene (DCE), was delineated as part of the remedial investigation (RI) (Parsons ES, 1994). The depth to the water table at the Ash Landfill site is relatively shallow, ranging from less than a foot during the spring to eight feet during the late summer/early fall. Consequently, the aquifer thickness ranges from approximately two to ten feet. The aquifer material is comprised of a low hydraulic conductivity glacial till/weathered shale material. The concentration of total volatile organic compounds (VOC) at every monitoring well and the extent of the plume at the time of the RI in 1992 is presented as Figure 1. The plume was determined to have originated at a source area near the western edge of the Ash Landfill and extended to the western boundary of the SEDA. Following delineation of the soil source area, the Army implemented a removal action, using Low Temperature Thermal Desorption (LTTD), between September 1994 and June 1995. This proactive effort successfully eliminated the presence of chlorinated organics in the soil source area. These materials were considered to have been responsible for the presence of the groundwater plume depicted as Figure 1. The removal action treated approximately 35,000 tons of impacted soil and a large volume of source area groundwater.

Groundwater monitoring has been on-going since the initial plume discovery and has continued following the removal action. Recent groundwater monitoring data from the second quarter of 1997, was used to supplement the previously available groundwater quality data in order to depict the reductions in concentrations that resulted from the removal action. This data is presented as Figure 2. Source area concentrations of VOCs in groundwater have been reduced by approximately 80 percent at well PT-18 and by 99 percent at MW-44A, (Figure 2). Both of these monitoring wells are located near or at the former source area.

Groundwater control alternatives were assembled and evaluated as part of a feasibility study (FS), (Parsons ES, 1996). These alternatives included:

- No Action
- Natural Attenuation with an Alternative Water Supply
- In-situ Treatment with Zero Valence Iron or Air Sparging
- Extraction, Treatment and Surface Water Discharge options.

In-situ treatment was determined to be a cost effective alternative, compared to extraction, treatment and discharge options, due to the minimal operation and maintenance (O&M) requirements associated with the in-situ alternative. With base closure as a consideration, in-situ treatment using a chemical reactant, such as zero valence iron, was determined to have advantages over other in-situ technologies, such as air sparging, since a chemical reactant does not require a mechanical system to operate and maintain.



NOTE:
THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILL/WEATHERED SHALE AQUIFER. THE VOC DATA ARE FROM SAMPLES COLLECTED IN JULY 1993.

PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

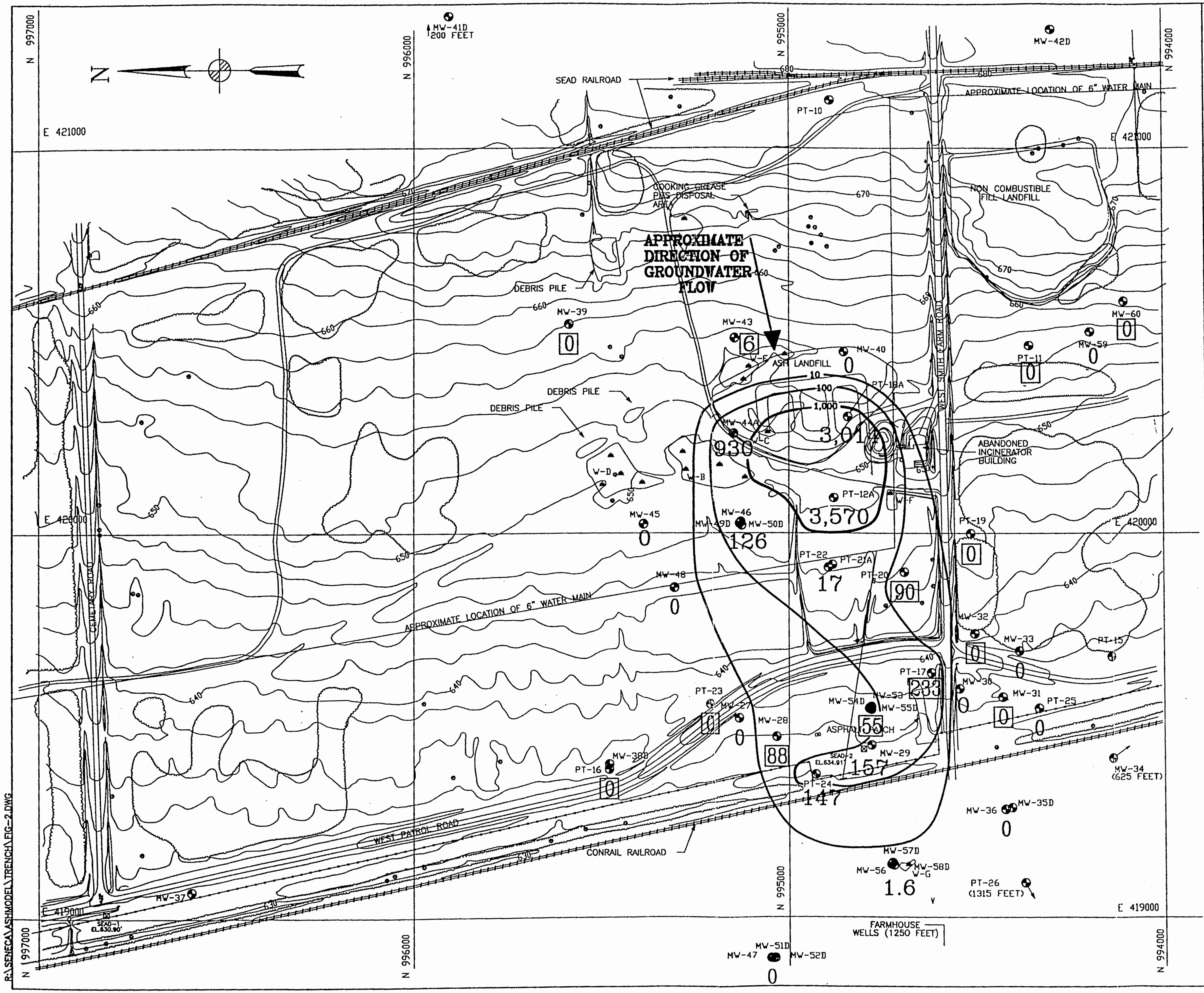
SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

DEPT.	Dwg. No.
ENVIROMENTAL ENGINEERING	726209-01002

FIGURE 1

ASH LANDFIL SITE MAP WITH VOLATILE ORGANICS PLUME: PRE-REMOVAL ACTION CONDITIONS

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0



NOTE:
THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILL/WEATHERED SHALE AQUIFER.

PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY
ASH LADFILL GROUNDWATER MODEL

DEPT. ENVIROMENTAL ENGINEERING	Dwg. No. 726209-01002

FIGURE 2

ASH LANDFIL SITE MAP WITH VOLATILE
ORGANICS PLUME: POST-REMOVAL ACTION CONDITIONS

SCALE AS NOTED	DATE DECEMBER 1997	REV 0

R:\SENECA\ASHMODEL\TRENCH\FIG-2.DWG

In-situ reactive treatment walls can achieve contaminant reductions through chemical and/or physical interactions between dissolved pollutants and reactive wall constituents, Vidic and Pohland (1996) and EPA (1995). For the treatment to be effective, groundwater must pass through the reactive portion of the wall. This is typically accomplished by an efficient wall design configuration using either a funnel and gate configuration or a continuous reaction wall configuration. Once groundwater is intercepted it can be reacted with a variety of materials including activated carbon, air sparging, Oxygen Releasing Compounds (ORC) and zero valence iron. Zero valence iron has shown promise as an effective reactant in eliminating dissolved chlorinated organics from groundwater and has been selected for application at the Ash Landfill site.

The application of zero valence iron for groundwater pollution control is patented by researchers from the University of Waterloo, Ontario Canada. One vendor, EnviroMetal Technologies, Inc. holds licensing agreements in the application of zero valence iron for reactive walls. Parsons ES has contacted this vendor regarding the application of zero valence iron at this site. EnviroMetal Technologies has provided a summary of similar in-situ field projects that have successfully utilized both zero valence iron with both the funnel and gate configuration and the continuous wall configuration (personal communication). These reports have provided useful information pertaining to the design and construction of both the continuous reactive wall system and the funnel and gate systems. The largest funnel and gate system using the zero valence iron treatment consisted of 1,040 ft of funnel section and four reactive gate sections each 40 ft wide. This technology has also been recently installed at a site in New York for removal of dissolved TCE in groundwater. Data from this installation indicates that the system has achieved the contaminant reduction goals.

Both groundwater collection configurations, the permeable wall and the funnel and gate configuration, were considered feasible for the in-situ alternative. The permeable wall has advantages in simplicity and ease of constructability. However, given the large fluctuation of the annual water table there is concern regarding the long term performance of zero valence iron when it is not continuously submerged. The effectiveness of zero valence iron may be reduced due to cyclic, exposure to submerged, low oxygen conditions, and non-submerged, higher oxygen conditions. This condition may require replacement of the zero valence iron. If replacement is required, the permeable wall configuration would require the entire trench to be excavated in order to replace the zero valence iron.

The funnel and gate configuration involves migration of groundwater along the impermeable wall to one or more gates filled with zero valence iron where the contaminants are destroyed via reductive dechlorination. A funnel and gate configuration offers advantages over a permeable wall in ease of change-out and greater ability to maintain saturated conditions in the zero valence iron. Although ease of change out is an advantage restricting groundwater flow through the gates can lead to hydraulic concerns. High water table conditions, combined with the low hydraulic conductivity soils, can lead to a large groundwater mound causing groundwater to be released at the ground surface or move around the confines of the collection trench. These concerns are less for typical extraction and treatment design that induce flow toward a well or a collection trench and continuously remove groundwater.

The application of the funnel and gate approach for groundwater collection is discussed by Starr and Cherry (1994). This paper presents the general configuration of the funnel and gate system and illustrates the effects of the cutoff wall and various gate configurations on the size and shape of the capture zone. The funnel diverts groundwater to the gate thereby increasing the amount of water through the gate cross-sectional area. As captured water is diverted to the gate there is a corresponding reduction in piezometric head at the funnel boundaries causing the capture zone to extend to near the edge of the wall. Starr and Cherry concluded from their analyses that for a given length of cutoff wall, the most efficient configuration, in an isotropic aquifer, is a funnel with sides of 180 degrees apart, oriented perpendicular to the regional hydraulic gradient. They also suggest that seasonal variation in the direction of groundwater flow and capture zone size be considered during design. No variation in the direction of groundwater flow has been observed at the Ash Landfill during the several years of monitoring.

Both a continuous reaction wall, and several funnel and gate configurations were modeled for this study. The continuous reaction wall is not expected to alter the existing groundwater flow regime. Groundwater will flow into and pass through the entire length of the treatment wall. This is because the reactive/treatment material in the wall has a higher permeability than the surrounding till/weathered shale aquifer, and thus groundwater will flow through the wall, unrestricted.

A funnel and gate configuration will have a significant effect on a groundwater flow regime as it relies on impermeable, cut-off walls to capture and redirect groundwater flow through the reactive gates. The reactive gates are positioned at strategic openings in the impermeable wall. Because it restricts flow, and the average hydraulic conductivity of the till/weathered shale aquifer, (3.6×10^{-4} cm/sec or 1.0 ft/day), is low, the funnel and gate design will produce an upgradient mounding of groundwater with the potential for breakout at the ground surface. An upgradient groundwater mound can cause divergent flow around the edges of the impermeable wall, if the mounding is larger than the ability of the trench to capture the flow. Thus, a funnel and gate configuration is hydraulically more complicated than the continuous reaction wall. Modeling was identified as a useful tool to provide valuable information regarding the most efficient wall configuration. Using a calibrated groundwater model, it is possible to consider a variety of configurations and select the optimum configuration of gates and cut-off walls to capture the VOC plume.

The funnel and gate design configurations investigated included: none, two, three and four gates. Modeling of a continuous, permeable, wall configuration with no gates was also performed. A discussion of these simulations is provided below.

2.0 OBJECTIVES

The purpose of any collection and treatment alternative is to capture groundwater and treat it to concentrations below established criteria. To accomplish this an alternative must continuously capture groundwater efficiently. Thus, for the funnel and gate alternative to be feasible, the capture zone must be understood. Potential operational difficulties must also be considered to ensure the long term operational effectiveness of this alternative. Groundwater modeling was selected as a cost effective tool to address these issues and support the trench design.

The overall objective of this effort is to evaluate the hydraulic behavior of such a potential system. To achieve this overall goal Parsons ES has conducted a groundwater flow modeling effort with the following objectives :

- Determine the optimal length of collection trench to prevent the plume from migrating past the edge of the trench.

- Determine the optimal number of gates to effectively treat the collected groundwater.
- Evaluate the potential for groundwater levels to rise above the ground surface during high water conditions.
- Estimate the expected groundwater flow into the reactive gate.
- Develop an expected time of travel to the reactive wall.

3.0 GROUNDWATER FLOW MODEL SIMULATION

A groundwater flow model, using MODFLOW, had been developed previously to evaluate the potential for natural attenuation as remedial alternative. This model used to evaluate natural attenuation involved a larger scale model than the current model because of the requirement to evaluate the potential for off-site migration. The results of this previous modeling effort is presented in the "Groundwater Modeling Report at the Ash Landfill" (Parsons ES, 1996). As many site conditions have remained constant, the current modeling effort has been based on the larger-scale model that established the groundwater flow system. This system was based on site physical and hydraulic boundaries, such as the groundwater divide near Route 96, the constant head at Seneca Lake and streamline no-flow boundaries to the north and south.

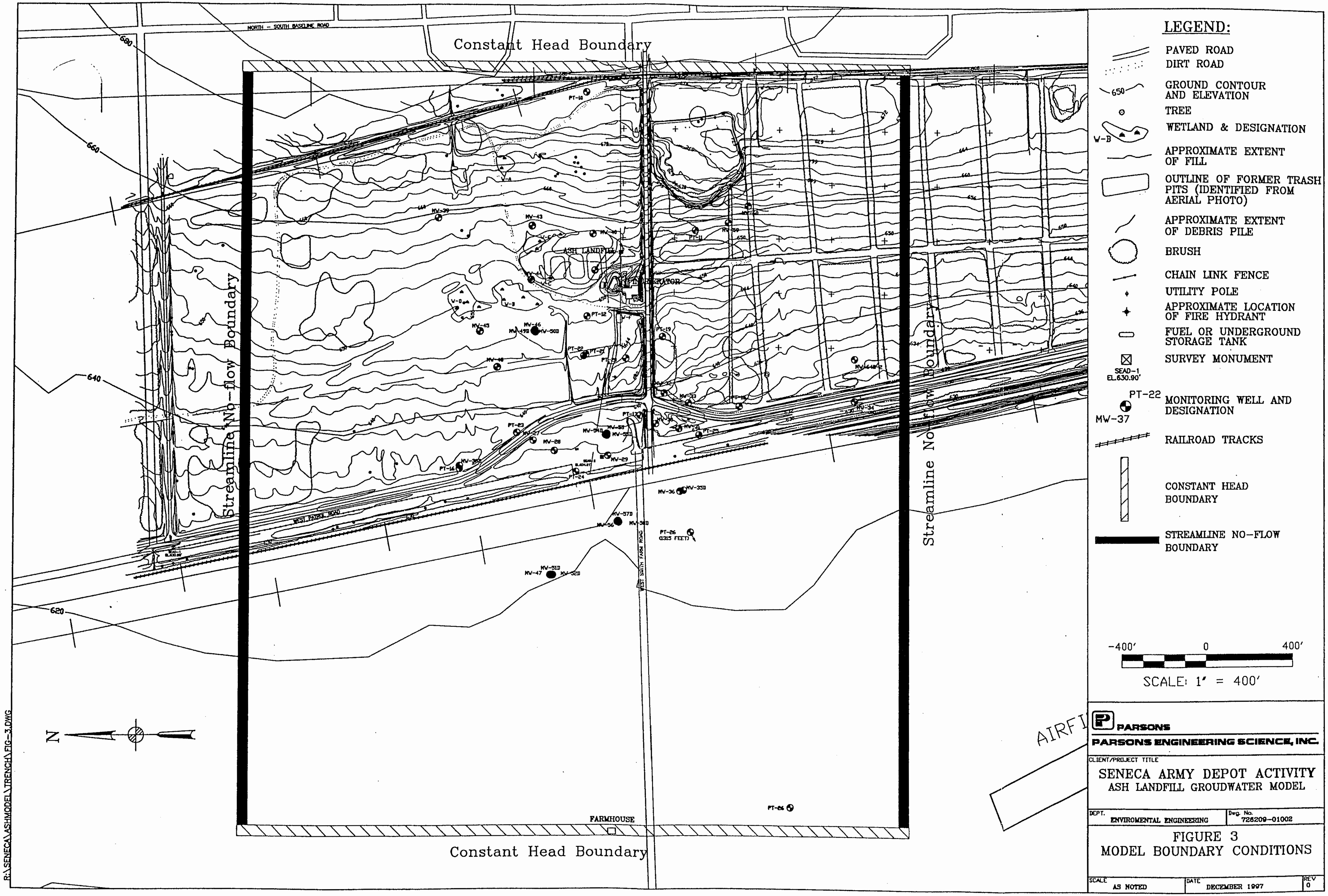
The new model is limited to the on-site plume area that extends up to the site boundary. This area allows the model to yield sufficient detail in the area of interest without making the model to large. Constant head boundaries were established on the upgradient (eastern) and downgradient (western) sides of the model, and streamline no-flow boundaries were established on the northern and southern sides (Figure 3). Input parameters used in the previous MODFLOW model were used to establish the boundaries of the current model and are shown in Table 1.

Groundwater Vistas (GV) Version 1.91 was used as the interface for MODFLOW and MODPATH, two widely used computer models developed and originally described by the United States Geological Survey (USGS) to simulate groundwater flow and water particle tracking (i.e., capture zone analysis). MODFLOW$^{\text{win32}}$ was used for the groundwater flow modeling, and MODPATH Version 3 was used for water particle tracking at the Ash Landfill site.

A block-centered finite difference grid was overlaid over the area to be modeled such that the horizontal plane of the aquifer was approximately collinear with the principle directions of hydraulic conductivity tensors Kx and Ky (Figure 4). The grid spacing was variable with each layer consisting of 45,843 cells; the entire model was comprised of 137,529 cells. A grid spacing of 5 ft was used in the area of the treatment wall to provide sufficient hydraulic details. Beyond this area of regularly spaced cells, the grid was expanded by 1.2 times until a spacing of 50 ft was reached; this spacing extended to the model boundaries in all directions. The model boundaries were established at a distance that was expected to be far enough away so that the influence from the remediation designs would be negligible.

The flow model used a stratigraphic three-dimensional grid (Figure 5) that was comprised of three discrete flow zones or model layers in order to represent current site conditions.

The three flow units that were modeled are:



R:\SENECA\ASHMODEL\TRENCH\FIG-3.DWG

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SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUDWATER MODEL

DEPT.	Dwg. No.
ENVIROMENTAL ENGINEERING	726209-01002

FIGURE 3
MODEL BOUNDARY CONDITIONS

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0

Table 1

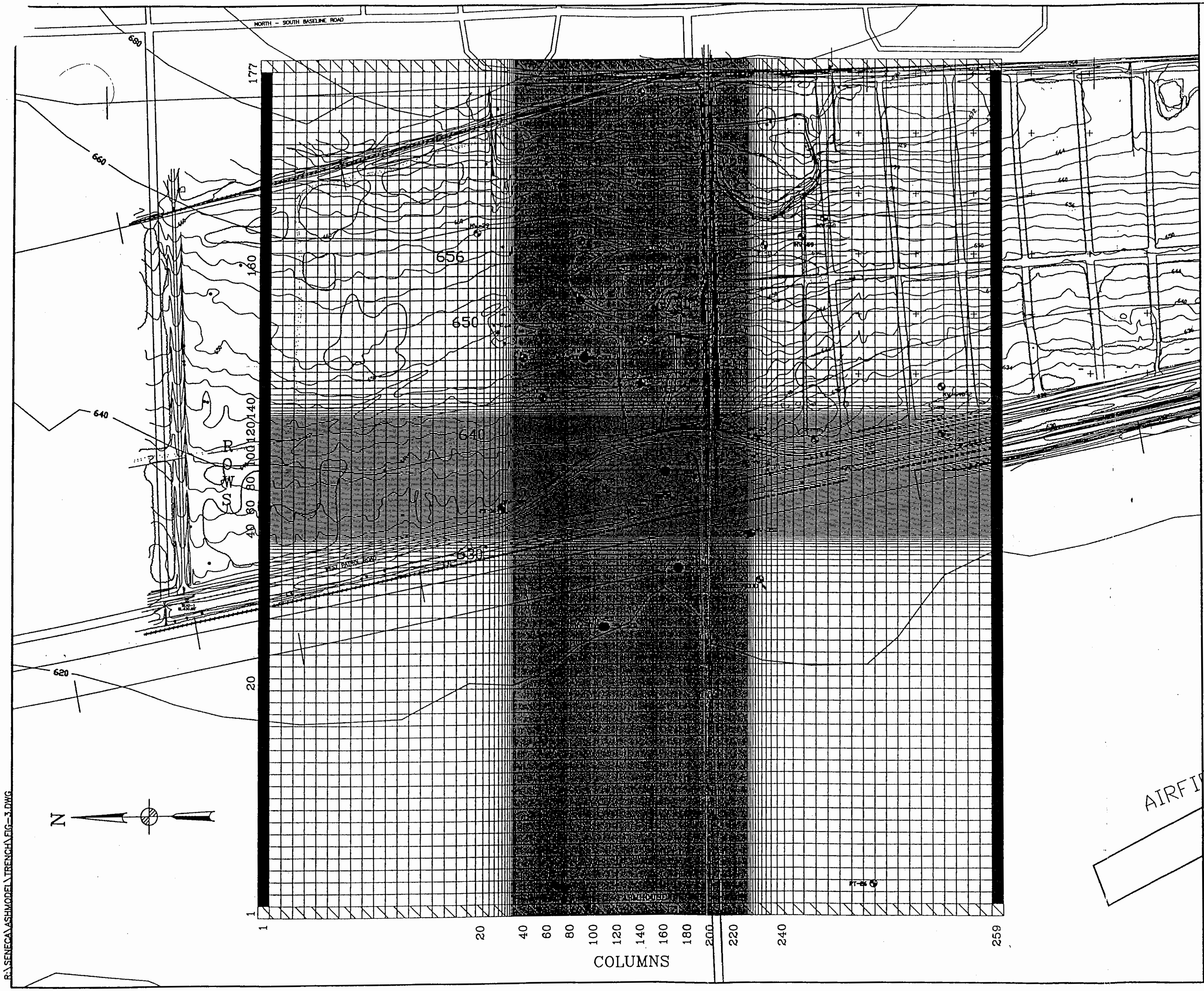
Modflow Input Parameters for Calibrated Ground Water Flow Model (Average Conditions)[1]

Seneca Army Depot Activity
Ash Landfill Groundwater Trench Model

Parameters	Units	Value/Type	Uncertainty	Scource
Aquifer Types:				
Layer 1	NA	unconfined	low	field data
Layer 2	NA	confined	low	field data
Layer 3	NA	confined	low	field data
Layer Thicknesses:				
Layer 1	(feet)	12	low	field data
Layer 2	(feet)	20	low	field data
Layer 3	(feet)	20	low	field data
Conductivity:				
Layer 1 Kh	(feet/day)	1.03 - 2.01	low	field data
Layer 1 Kv	(feet/day)	0.11	medium	Literature
Layer 2 Kh	(feet/day)	0.2	low	field data
Layer 2 Kv	(feet/day)	0.02	medium	Literature
Layer 3 Kh	(feet/day)	0.04	low	field data
Layer 3 Kv	(feet/day)	0.0004	medium	field data
Transmissivity:				
Calculated by model				
Boundaries:				
Northern Boundary	NA	streamline no-flow	low	field data/gw model
Southern Boundary	NA	streamline no-flow	low	field data/gw model
Eastern Boundary	NA	constant head	low	field data/gw model
Western Boundary	NA	constant head	low	field data/gw model
Bottom Boundary	NA	low conductivity	low	field data/gw model

Notes:

1) A small recharge value (5×10^{-5} ft/day) was added to the model to calibrate to the high water table conditions.



R:\SENECA\ASHMODEL\TRENCH\FIG-3.DWG

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SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

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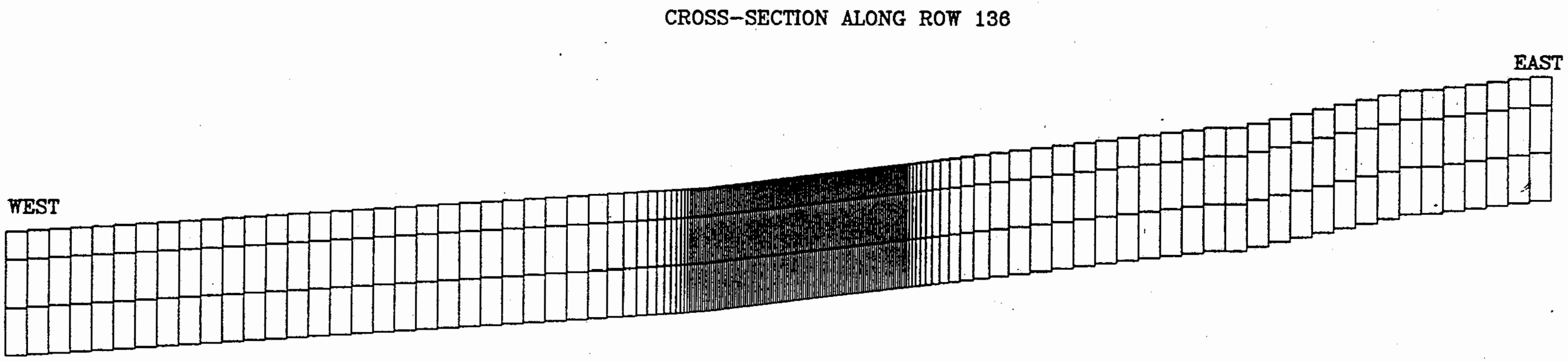
FIGURE 4
GROUNDWATER FLOW MODEL GRID AND BOUNDARY CONDITIONS

SCALE AS NOTED	DATE DECEMBER 1997	REV 0



NOTE:
VERTICAL EXAGGERATION 10X.

SCALE: 1″ = 400′

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FIGURE 5
CROSS SECTION OF MODEL GRID

SCALE AS NOTED	DATE DECEMBER	REV 0

R:\SENECA\ASHMODEL\TRENCH\DWG\FIG-5.DWG

- Layer 1 represents the till/weathered shale unit that extends from 0 to 12 ft below the ground surface. Horizontal and vertical flow is capable through the largely porous media;
- Layer 2 represents the competent shale unit that is comprised of some horizontal and vertical fractures that extends from 12 to 32 ft below the ground surface. Flow is possible through the existing fracture planes; and
- Layer 3 represents competent shale that is comprised of almost no fracture planes, extending from 32 ft to 52 ft below the ground surface.

3.1 THE FUNNEL / CUT-OFF WALL

The length of the funnel was established at 645 feet. This is slightly greater than the width of the plume of VOCs to ensure complete capture. The funnel was positioned at the "toe" of the plume, at the depot perimeter to eliminate the potential for off-site migration of the plume, see Figure 9. The cut-off wall was simulated using the horizontal flow barrier (or wall) package of MODFLOW. This package simulates a thin, vertical, low permeability wall that will impede the horizontal flow of groundwater between two adjacent model cells. The cut-off wall extended from the ground surface to the bottom of the till/weathered shale (i.e., bottom of Layer 1). The wall was simulated with funnels 180 degrees apart, oriented perpendicular to the regional hydraulic gradient, as recommended by Starr and Cherry (1994). The southern portion of the trench wall bends at an angle of approximately 19 degrees to avoid the chain link fence at the depot boundary. In total, the wall (or funnel) was 645 ft long. The required length was based on the most recent observed width of the existing VOC plume.

The model simulated a cut-off wall constructed of an impermeable material, such as high density polyethylene (HDPE), having a low conductivity of $1\text{x } 10^{-13}$ cm/sec or $2.8 \text{ x } 10^{-10}$ ft/day, Delvin and Parker, (1996). Delvin and Parker, (1996) suggest that diffusion may be a mechanism of transport across the impermeable material if strong concentration gradients are present on either side of the impermeable material. This was not considered likely as large concentration gradients do not exist at in the location of the trench.

For this simulation, a 1.5-ft thick permeable zone with the conductivity equivalent to a clean sand ($1 \text{ x } 10^{-2}$ cm/sec or 28 ft/day, Freeze and Cherry, 1979) was simulated on the upgradient and downgradient sides of the cut-off walls and gates. The sand on the upgradient side of the cut-off wall provided a permeable channel for groundwater to flow toward the gates, and then, once through the gates, the sand on the downgradient side provided a preferred pathway for the distribution of groundwater into the aquifer. A 1.5-ft thick sand zone was simulated on each side of the impermeable wall. This thickness was used because of the anticipated construction methods to be used for the trenching at the Ash Landfill site. A typical excavator bucket cuts a 3-ft wide trench. The impermeable wall and the permeable up- and downgradient sand zones will be installed in one pass with the excavator.

3.2 THE GATES

Treatment gates were simulated to be 5 feet thick. A 5-foot thick gate, filled with zero valence iron, was determined to provide a sufficient amount of residence time to achieve the required discharge concentration. Information provided by EnviroMetal Technologies, Inc., indicate that one day of residence time should be sufficient to reduce TCE and/or DCE at concentrations at hundreds of parts per billion to non-detected levels (personnel communication, 1997). The treatment gates will be expected to be constructed using sheet piles driven around the perimeter of the planned gate and subsequent excavation of the soil inside the gate. A separate analysis of the required residence times in the gates at the Ash Landfill site is provide in a later section of this report (Residence Times in the Gate).

The treatment gate was simulated with a hydraulic conductivity of 260 ft day. This is an average conductivity based on column studies that were comprised completely of Master Builders zero valence iron (243 ft/day) or Peerless zero valence iron (277 ft/day). These tests were performed in during a pre-design phase of laboratory tests for a site in Elizabeth City, NC (Parsons ES project files and personnel communication with Parsons ES Cary, NC project engineers).

4.0 GROUNDWATER FLOW MODEL CALIBRATION

4.1 AVERAGE WATER TABLE CONDITIONS

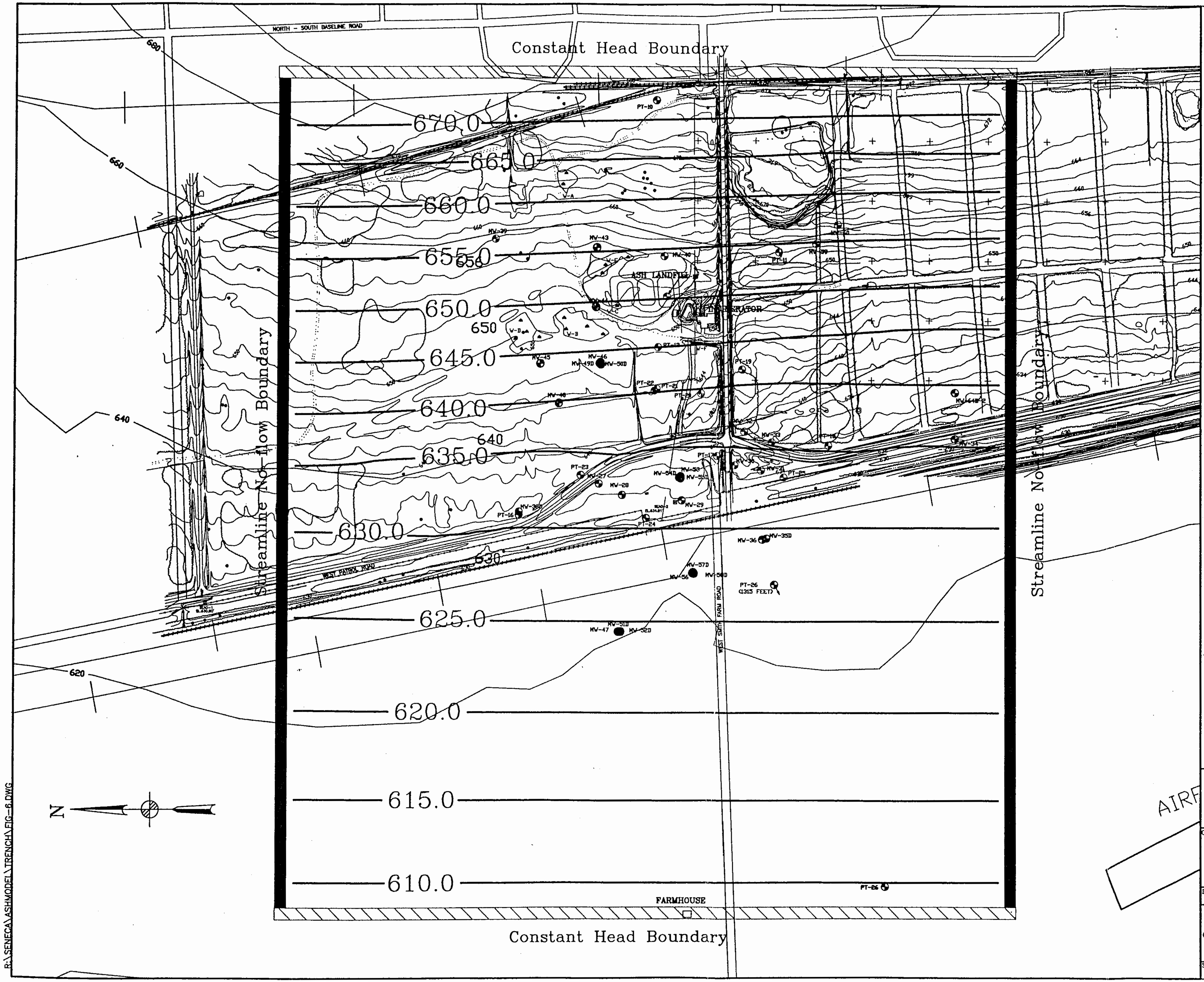
The groundwater flow model was calibrated to the average water table conditions at the site using hydraulic head matching and water balance results. The final calibrated contour map of the calibrated groundwater heads is depicted as Figure 6.

The groundwater flow model was calibrated by comparing modeled heads to the heads established for 47 target wells. The target heads were set as the seasonal arithmetic mean of the observed water table elevations in monitoring wells from 1990 through 1995 (Parsons ES, 1996). Because constant heads were used on the eastern and western boundaries, heads from the initial calibration run were not substantially different from the target heads. The hydraulic conductivity was varied within the acceptable range of measured values until the modeled piezometric head values matched observed averaged water table elevations and the model was considered calibrated.

The degree to which the model heads matched the measured heads was determined by an evaluation of residuals. Residuals are the difference between the modeled and measured heads. Residuals for each of the 47 target wells were well distributed when plotted on a site map, suggesting that the model residuals were random and not associated with a inexact representation of site conditions. Graphical plots of the modeling results provides an indication of how closely the modeled conditions match observed site conditions. A scatter plot of observed target values versus the values computed by the model indicates that the points generally fall on a straight line with a 45 degree slope, an indication that the modeled heads closely matches the observed heads (Figure 7).

The model was calibrated with a residual mean of -0.62 ft, which was computed by dividing the sum of the residuals by the number of residuals. The residual mean reflects the degree to which the positive and negative values cancel each other out, and it should be close to zero for calibration. The absolute residual mean is a measure of the overall error in the model. This was determined to be 1.55 ft. Another useful measurement of calibration is the ratio of the overall head change (65 ft) to the residual standard deviation (2.10 ft). This was determined to be 0.03 (or 3 %), which is below the 10 % cut-off value generally used to determine if a model is calibrated.

A water balance also served as a calibration criteria for the model (Figure 8). The percent error in the volumetric budget as calculated by the MODFLOW model was 0.0 %, with a total flow in of 1006.8 ft^3/day along the eastern line of constant head cells and a total flow out of 1006.8 ft^3/day along the western line of constant head cells.



LEGEND:

- PAVED ROAD
- DIRT ROAD
- GROUND CONTOUR AND ELEVATION (650)
- TREE
- WETLAND & DESIGNATION (W-B)
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- SURVEY MONUMENT (SEAD-1 EL.630.90')
- MONITORING WELL AND DESIGNATION (PT-22, MW-37)
- RAILROAD TRACKS
- CONSTANT HEAD BOUNDARY
- STREAMLINE NO-FLOW BOUNDARY
- GROUNDWATER ELEVATION CONTOUR (615.0)

-400' 0 400'

SCALE: 1' = 400'

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SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

DEPT.	Dwg. No.
ENVIROMENTAL ENGINEERING	726209-01002

FIGURE 6

GROUNDWATER CONTOURS FOR CALIBRATED MODEL UNDER AVERAGE WATER TABLE CONDITIONS TILL/WEATHERED SHALE AQUIFER

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0

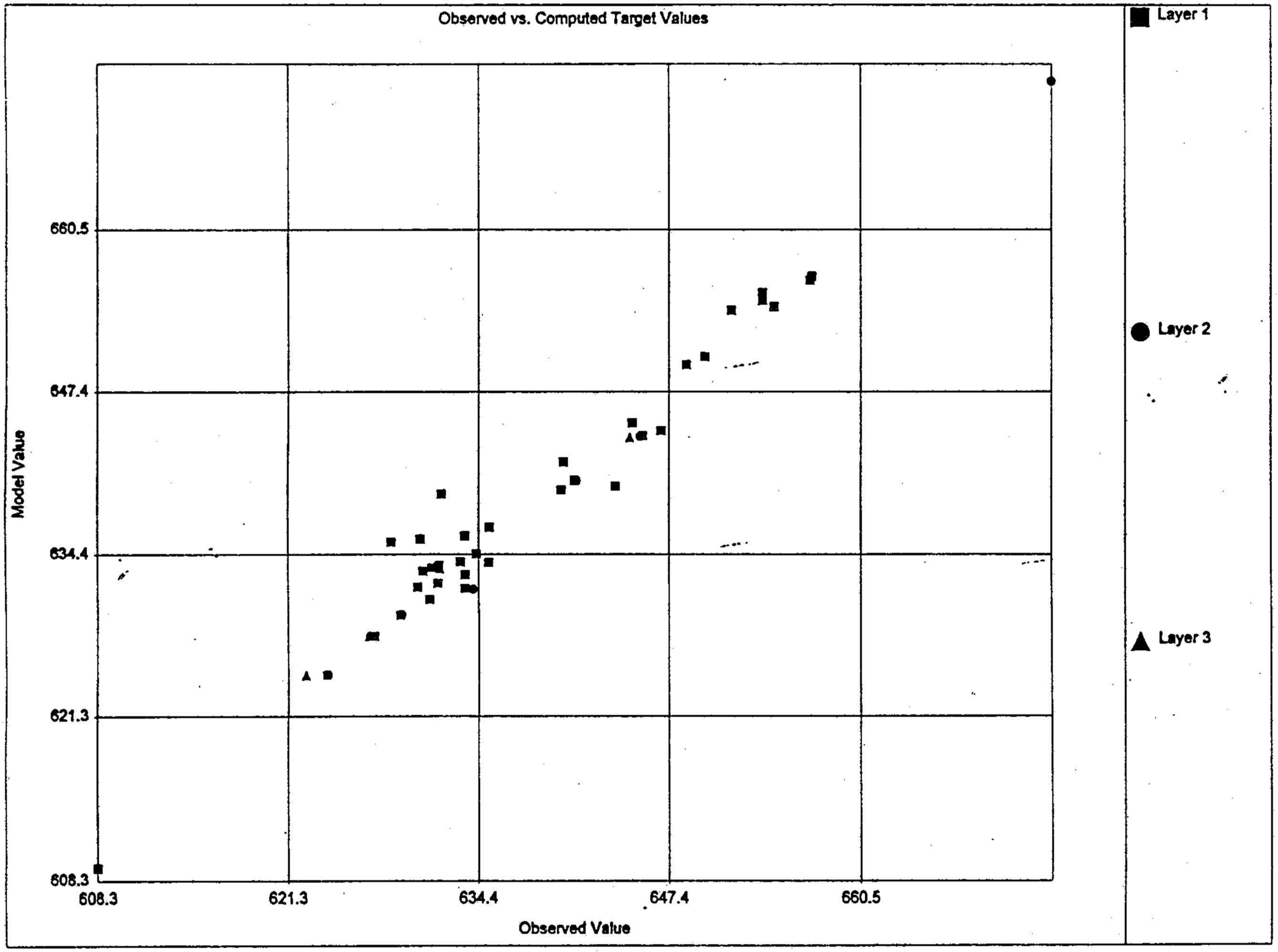

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FIGURE 7
OBSEREVED vs. COMPUTED HEADS

SCALE	DATE	REV
AS NOTED	DECEMBER	0

R:\SENECA\ASHMODEL\TRENCH\DWG\FIG-7.DWG

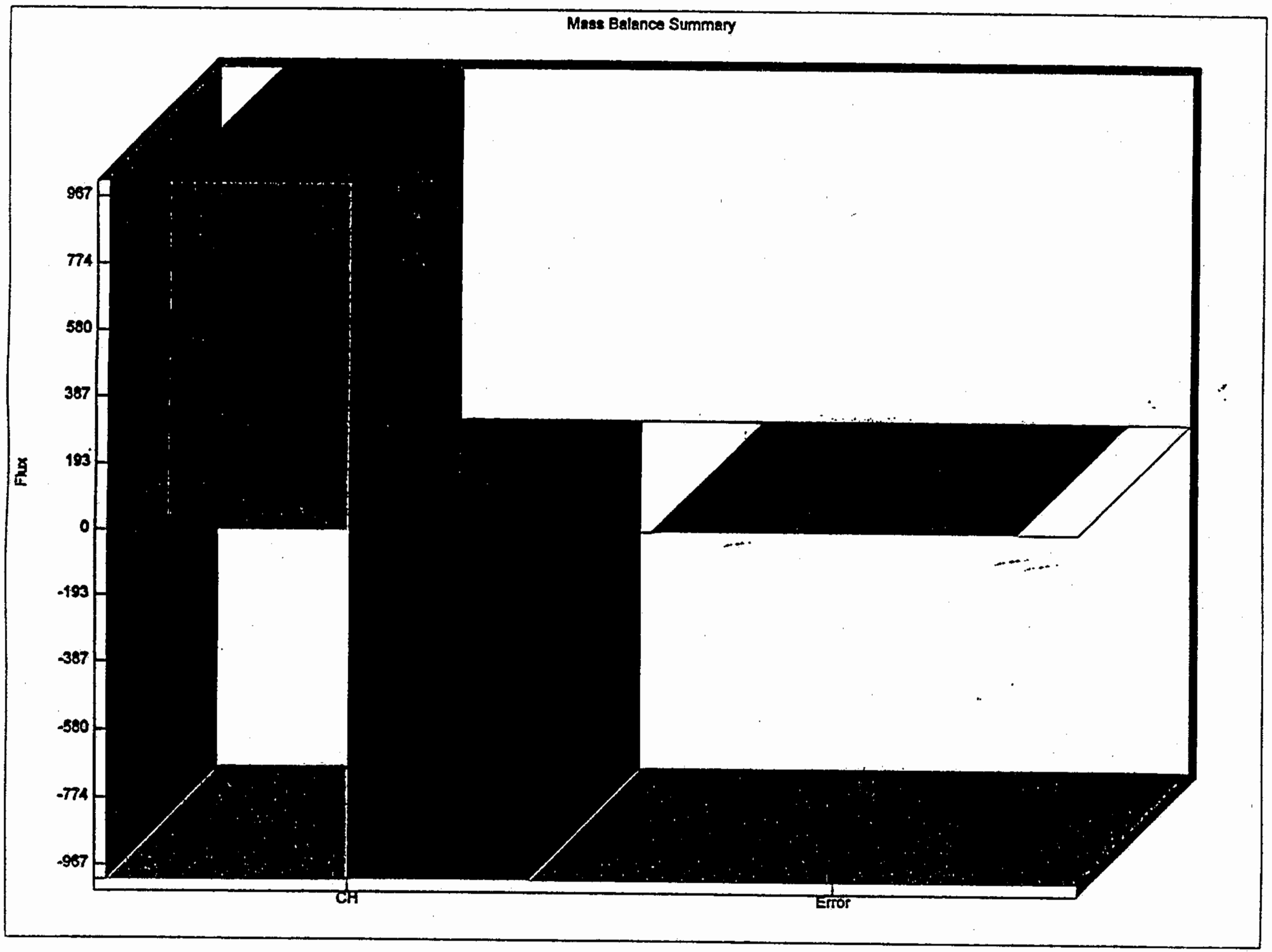

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FIGURE 8
MASS BALANCE SUMMARY
FOR CALIBRATED MODEL

SCALE	DATE	REV
AS NOTED	DECEMBER	0

R:\SENECA\ASHMODEL\TRENCH\DWG\FIG-8.DWG

A sensitivity analysis was not performed on this calibrated groundwater flow model because a comprehensive sensitivity analysis was performed on the previous, larger scale model (Parsons ES, 1995). This previous effort provided the justification for the physical aspects and hydrogeologic parameters used in this model. This model is, in effect, an extension of the previous model.

4.2 HIGH WATER TABLE CONDITIONS

A second calibration was performed using high water table conditions to address the performance of the treatment walls and determine the potential for breakout. The target high water table heads were determined using the maximum heads observed in the 47 target wells from 1990 to 1995. The calibration results were similar to those for the average water table conditions.

5.0 DESIGN MODELING METHODOLOGY

Initially, a continuous impermeable wall (with zero gates) was simulated to evaluate the maximum extent of groundwater mounding that could be expected upgradient the wall. This was done to evaluate the potential for groundwater to be released at the ground surface. The results from this simulation also served as a basis of comparison for the funnel and gate simulations to follow. Next, gates were added to the cut-off wall to evaluate capture zone and decrease the size of the groundwater mound. The designs investigated included two, three, and four gates, and a continuous reaction wall.

The funnel and gate design configurations were evaluated through an iterative process that involved changing the number and widths of gates in the cut-off wall, evaluating the capture zone and potential for groundwater breakout at each step. The results from the MODPATH particle pathline analysis, in the two, three, and four gate configurations, suggested that it was necessary for the gates to extend to at least within 50 ft to 75 ft of the ends of the funnel in order to ensure that the edges of the plume were captured. The modeling suggested that gates at more central locations along the funnel were not able to sufficiently capture the edges of the plume.

Both average water table conditions and high water table conditions were modeled during the study.

6.0 MODEL OUTPUT

Various funnel and gate configurations were incorporated into the calibrated groundwater model to determine the optimal design that has a low potential for groundwater breakout. The magnitude of the groundwater mounding (i.e., breakout potential) upgradient of the cut-off wall was evaluated by observing head profiles along rows that were perpendicular to the midpoints between the gates.

6.1 ZERO GATES (IMPERMEABLE WALL) CONFIGURATION

A continuous impermeable wall (with zero gates) was simulated to evaluate the maximum extent of groundwater mounding upgradient of the wall. If a large mound is produced it may be possible for groundwater to be released at the ground surface. This simulation identified the maximum increase in groundwater elevation as occurring approximately 3 ft upgradient (easterly) of the wall, relative to the average water table elevation. This means that the water table would be within 0.5 ft of the ground surface under average water table conditions. At approximately 323 ft upgradient of the wall the water table rise was predicted to be approximately 1 foot, and at 525 ft the rise was 0.5 ft. The maximum extent of influence from the groundwater mound (i.e., a 0.1 foot rise in the water table) was approximately 1,060 ft upgradient of the cut-off wall, which is near the eastern edge of the Ash Landfill. Immediately downgradient of the impermeable wall, the water table was 1.4 ft lower, relative to initial calibrated conditions.

6.2 TWO GATE CONFIGURATION

Two gates, 100-ft and 120-ft wide, were then added to the impermeable wall to observe the effects in reducing the mounded hydraulic head and capturing the entire plume. The northern gate was 120 ft wide and the southern gate was 100 ft. The ratio between the combined width of the gates and the full length of the funnel (cut-off wall/gate system) is 220 ft : 645 ft, or 0.34 (Table 2).

An upgradient groundwater mound was present, although the magnitude of the mound was less than that predicted during the simulation of a completely impermeable wall. The groundwater table at the mid-point location between the two gates (at model row 140) was elevated 1.5 ft immediately upgradient of the wall, relative to initial calibrated conditions. This mean that the water table would rise to within 1.8 ft of the ground surface. At a location approximately 53 ft upgradient of the wall the water table rise was approximately 1 ft. A 0.5-ft rise in the water table was predicted at approximately 178 ft upgradient of the cut-off wall. Immediately downgradient of the wall, at the same relative location between the two gates noted above, the water table was approximately 1.0 ft lower relative to the calibrated conditions.

Under high water table conditions the modeling predicted a maximum upgradient groundwater mound that extended to within 0.3 ft below the ground surface.

The results from the MODPATH simulations indicate that the travel time for a particle of groundwater to reach the treatment gates after release from the eastern (upgradient) end of the plume ranged from 10.8 years to 15.5 years. The average travel time was 12.0 years. This neglected the effect of solute retardation and only considered the travel time for a particle of water. A particle of TCE or DCE would require longer to reach the same point due to adsorption interactions with aquifer materials.

An analysis of residence times through the two gates was performed using particle tracking. The results show that the groundwater travel times through the 5-ft thick gates ranged between 5.5 days and 20 days, which translate into velocities that range between 0.9 ft/day and 0.25 ft/day (Table 2). From previous studies involving zero valence iron, residence times of approximately 1 day is generally required for treatment.

6.3 THREE GATE CONFIGURATION

A funnel and gate configuration involving three 50-ft to 60-ft wide gates were also simulated. The northern gate was estimated to be 60 ft wide, and the middle and southern gates were each 50 ft wide. The ratio between the combined width of the gates and the full length of the funnel is 160 ft : 645 ft, or 0.24.

The groundwater mound, created upgradient of the impermeable wall, was less than that observed with two gates. The groundwater table at two locations between the three gates (rows 115 and 160) were elevated between 0.97 ft and 1.1 ft immediately upgradient of the wall, relative to calibrated conditions. This brought the water table to within 2.4 to 2.3 ft of the ground surface. A 0.5-ft rise in the water table was predicted at 73 ft upgradient of the cut-off

Table 2

Comparison of Modeling Results for Average and High Water Table Conditions

Seneca Army Depot Activity
Ash Landfill Groundwater Trench Model

				Average Water Table Conditions				**High Water Table Conditions**			
Design Scenario	Funnel Length (ft)	Gate Lengths (ft)	Ratio of Funnel to Gate	Maximum Rise in Water Table Between Gates (ft)	Approximate Depth to Water Below Ground Surface at Maximum Rise in Water Table (ft)	Distance Upgradient of Wall Where Water Rise is 0.5 (ft)	Groundwater Velocity Through Gate (ft/day)	Maximum Rise in Water Table Between Gates (ft)	Depth to Water Below Ground Surface at Maximum Rise in Water Table (ft)	Distance Upgradient of Wall Where Water Rise is 0.5 (ft)	Groundwater Velocity Through Gate (ft/day)
Impermeable Wall (reference run)	645	NA	NA	3	0.5	525	0	NA	NA	NA	NA
Funnel and Gate (2 Gates)	645	120,100	0.34	1.5	1.8	178	0.25 to 0.90	1.52	0.3	188	0.25 to 0.90
Funnel and Gate (3 Gates)	645	60,50,50	0.24	1.1	2.4	73	0.41 to 1.5	1.07	0.8	83	0.41 to 1.6
Funnel and Gate (4 Gates)	645	30,30,30,30	0.18	0.83	2.7	53	0.5 to 1.7	0.84	1.1	53	0.5 to 1.7
Continuous Reaction Wall	645	645	1	0.1	3.2	NA	0.2 to 0.3	NA	NA	NA	NA

NA = Not Applicable

wall. Immediately downgradient of the wall, at the same location between each of the gates noted above, the water table was between 0.64 ft to 0.62 ft lower relative to calibrated conditions.

Under high water table conditions the maximum upgradient groundwater mound predicted was 0.8 ft below the ground surface.

The results from the MODPATH simulations indicate that the travel time for a particle of groundwater to reach the treatment gates after release from the eastern (upgradient) end of the plume ranged from 10.7 years to 13.5 years. The average travel time for the particle was 11.7 years.

An analysis of residence times through the three gates was performed using particle tracking. The results show that the groundwater travel times through the 5-ft thick gates ranged between 3.4 days and 12.0 days, which translate into velocities that range between 1.5 ft/day and 0.4 ft/day (Table 2). In all instances, the velocities of particles traveling through the ends of the gates were fastest, and velocities were slowest at the middle of the gates.

6.4 FOUR GATE CONFIGURATION

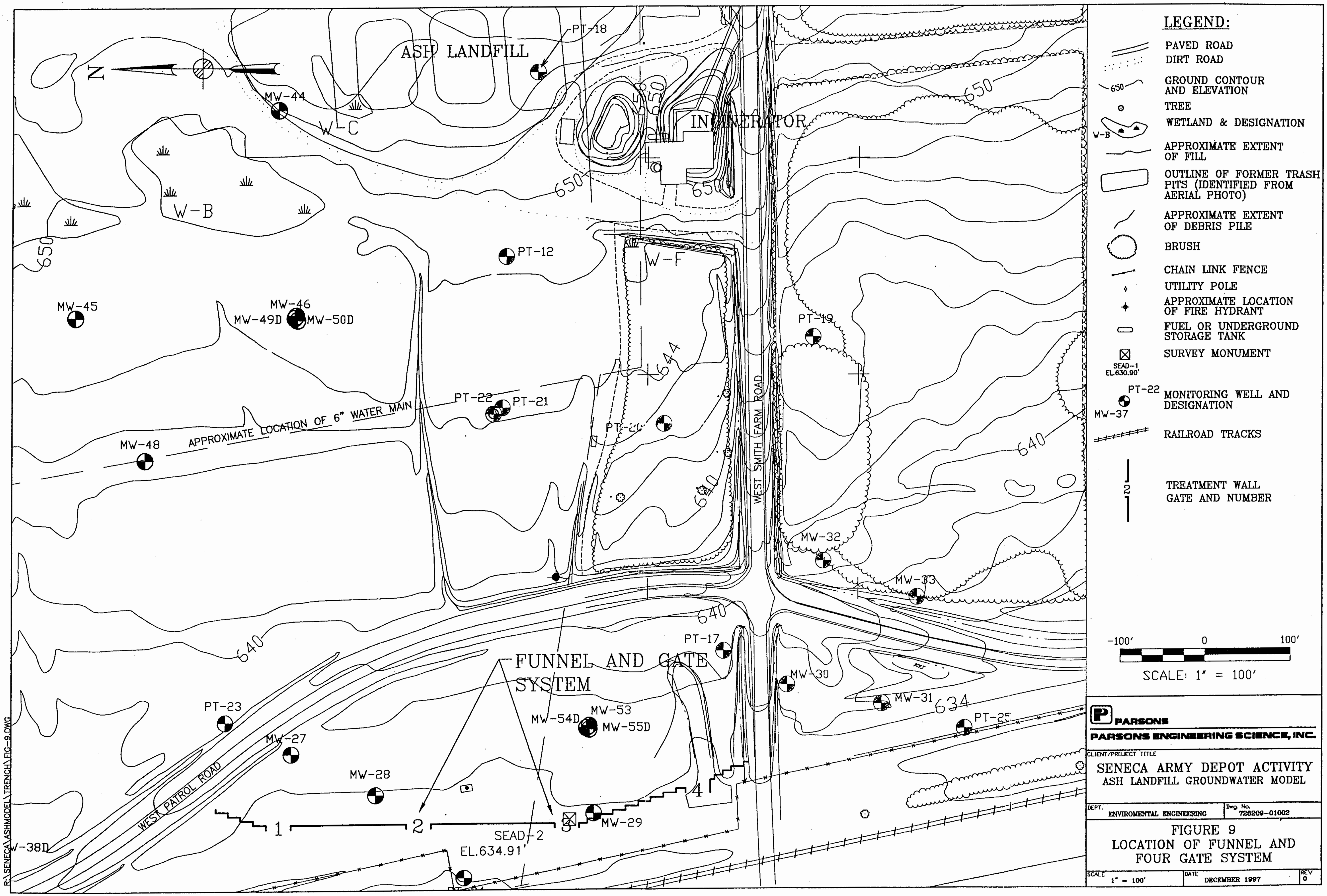
Modeling of a four gate configuration was conducted with four 30-ft wide gates leaving the remaining 525-ft of funnel. This configuration is depicted as Figure 9. The capture zone of the four gate configuration is provided as Figure 10. The vertical cross-sectional profile is shown as Figure 11. The ratio between the combined width of the gates and the full length of the funnel is 120 ft : 645 ft, or 0.18 (Table 2).

The four gate configuration predicted a groundwater mound upgradient of the funnel wall that was less than that produced for the three gate configuration. The maximum groundwater mound at three mid-point locations between each of the four gates was determined to be elevated between 0.76 ft and 0.83 ft adjacent to the wall, relative to calibrated conditions. This corresponds to a predicted water table elevation of between 2.5 to 2.7 ft from the ground surface. At approximately 53 ft upgradient of the mid point of the cut-off wall the water table rise was predicted to be 0.5 ft. Influence from the groundwater mound (i.e., a 0.1 ft rise in the water table) was estimated to be approximately 400 ft upgradient of the cut-off wall. Immediately downgradient of the wall at the same relative location between each of the four gates noted above, the water table was between 0.44 ft to 0.53 ft lower relative to calibrated average water table conditions.

Under high water table conditions modeling predicted that the groundwater mound would be 1.1 ft below the ground surface.

The results from the MODPATH simulations indicate that the travel time for a particle of groundwater to reach the treatment gates after release from the eastern (upgradient) end of the plume ranged from 10.7 years to 12.5 years. The average travel time for the particles was 11.8 years.

An analysis of residence times through the four gates was performed using particle tracking. The results show that the groundwater travel times through the 5-ft thick gates ranged between 3.2 days and 10 days, which translate into velocities that range between 0.5 ft/day and 1.7 ft/day



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SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

DEPT. ENVIROMENTAL ENGINEERING

Dwg. No. 726209-01002

FIGURE 9
LOCATION OF FUNNEL AND
FOUR GATE SYSTEM

SCALE 1" = 100'

DATE DECEMBER 1997

REV 0

R:\SENECA\ASHMODEL\TRENCH\FIG-9.DWG

R:\SENECA\ASHMODEL\TRENCH\FIG-10.DWG

LEGEND:

PAVED ROAD
DIRT ROAD
650 GROUND CONTOUR AND ELEVATION
TREE
W-B WETLAND & DESIGNATION
APPROXIMATE EXTENT OF FILL
OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
APPROXIMATE EXTENT OF DEBRIS PILE
BRUSH
CHAIN LINK FENCE
UTILITY POLE
APPROXIMATE LOCATION OF FIRE HYDRANT
FUEL OR UNDERGROUND STORAGE TANK
☒ SEAD-1 EL.630.90' SURVEY MONUMENT
PT-22 MW-37 MONITORING WELL AND DESIGNATION
RAILROAD TRACKS
615.0 GROUNDWATER ELEVATION CONTOUR
2 TREATMENT WALL GATE AND NUMBER
↓ PARTICLE TRACK

-100' 0 100'
SCALE: 1" = 100'

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ASH LANDFILL GROUNDWATER MODEL

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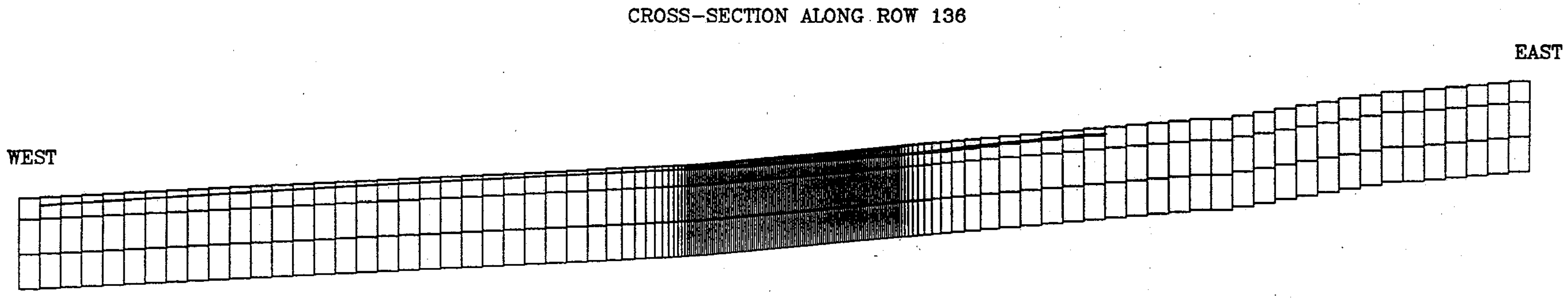
FIGURE 10
CAPTURE ZONE FOR FUNNEL AND FOUR GATE SYSTEM

SCALE AS NOTED
DATE DECEMBER 1997
REV 0



NOTE:
VERTICAL EXAGGERATION 15X.

SCALE: 1" = 400'

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FIGURE 11

CROSS SECTION OF FUNNEL AND FOUR GATE SYSTEM WITH PARTICLE TRACKS

SCALE	DATE	REV
AS NOTED	DECEMBER	0

R:\SENECA\ASHMODEL\TRENCH\FIG-11.DWG

(Table 2). This would be within the acceptable range of treatment times required for sufficient reduction of the influent concentrations.

6.5 CONTINUOUS REACTION WALL CONFIGURATION

Modeling of a 645-ft continuous reaction wall configuration was successful in capturing the entire VOC plume and, as expected, produced no groundwater mound upgradient of the wall. The pathline analysis indicated that that was some upgradient convergent flow of groundwater at the edges of the capture zone due to the angled wing-walls on the ends of the wall.

The results from the MODPATH simulations indicate that the travel time for a particle of groundwater to reach the treatment wall after release from the eastern (upgradient) end of the plume ranged from 10.5 years to 12.0 years. The average travel time was 11.4 years.

Analyses of residence time through the continuous reaction wall was performed using particle tracking. The predicted groundwater residence times through the 5-ft thick treatment wall ranged from between 18 days and 25 days. These travel times translate into velocities that range between 0.20 ft/day and 0.27 ft/day within the reaction wall (Table 2). These residence treatment times are greater than for configurations involving gates because there is little difference in hydraulic head between the treatment zone.

7.0 DISCUSSION OF MODELING RESULTS

7.1 LENGTH OF THE TREATMENT WALL

For each of the configurations discussed above, the length of the impermeable wall, the funnel, was extended until the modeling results indicated that the capture zone, formed by the migration of groundwater into the funnel, encompassed the entire width of the plume. Through trial and error, this length was determined to be 645 feet. This remained constant for each of the design configuration simulations.

7.2 GROUNDWATER MOUNDING UPGRADIENT OF THE TREATMENT WALL

An acceptable depth to water below the ground surface for mounding was considered to be 0.9 feet. This value was derived from groundwater monitoring elevation data collected in 16 wells between 1990 and 1995 in the area of the modeled treatment wall. These data indicated that the average depth to water, under high watertable conditions, was 1.4 ft. We applied a safety factor of 0.5 feet, yielding the allowable depth to water of 0.9 ft. Therefore, a depth to water of 0.9 feet, below the ground surface, was considered to be acceptable goal to reduce the potential for breakout in a funnel and gate configuration.

Increased groundwater mounds were the least for funnel and gate configurations with the most gates. This is because the groundwater flow restrictions, and subsequent hydraulic head increases, are the least with the most gates.

Under high water table conditions, the two, three, and four gate systems produced mounds with depths to the water table of 0.3 ft, 0.8 ft, and 1.1 ft, respectively, of the ground surface. Therefore, only the four gate configuration was below the acceptable criteria, as this configuration produced a water table that was below the 0.9 ft criteria. Therefore, a design configuration consisting of a 645 ft of funnel with four gates, each 30 ft wide, was determined to be the best configuration to capture the entire plume width and have the least amount of potential for breakout of groundwater at the ground surface upgradient of the treatment wall. This configuration is depicted as Figure 10.

Under average water table conditions, the four gate funnel configuration produced a depth to the water table of 2.6 ft below the ground surface. The two and three gate configurations produced depths to the water table of 1.8 ft and 2.4 ft below the ground surface, respectively. Thus, under average conditions, all of these design configurations yielded acceptable increases in hydraulic head.

The continuous, permeable, reactive wall, consisting of all zero valence iron, produced no groundwater mounding, and would also capture the entire plume.

7.3 RESIDENCE TIME IN THE GATE

The reduction of VOCs in the treatment gate is based primarily on the residence time required in the gate to reduce concentrations to below the target criteria. Thus, the thickness of the treatment wall determines the residence time. Starr and Cherry (1994) note that, if required, the residence time in the gate can be increased without substantially affecting the capture zone by making gates longer in the direction parallel to groundwater flow.

EnviroMetal Technologies, Inc., suggests that one day of residence time should be sufficient to reduce TCE and/or DCE to target concentrations (personnel communication, 1997). The modeling results showed that under the four gate configuration, groundwater flow-through velocities in the gates ranged from 0.5 ft/day to 1.7 ft/day. Therefore, a thickness of zero valence iron of 1.7 ft would be sufficient to treat the groundwater given the expected concentrations. Under the continuous reactive wall design, the flow-through velocities ranged from 0.2 ft/day to 0.3 ft/day, and thus approximately 0.3 ft thickness of iron would be sufficient. In addition, EnviroMetal Technologies, Inc. suggests adding a safety factor of two to the thickness estimated in the treatment gate or wall. All modeling simulations were performed assuming a 5 foot thick zone of zero valence iron.

The life expectancy of the treatment material (e.g., zero valence iron) is not known with certainty. The use of zero valence iron is a relatively new technology and there is no long term data, greater than ten years, to document the life expectancy of such in-situ treatment systems. However, several systems have been operating for approximately five years without changeout.

8.0 CONCLUSIONS

The modeling simulated the hydraulics of the various groundwater collection configurations and provided information that can used to support the design of a treatment gate/wall.

The results showed that a configuration consisting of a 645 ft of funnel and four gates, each 30 ft wide, was determined to be the optimal design to capture the entire plume width and have the least amount of potential for breakout of groundwater at the surface upgradient of the system. In addition, the modeling showed that a 645 ft continuous reaction wall, which would produce no groundwater mounding, would also capture the plume.

For the funnel and gate and continuous reaction wall designs, the total time to achieve clean-up levels, assuming three pore volume flushes, was estimated to be approximately 42.6 years and 41.1 years, respectively. These treatment times can be decreased by using multiple treatment walls. By adding a another system half way between the source area and the systems modeled at the “toe” of the plume in this study, the treatment time would be reduced by half. Three evenly spaced systems would remediate the plume in one third of the time that is need for one system at the “toe” of the plume.

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Appendix D

Division II Technical Specifications, Drawings and Appendices for Construction of Continuous Reactive Wall (Trench)

Reactive Iron Specifications

Division II Technical Specifications, Drawings and Appendices for Construction of Continuous Reactive Wall (Trench)

SECTION 02221

EXCAVATION AND FILLING

PART 1 GENERAL

1.01 WORK INCLUDED

A. Furnish all materials, labor and equipment and perform all operations required for excavating, dewatering, trenching, filling, backfilling, and grading as indicated on the Drawings, as specified herein, and as evidently required to complete the work.

B. Related work specified in other sections:
   1. Section 02373 - Geotextile

1.02 CODES AND STANDARDS

A. Current editions or revisions of the following standards as of the effective date of the Contract shall govern, unless specifically noted otherwise herein or on the Drawings.

1. American Society for Testing Materials

   a. ASTM C136: Sieve Analysis of Fine and Coarse Aggregates

   b. ASTM D2434: Permeability of Granular Soils (Constant Head)

   c. ASTM D4767: Consolidated-Undrained Triaxial Compression Test on Cohesive Soils

2. Occupational Safety and Health Administration (OSHA) Construction Standards for Excavations, 29 CFR Part 1926, Subpart P.

3. United States EPA, Test Methods for Solid Waste (USEPA SW846).

   a. Target Compound List (TCL)
      1. Volatile Organic Compounds (VOCs) - Method 8260
      2. Semi-Volatile Organic Compounds (VOCs) - Method 8270
      3. Pesticides/PCBs - Method 8081/2

   b. Target Analyte List (TAL)
      1. Metals - Method 6010
      2. Cyanide - Method 9010
      3. Mercury in Soil - Method 7471

4. NYS D.O.T. Standard Specifications Construction and Materials

a. Specification 703-07: Concrete Sand

b. Specification 713-01: Topsoil from Borrow

1.03 SUBMITTALS

A. Submit the following items to the Contractor no less than 14 days prior to construction unless otherwise specified:

1. Chemical and geotechnical test results for representative sample of fill materials. See Article 2.01 B, C, and G.

2. Samples of fill materials. See Article 2.01 E.

3. Work plan describing equipment to be used for excavation. See Articles 2.01C.3, 2.01F.4, 2.01G.2., 2.01 G.3, 3.01E, 3.02B.

1.04 PROJECT CONDITIONS

A. No work shall commence until all required permits have been obtained.

B. Perform work in accordance with all city, state and federal regulations, codes, standards, and permits. Comply with all safety ordinances applicable at the site, including current OSHA regulations.

C. Dust and Dirt Control - Perform the work so as to prevent the nuisance of dust in surrounding areas. Maintain haul routes, and use water, approved chemicals, or other materials to keep dust down. Furnish all materials and equipment required to control dust. Clean all parking lot paving, walks, and roads on and off site that become dirty or littered due to the excavation and filling work.

D. Erosion Control - Take all necessary precautions to minimize soil erosion and perform any required work to prevent silting of adjacent drainage facilities or properties. Conform to all local, state, and federal erosion control laws and regulations.

E. Hazardous Materials - Hazardous materials or contaminated soils may be present at low concentrations at the site. Take precautions to prevent inhalation of dust during dry conditions, including dust suppression and use of dust masks. Notify the Contractor immediately if suspected hazardous materials or contaminated soils are encountered during the excavation work. Do not under any circumstances remove any suspected hazardous material or contaminated soil from the site without written authorization from the Contractor.

F. Excavation Near Existing Utilities

1. A six-inch water main which runs through the proposed location for the funnel and gate system location has been identified on Figure 1. The water main is approximately 42 to 48 inches deep, but it will be the responsibility of the Subcontractor to confirm presence of this water main and accurately locate it. Subcontractor shall excavate around the portion of the water main which intersects the trench, and backfill around the water main, supporting it as

necessary. If it is necessary to cut the water main, refer to Specification 02555. Water main will be out-of-service during construction activities.

2. The six-inch water main described above is the only known utility within the work area, but the completeness or accuracy of this information is not guaranteed. In advance of normal machine excavation, location of active services shall be investigated and the expected location marked. It shall be the responsibility of the Subcontractor to contact the appropriate utility company and Dig Safe at least 72 hours in advance of any excavation to have utility locations marked out. As the excavation approaches these services and other expected pipes, conduits or other underground structures, digging by machinery shall be discontinued and the excavation shall be done by means of hand tools. In no case shall machine excavation be utilized in the vicinity of piping containing combustible or hazardous fluids or gases; hand digging only shall be employed.

3. Notify the Contractor immediately if unforeseen interference with existing underground piping or structure is encountered.

4. All water, gas, or other pipes, mains, services, conduits or fixtures which may be uncovered or interfered with during any excavations made in connection with this Contract shall be properly supported and maintained in position, unless otherwise indicated by the Contractor. Any such lines must also be supported during construction of the continuous reactive trench. Backfill shall be installed around foreign utilities in such a manner as to maintain support and prevent settlement.

5. No alterations or interferences shall be made with any existing underground utilities except at the direction of the Contractor. Permission for any such alterations will be obtained by the Contractor. Cost of any such alterations to existing utilities will be paid for by the Owner in accordance with the terms and conditions of the Contract.

G. Employ all possible methods necessary to minimize noise caused by construction equipment. Such methods shall conform to local noise abatement ordinances.

PART 2 PRODUCTS

2.01 MATERIALS

A. General Fill Requirements

Fill and backfill shall not contain frozen soil, snow, ice, roots, sticks, timber, trash, cinders, topsoil (except for topsoil fill specified), organic materials, or other objectionable materials which may be compressible or which prevent satisfactory compaction.

C. Sand Fill for Mixing with Iron Filings for Continuous Reactive Trench

1. A well graded, fine- to medium-grained sand, free from calcareous grains or material must be obtained from the borrow source. Sand fill shall conform to Section 703-07, Concrete Sand, of NYSDOT Standard Specifications for Construction and Materials. Subcontractor shall submit documentation that a representative sample of the sand fill meets these specifications as outlined in Articles 1.03 and 3.06 of this specification (ASTM D2434). In addition, the moisture content of the sand fill is not to exceed 5 to 7%. Contractor shall provide documentation that moisture content meets requirements.

3. A minimum of 2600 CF of iron fillings will be placed along the entire 645-foot length of the trench. The remainder of the trench volume shall be comprised of the sand fill specified in Article 2.01 C.1. The iron and sand shall be mixed prior to filling such that the iron is distributed uniformly. The method of mixing is optional, but subject to the approval of the Contractor. Subcontractor shall describe in detail the mixing methods to be used in the Work Plan described in Article 1.03 - Submittals. It is anticipated, therefore, that the mixture will be approximately 48% iron by volume for the entire trench. The Subcontractor, while mixing the first two batches of iron and sand, shall demonstrate to the Contractor that uniform mixing has occurred and will establish a minimum mixing time to be used for the remainder of the batches.

4. Sand fill shall be clean, as determined by the sole interpretation of the Contractor, by testing the fill for constituents contained on the USEPA target analyte list (TAL) and target compound list (TCL). See Articles 1.03 and 3.06 of this Specification for testing requirements.

D. Excavated On-Site Material

Excavated material shall be transported and stockpiled at the Abandoned Incinerator Building (see Figure 1). A portion of the excavated material may be stockpiled in the area of the trench for use as backfill for 8 inches of the upper one-foot of the trench (see Figure 6).

D1. Topsoil

1. Topsoil shall conform to Section 713-01, Topsoil from Borrow, of NYSDOT Standard Specifications for Construction and Materials. Subcontractor shall submit documentation that a representative sample of the topsoil meets these specifications as outlined in Articles 1.03 and 3.06 of this specification.

2. Topsoil shall be clean, as determined by the sole interpretation of the Contractor, by testing the fill for constituents contained on the USEPA target analyte list (TAL) and target compound list (TCL). See Articles 1.03 and 3.06 of this Specification for testing requirements.

E. Subcontractor shall deliver to the site, at least five working days prior to use, a representative 50-lb. bag sample for each proposed off-site borrow material. Clearly label each sample as to source of material and proposed use.

F. Trench Excavation Equipment

Equipment used for the installation of the reactive wall shall be an integral, chain-type trencher with attached permeable treatment material installation assembly. Equipment shall be capable of excavating a nominal 14-inch wide trench and installing the permeable treatment material in a single pass, performed below the water table in generally unconsolidated materials. Installation with this type of equipment can typically be performed without dewatering. Therefore, dewatering is not anticipated to occur during construction of the permeable treatment wall. The equipment shall be able to reach at least 1 foot deeper than the maximum depth shown on the drawings.

PART 3 EXECUTION

3.01 EXCAVATION

A. General

A trench will be excavated down to competent bedrock to a target elevation of 625 feet MSL as shown in the Drawings. Geological cross-sections from the area provided in Figures 3, 4, and 5 give an estimate of the depth to competent bedrock. However, actual site conditions will prevail and Subcontractor shall allow for an installation depth of 6 to 12 feet below grade.

Prior to excavation with the chain trencher, test pits will be excavated at 100 ft intervals along the installation path to determine the approximate depth to bedrock. After determining the depth to bedrock at these locations, the test pits shall be immediately refilled with the excavated materials. The trench depth shall be depth on grade to the top of bedrock between the test pit locations (known depth to bedrock) using the laser-guided depth control system. Manual override of the laser-guided depth control system shall only be performed if either (1) there is no "chatter" from the cutting chain indicating that the excavation is above competent bedrock, or (2) there is excessive "chatter" indicating that the excavation is cutting significantly into bedrock. The depth of permeable treatment material installation shall be continuously monitored and recorded during installation of the permeable treatment wall.

B. Classification. - All material is anticipated to be common excavation, which is defined as material removable by means of mechanical excavation equipment or by pick and shovel.

C. Unexpected Conditions. - Notify the Contractor immediately of unexpected subsurface conditions, and discontinue work in that area until notified by the Contractor to resume work.

D. When excavating under, around or adjacent to underground services, protect the services against exposure and damage by the excavating equipment. Support all exposed services as required.

E. Excavated Material - The material shall be excavated and stockpiled at the Abandoned Incinerator Building. A berm (of hay bales or other suitable material) shall be constructed to provide erosion control. The stockpile shall be covered with a tarp and the cover shall be secured. A portion of the excavated material may be stockpiled near the excavation for use as backfill. This backfill will be placed on top of the geotextile layer which is placed on top of the sand and iron filings mixture in the trench. The thickness of backfill shall be 8 inches.

F. Stockpiles

1. Stockpiles and excavated material shall be placed a minimum distance from the trench equal to 60 percent of the trench depth, but in no case closer than 30 feet from the lip of the trench. Slopes of stockpiles and excavated material shall be no steeper than 1 vertical to 3 horizontal and no higher than 10 feet above the work area.

2. Stockpiles shall be graded to drain, sealed by tracking parallel to the slope with a dozer or other means approved by the Contractor, and dressed daily during periods when fill is taken from the stockpile. The Subcontractor may cover fill stockpiles with plastic sheeting or other material approved by the Contractor to minimize erosion and /or preserve moisture content of the fill. The Subcontractor shall employ temporary erosion and sediment control measures around stockpile areas as necessary or as directed by the Contractor.

I. Bottom Preparation

1. The bottom target elevation of the trench shall be 625 feet MSL +/- one foot.

3.02 FILLING AND BACKFILLING

A. General Requirements

1. Place and compact designated fill and backfill materials in the manner and to the limits specified herein and on the Drawings.

2. Do not place fill or backfill material on surfaces that are below water, muddy, or frozen.

3. Do not leave debris, wood, or other foreign matter in the spaces to be backfilled.

4. Slowly and carefully place fill and backfill in uniform horizontal lifts of the specified thickness.

B. Compaction Requirements

1. Type of fill and compaction requirements for various portions of the project are tabulated below.

Fill Area	Fill Material	Required Compaction

Trench	Sand & Iron Filings for Trench (Article 2.01 C)	None - Let fill set overnight prior to capping with excavated material. Backfill with additional material to specified elevation if necessary.
Trench	Excavated Material (Article 2.01D)	Place in 8-inch maximum lifts. Compact each lift with passage of hauling and spreading equipment.
Trench	Top Soil (Article 2.01D1.)	Place in 4-inch lifts. Compact each lift with passage of hauling and spreading equipment.

2. If subgrade soils or completed areas of compacted fill subsequently become softened or loosened due to construction activities or the action of the elements, rework or replace the disturbed material and compact to the required density.

D. Sand Fill for Mixing with Iron Filings for Reactive Trench

1. Sand will be mixed with iron filings provided by the Contractor as specified in Article 2.01C prior to filling. The mixture shall be placed continuously through a steel-sided delivery system attached to the cutting boom. This delivery system stabilizes the trench side-walls during construction to allow placement of the permeable treatment media before the side-walls can collapse. The mixture shall be placed from the top of competent bedrock to on-foot below ground surface at a nominal width of 12-inches.

2. The sand/iron mixture shall be a thoroughly mixed sand and iron filings mixture. These materials have different densities. To eliminate the potential for layering during placement, the sand/iron mixture shall be continuously loaded into the delivery system such that the level of the mixture in the delivery system remains above the water table. The sand/iron mixture shall not be allowed to fall through the standing groundwater column as this can result in layering of the sand and iron.

3. No compaction is required for the sand/iron mixture as described in the table above.

4. After the chain trencher has installed the sand/iron mixture, the depth to top of this media from ground surface shall be measured along the wall path using a measuring tape. The depth to the top of the sand/iron mixture shall be adjusted as necessary with a shovel so that the top of the permeable treatment media is on-foot below ground surface.

E. Excavated On-Site Material

1. The material shall be excavated and stockpiled at the Abandoned Incinerator Building. A berm (of hay bales or other suitable material) shall be constructed to provide erosion control. The stockpile shall be covered with a tarp and the cover shall be secured. A portion of the excavated material may be stockpiled near the excavation for use as backfill. This backfill will be placed on top of the geotextile layer which is placed on top of the sand and iron filings mixture in the trench. The thickness of backfill shall be 8 inches.

2. The excavated on-site material will be compacted in the trench as described in the table above.

F. Topsoil

1. Topsoil specified in Article 2.01D1 shall be placed over excavated material in the upper four inches of the trench and shall be graded level with the surrounding ground surface.
2. The topsoil will be compacted in the trench as described in the table above and shall be prepared for revegetation as described in Specification 02930

3.06 TESTING

Testing shall be the responsibility of the Subcontractor and shall be performed at no additional cost to the Contractor.

A. Testing Facilities - Tests shall be performed by an approved independent commercial testing laboratory furnished by the Subcontractor. No work requiring testing will be permitted until the facilities have been approved by the Contractor.

B. Testing of Backfill Materials - Characteristics of backfill materials shall be determined in accordance with sieve analysis of fine and coarse aggregates ASTM C136. A minimum of one sieve analysis shall be performed on sand used for backfill.

C. TAL/TCL Analyses - Subcontractor shall provide evidence to Contractor that a representative sample of the soil has been tested using USEPA SW846 test methods for constituents contained in the USEPA target compound list (TCL) and target analyte list (TAL) as listed in Article 1.02. Soil from each off-site borrow source shall be tested to demonstrate that the soil is not contaminated. Borrow source areas and test results must be reviewed and approved by the Contractor prior to any material being brought on site as specified in Article 1.03.

3.07 DISPOSAL OF EXCESS MATERIAL

A. Excavated soil in excess of fill shall be disposed of on the Owner's property at locations as directed by the Contractor. The material shall be spread and graded as directed.

3.08 TREATMENT OF TOP OF TRENCH

A. Geotextile specified in Specification 02373 will be placed over iron filings and sand mixture along the entire length of the trench.

B. The upper one foot of the trench shall be comprised of 8 inches of excavated material and 4 inches of top soil as shown in Figure 6.

C. Excavated materials and topsoil shall be compacted as described in Article 3.04 B.

3.09 GRADING

A. Topsoil backfilled over the trench shall be graded level with the surrounding ground.

3.10 CLEAN-UP

A. Remove all trash and debris resulting from the excavation and filling work from the site.

3.11 RECORD DRAWING

A. A record drawing of the trench bottom, and elevations & slopes of fill, including the iron/sand mixture and descriptions of materials encountered in the trench bottom shall be continuously maintained. This profile shall indicate extent of excavation and the backfill profile at the end of the each work day.

END OF SECTION

SECTION 02373

GEOTEXTILE

PART 1 GENERAL

1.01 WORK INCLUDED

A. Furnish all materials, labor and equipment and perform all operations required for installing geotextile.

B. Related work specified in other sections:
  1. Section 02221-Excavation and Backfilling

1.02 CODES AND STANDARDS

A. Current editions or revisions of the following standards as of the effective date of the Contract shall govern, unless specifically noted otherwise herein or on the Drawings.

1. American Society for Testing and Materials (ASTM)

  a. ASTM D 3786: Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method
  b. ASTM D 4354: Sampling of Geosynthetics for Testing
  c. ASTM D 4355: Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus)
  d. ASTM D 4491: Water Permeability of Geotextiles by Permittivity
  e. ASTM D 4533: Trapezoid Tearing Strength of Geotextiles
  f. ASTM D 4632: Grab Breaking Load and Elongation of Geotextiles
  g. ASTM D 4759: Determining the Specification Conformance of Geosynthetics
  h. ASTM D 4833: Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
  i. ASTM D 4873: Identification, Storage, and Handling of Geosynthetic Rolls

1.03 SUBMITTALS

A. Manufacturing Quality Control Sampling and Testing - A minimum of 14 days prior to scheduled use, manufacturer's quality control manual including instructions for geotextile storage, handling, and installation.

B. Geotextile - A minimum of fourteen days prior to scheduled use, manufacturer's certificate of compliance stating that the geotextile meets the requirements of this section. This submittal shall include copies of manufacturer's quality control test results.

1.04 DELIVERY, STORAGE, AND HANDLING

Delivery, storage, and handling of geotextile shall be in accordance with ASTM D4873.

A. Delivery - The Contractor will be present during delivery and unloading of the geotextile. Rolls shall be packaged in an opaque, waterproof, protective plastic wrapping. Wrapping shall not be removed until deployed. Geotextile or plastic wrapping damaged during storage or handling shall be repaired or replaced, as directed. Each roll shall be labeled with the manufacturer's name, geotextile type, roll number, roll dimensions (length, width, gross weight), and date manufactured.

B. Storage - Geotextile rolls shall be protected from becoming saturated. Rolls shall either be elevated off the ground or placed on a sacrificial sheet of plastic. The geotextile rolls shall also be protected from the following: construction equipment, ultraviolet radiation, chemicals, sparks and flames, temperatures in excess of 160 degrees F, and any other environmental condition that may damage the physical properties of the geotextile.

C. Handling - Geotextile rolls shall be handled and unloaded with load carrying straps, a fork lift with a stinger bar, or an axial bar assembly. Rolls shall not be dragged along the ground, lifted by one end, or dropped to the ground.

PART 2 PRODUCTS

2.01 RAW MATERIALS

A. Geotextile shall be a nonwoven pervious sheet of polymeric material and shall consist of long-chain synthetic polymers composed of at least 95 percent by weight polyolefins, polyesters, or polyamides. The use of woven slit film geotextiles will not be allowed. Stabilizers and/or inhibitors shall be added to the base polymer, as needed, to make the filaments resistant to deterioration by ultraviolet light, oxidation, and heat exposure. Regrind material, which consists of edge trimmings and other scraps that have never reached the consumer, may be used to produce the geotextile. Geotextile shall be formed into a network such that the filaments or yarns retain dimensional stability relative to each other, including the selvages. Geotextile shall have a unit weight of not less than 6 ounces per square yard as measured by ASTM D3776 and be a non-woven, needle pounded fabric. Geotextiles and factory seams shall meet the requirements specified in Table 1. Where applicable, Table 1 property values represent minimum average roll values (MARV) in the weakest principal direction.

Table 1

Property	Test Value	Test Method
Elongation at Break, percent	greater than 50	ASTM D4632
Permittivity, sec^{-1}	0.5	ASTM D4491
Puncture, lbs	80	ASTM D 4833
Grab Tensile, lbs	180	ASTM D4632
Trapezoidal Tear, lbs	50	ASTM D 4533
Burst Strength, psi	290	ASTM D 3786
Ultraviolet Stability (% strength retained at 150 hours)	70	ASTM D 4355
Seam Strength (lbs)	160	ASTM D 4632

PART 3 EXECUTION

3.01 GEOTEXTILE PLACEMENT

A. The Subcontractor shall request the presence of the Contractor during handling and installation. Geotextile rolls which are damaged or contain imperfections shall be repaired or replaced as directed. The geotextile shall be laid flat and smooth so that it is in direct contact with the subgrade. The geotextile shall also be free of tensile stresses, folds, and wrinkles.

B. Geotextile shall be placed on top of the iron/sand mixture along the trenchas shown in Figure 6.

3.02 PROTECTION

The geotextile shall be protected during installation from clogging, tears, and other damage. Damaged geotextile shall be repaired or replaced as directed. Adequate ballast (e.g. sand bags) shall be used to prevent uplift by wind. The geotextile shall not be left uncovered for more than 14 days during installation.

3.03 COVERING

Geotextile shall not be covered prior to approval by the Contractor. The Subcontractor shall request the presence of the Contractor during covering of the geotextile. The direction of backfilling shall proceed in the direction of downgradient shingling of geotextile overlaps. Cover fill shall be placed in a manner that prevents soil from entering the geotextile overlap zone, prevents tensile stress from being mobilized in the geotextile, and prevents wrinkles from folding over onto themselves. No equipment shall be operated directly on top of the geotextile.The excavated on site material specified in 02221, Article 2.01D will cover the top layer of geotextile in the trench shown in Figure 6.

END OF SECTION

SECTION 02555

WATER DISTRIBUTION SYSTEM

PART 1 GENERAL

1.01 WORK INCLUDED

A. Furnish all materials, labor and equipment and perform all operations required to remove and re-install the 6-inch water main in area of Work as specified in these specifications and as shown on the attached drawings.

1.02 CODES AND STANDARDS

A. Current editions or revision of the following standards as of the effective date of the Contract shall govern, unless specifically noted otherwise herein or on the Drawings.

1. AMERICAN WATER WORKS ASSOCIATION (AWWA)

a. AWWA C104 Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water

b. AWWA C105 Polyethylene Encasement for Ductile-Iron Piping for Water and Other Liquids

c. AWWA C111 Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings

d. AWWA C151 Ductile-Iron Pipe, Centrifugally Cast, for Water or Other Liquids

e. AWWA C600 Installation of Ductile-Iron Water Mains and Their Appurtenances

1.03 SUBMITTALS

None required

1.04 HANDLING

A. Pipe and accessories shall be handled so as to ensure delivery to the trench in sound, undamaged condition. Particular care shall be taken not to injure the pipe coating or lining. If the coating or lining of any pipe or fitting is damaged, the repair shall be made by the Contractor at his expense in a satisfactory manner. No other pipe or material of any kind shall be placed inside a pipe or fitting after the coating has been applied. Pipe shall be carried into position and not dragged. Use of pinch bars and tongs for aligning or turning the pipe will be permitted only on the bare ends of the pipe. The interior of pipe and accessories shall be thoroughly cleaned of foreign matter before being lowered into the trench and shall be kept clean during laying operations by plugging or other approved method. Before installation, the pipe shall be inspected for defects. Material found to be defective before or after laying shall be replaced with sound material without additional expense to the Government. Rubber gaskets that are not to be installed immediately shall be stored in a cool and dark place.

PART 2 PRODUCTS

A. Piping - Ductile-iron pipe shall conform to AWWA C151, working pressure not less than 1.03 MPa (150 psi). Pipe shall be cement-mortar lined in accordance with AWWA C104. Linings shall be standard. Pipe shall be encased with polyethylene in accordance with AWWA C105.

B. Joints

1. Mechanical joints shall be of the stuffing box type and shall conform to AWWA C111.
2. Push-on joints shall conform to AWWA C111.
3. Rubber gaskets and lubricant shall conform to the applicable requirements of AWWA C111.

PART 3 EXECUTION

A. Contractor shall arrange for water main source to be shut off during removal and re-installation of water main.

B. Removal and re-installation of pipe shall be conducted within the same working day to minimize time which excavation is open.

C. Removal of Existing Six-Inch Water Main

1. Subcontractor shall identify location of existing six-inch water main (or pipe).
2. Subcontractor to excavate such that pipe may be removed at existing joints.
3. Subcontractor shall cut pipe at the joints in a neat and workmanlike manner without damage to the pipe in place. Cutting shall be done with an approved type mechanical cutter. Wheel cutter shall be used when practical. Squeeze type mechanical cutters shall not be used for ductile iron.
4. Subcontractor shall cap both ends of the pipe that remain in place.
5. Subcontractor shall place existing pipe which is removed in a location designated by the Contractor. Contractor shall dispose of pipe.

C. Re-installation of Six-inch Water Main

1. Pipe shall be re-installed in original location.
2. Pipe shall be installed through the fabricated boot sleeve of the geomembrane (refer to Specification 02372 and Figure 9).
3. The maximum allowable deflection shall be as given in AWWA C600.
4. Pipe shall be carefully lowered into the trench by means of derrick, ropes, belt slings, or other authorized equipment. Under no circumstances shall any of the water-line materials be dropped or dumped into the trench. Care shall be taken to avoid abrasion of the pipe coating. Except where necessary in making connections with other lines or as authorized by Contractor, pipe shall be laid with the bells facing in the direction of laying. The full length of each section of pipe shall rest solidly upon the pipe bed, with recesses excavated to

accommodate bells, couplings and joints. Pipe that has the grade or joint disturbed after laying shall be taken up and relaid. Pipe shall not be laid in water or when trench conditions are unsuitable for the work. Water shall be kept out of the trench until joints are complete. When work is not in progress, open ends of pipe, fittings, and valves shall be securely closed so the no trench water, earth, or other substance will enter the pipes or fittings. Where any part of the coating or lining is damaged, the repair shall be made by the Subcontractor at his expense in a satisfactory manner. Pipe ends left for future connections shall be valved, plugged, or capped, and anchored.

5. Mechanical and push-on type joints shall be installed in accordance with AWWA C600 for buried lines.
6. After the pipe is laid and the joints completed, the pipe shall be pressure and leak tested.
7. Subcontractor shall flush new line.

END OF SECTION

SECTION 02930

REVEGETATION

PART 1 GENERAL

1.01 WORK INCLUDED

A. This section includes furnishing and placing seed, fertilizer, lime, and mulch to provide an acceptable stand of vegetation over the disturbed areas of the site.

1.02 CODES AND STANDARDS

A. Current editions or revisions of the following standards as of the effective date of the Contract shall govern, unless specifically noted otherwise herein or on the Drawings.

1. N.Y.S. Department of Transportation Standard Specifications: Construction and Materials,

   Section 610 - Turf Establishment

1.03 SUBMITTALS

A. Subcontractor shall submit Manufacturer's certification to Contractor that seed, lime, and fertilizer meet specification requirements.

1.04 DELIVER, STORAGE AND HANDLING

A. Subcontractor shall deliver packaged materials in containers showing weight, analysis, and name of Manufacturer.

B. Subcontractor shall protect materials from deterioration during delivery, and while stored at site.

PART 2 PRODUCTS

2.01 MATERIALS

A. Fertilizer materials and application methods shall meet the requirements of the N.Y.S.D.O.T. Standard Specifications, Section 610.

PART 3 EXECUTION

3.01 INSTALLATION

A. Areas to be seeded shall be finish graded, raked, and debris removed; soft spots and uneven grades shall be eliminated; the Contractor shall approve the finish grade of all areas to be seeded prior to application of seed.

B. Seeding, mulching, and conditioning shall only be performed during those periods within the seasons which are normal for such work as determined by the weather and locally accepted practice, as approved by the Contractor. The Subcontractor shall hydroseed only on a calm day.

C. Schedules for seeding and fertilizing must be submitted to the Contractor for approval prior to the work.

D. When newly graded subgrade areas cannot be seeded because of season or weather conditions and will remain exposed for more than 30 days, the Subcontractor shall protect those areas against erosion and washouts by whatever means necessary such as straw applied with an approved tackifier, wood chips, or by other measures as approved by the Contractor. Any such materials applied for erosion control shall be thoroughly incorporated into the subgrade by disking.

E. The Subcontractor shall provide against washouts by a method approved by the Contractor. Any washout which occurs shall be regraded and reseeded at the Subcontractor's expense until a good sod is established.

3.02 MAINTENANCE AND PROVISIONAL ACCEPTANCE

A. Subcontractor shall keep all seeded and mulched areas watered and in good condition, reseeding all seeded areas if and when necessary until a good, healthy, uniform growth is established over the entire area seeded. Subcontractor shall maintain all seeded areas in a approved condition until acceptance by the Contractor.

END OF SECTION

APPENDIX A
SELECTED SOIL BORING LOGS FOR THE ASH LANDFILL AREA

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHB-ES)

PROJECT Seneca Army Depot

DATE 14 November 1989

LOCATION 86.5 feet SW from PT-23
110.5 feet from MW-28

DRILLERS D. Kestner, S. Curran

DRILL RIG Mobile B-80 with 6-inch hollow stem auger

BORE HOLE MW- 27

DEPTH	SAMPLE TYPE BLOWS PER 6 IN.	DESCRIPTION	REMARKS
0		Dark brown silty clay	
1		Weathered gray shale	
5			
		BOH	
8		Gray shale	
10			

AEHA Form 130, 1-Nov 82

Replaces HSHB Form 78, 1 Jun 80, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHB-ES)

PROJECT Seneca Army Depot

DATE 14 November 1989

LOCATION 81 feet from fence line
110.5 feet from MW-27

DRILLERS D. Kestner, S. Curran

DRILL RIG Mobile B-80 with 6-inch hollow stem auger

BORE HOLE MW- 28

DEPTH	SAMPLE TYPE BLOWS PER 6 IN	DESCRIPTION	REMARKS
0		Dark brown silty clay	
1		Weathered gray shale	
5			
		BOH	
8		gray shale	
10			

AEHA Form 130, 1-Nov 82

Replaces HSHB Form 78, 1 Jun 80, which will be used.

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHB-ES)

PROJECT Seneca Army Depot

DATE 14 November 1989

LOCATION 167 feet from PT-24 58' feet from fence

DRILLERS D. Kestner, S. Curran

DRILL RIG Mobile B-80 with 6-inch hollow stem auger

BORE HOLE MW- 29

DEPTH	SAMPLE TYPE BLOWS PER 6 IN.	DESCRIPTION	REMARKS
0		Dark brown silty clay	
1		Weathered gray shale	
5			
		BOH	
9		Gray shale	
10			

AEHA Form 130, 1-Nov 82

US ARMY ENVIRONMENTAL HYGIENE AGENCY

DRILLING LOG

(The proponent of this form is HSHB-ES)

PROJECT Seneca Army Depot

DATE 14 November 1989

LOCATION 58.5 feet from fence 114.5 feet from MW-30

DRILLERS D. Kestner, S. Curran

DRILL RIG Mobile B-80 with 6-inch hollow stem auger

BORE HOLE MW- 31

DEPTH	SAMPLE TYPE / BLOWS PER 6 IN	DESCRIPTION	REMARKS
0		Dark brown silty clay	
1			
2		Weathered gray shale	
5			
8			
9		BOH Gray shale	
10			

AEHA Form 130, 1-Nov 82

FIGURE NO.

CHAS. T. MAIN, INC.	TEST BORING REPORT	BORING NO: MW-38D

PROJECT: SEAD, ASH LANDFILL RIFS
CLIENT: SENECA ARMY DEPOT
CONTRACTOR: EMPIRE DRILLING

JOB NO: 720229–0600
SHEET NO: 1 OF 2
ELEV. DATUM 1929, NGD
ELEV.(GS): 635.4
ELEV.(TOC): 637.93
DATE START 11–6–91
DATE FINISH 11–6–91
DRILLER: Empire
INSPECTOR: –

	CASING	SAMPLER	CORE BARREL
TYPE:	AUGER	SPLIT SPOON	–
SIZE ID/OD:	6.24/9.63	3" O.D.	–
HAMMER WEIGHT:	–	140 LB	–
HAMMER FALL:	–	30 INCH	–

GROUNDWATER READINGS

DATE	TIME	DEPTH TO WATER	STABILIZATION TIME

DEPTH (FT.)	SAMPLE: CASING BLOWS PER FOOT	SAMPLE BLOWS PER 6 INCHES	RECOVERY (FT.)	SAMPLE DEPTH RANGE	VOC SCREEN (PPM)	SAMPLE DESCRIPTION	STRATUM DESCRIPTION
1						Olive–gray SILT, Some +CLAY, trace –GRAVEL, trace fine to medium SAND	Till (ML)
2							
3							
4							
5							
6						Gray weathered shale, fissile, some SILT	Weathered Shale
7							
8							
9							
10							
11							
12							
13							

GRANULAR SOILS BLOWS/FT	DENSITY	COHESIVE SOILS BLOWS/F	CONSISTENCY
0–4	V. LOOSE	<2	V.SOFT
4–10	LOOSE	2–4	SOFT
10–30	M.DENSE	4–8	M.STIFF
30–50	DENSE	8–15	STIFF
>50	V.DENSE	15–30	V.STIFF
		>30	HARD

VOL. WATER LOST: GAL. DATE WELL DEVELOPED:
VOC DETECTOR: ORGANIC VAPOR METER
WELL PIPE PVC DIAM. 2" SLOT SIZE: 0.010"
REMARKS: Weathered Bedrock Monitoring Well Installed

CHAS. T. MAIN, INC. **TEST BORING REPORT**

BORING NO: MW-38D

SHEET NO: 2 of 2

DEPTH (FT.)	SAMPLE: CASING BLOWS PER FOOT	SAMPLE: SAMPLE BLOWS PER 6 INCHES	SAMPLE: RECOVERY (FT.)	SAMPLE: SAMPLE DEPTH RANGE	SAMPLE: VOC SCREEN (PPM)	SAMPLE DESCRIPTION	STRATUM DESCRIPTION
14						Gray Weathered Shale, Fissile, Some SILT	Weathered Shale
15							
16							
17						Gray Shale	Competent Shale
18							
19							
20							
21							
22							
23							
24							
26							
27							

OVERBURDEN BORING REPORT

ENGINEERING–SCIENCE, INC.	CLIENT: SEAD	BORING #: MW 45

MONITORING			
INSTRUMENT	INTERVAL	BGD	TIME

COMMENTS: MONITORING WELL #45

DRILLER: AMERICAN

INSPECTOR: ACG

DATE: 5-4-93

DEPTH (FT)	SAMPLING			SAMPLE				SAMPLE DESCRIPTION (As per Burmeister: color, grain size, MAJOR COMPONENT, Minor Components with amount modifiers and grain-size, density, stratification, wetness, etc.)	USCS CLASS	STRATUM CLASS
	BLOWS PER 6 INCHES	PENETRATION RANGE (FEET)	RECOVERY RANGE (FEET)	DEPTH INT (FEET)	NO.	VOC	RAD SCRN			
	1	0'				0	N			
	5	↓	~~CS~~	CS		0	c			
1	8	2'	3'	0' ↓		ppm		Dark Brown Loam (3")		
	11			2'						
2	3	2'		2'		↓	↓	- Dark Brown Loam		
	7	↓	2'	↓				} tight grey-green silty clay		
3	18	4'		4'					OL	
	21							- sand	SM	
4	7	4' ↓		4'				WATER @ 4'		
5	40	6'		↓				} silty-clay / weathered shale	OL	
	50	2"		6'				} hard shale	BRK	
	—									
6										
10										
15										
20										

OVERBURDEN BORING REPORT

ENGINEERING-SCIENCE, INC.

CLIENT: SEAD

BORING #: MW 46

MONITORING

INSTRUMENT	INTERVAL	BGD	TIME

COMMENTS: MW #46

DRILLER: J. Pietruch

INSPECTOR: A. Gifford

DATE:

DEPTH (FT)	SAMPLING BLOWS PER 6 INCHES	PENETRATION RANGE (FEET)	RECOVERY RANGE (FEET)	SAMPLE DEPTH INT (FEET)	NO.	VOC*	RAD SCRN	SAMPLE DESCRIPTION (As per Burmeister: color, grain size, MAJOR COMPONENT, Minor Components with amount modifiers and grain-size, density, stratification, wetness, etc.)	USCS CLASS	STRATUM CLASS
	1 2 5 9	0' ↓ 2'	2'	0' ↓ 2'	1	0	BG	} Dark Brown Loam } Packed Silt/clay soil - Med Dark Brown	OH OH	Till Till
	4 6 11 16	2' ↓ 4'	10"	2' ↓ 4'	2	0	BG	recovered 10" sample Clay		Till
5	14 21 26 24	4' ↓ 6'	4"	4' ↓ 6'	3	0	BG	recovered 4" sample Clay		Till
	5 14 64	6' ↓ 8'	14"	6' ↓ 8'	4	0	BG	7" clay 5" ~~[illegible]~~ weathered Till 2" shale - grey	CL BRK	Till — Weathered Bedrock
		8' ↓ 9'		8' ↓ 9'	5	0	BG	shale - grey S.S. refused at 9'	BRK	Bedrock
10										
15										
20										

SEE MASTER ACRONYM LIST FOR COMPLETE LISTING OF ABBREVIATIONS

APPENDIX B
SECURITY REQUIREMENTS AT SENECA ARMY DEPOT ACTIVITY

APPENDIX B

Security Requirements

The following requirements must be followed by the A-E at Seneca Army Depot to facilitate entry and exit of AE employees and to maintain security. It is the AE's responsibility to assure that his and his subcontractor's personnel are following these security requirements. Failure to do so will contribute to unnecessary delays.

Personnel Registration

A list of all AE employees, subcontractors and suppliers indicating firm name and address will be furnished through POC/COR to the Counterintelligence Division, Building 710, 72 hours prior to commencement of work.

A confirmation of employment SDSSE-SC Form 268 will be executed by the AE concerning each employee, to include all subcontractors and their personnel. No forms will be transferred to another file if the AE has other on-going contracts at SEAD. The AE will provide a list of personnel who are authorized to sign Form 268 for the firm. A sample of each signature is required. Counterintelligence Division must be notified, in writing, of any changes to this list. All completed forms will be provided through COR/POC to the Counterintelligence Division 72 hours prior to commencement of work. Failure to complete Form 268 correctly will result in employee's denial of access to Seneca. The Counterintelligence Division must be notified, in writing through POC/COR to Counterintelligence, at least 72 hours prior to requesting any action. The chain of command for all AE actions will be through POC/COR to Counterintelligence Division. There will be no exceptions.

Camera permits require written notice from the POC/COR prior to access. Open camera permits will not be issued. The following information is required:

a. Camera make, model and serial number.
b. Contract name and name of individual responsible for the camera.
c. Dates camera will be used.
d. Where it will be used.
e. What will be photographed and why.

If a rental, leased or privately owned vehicle is required in place of a company vehicle, the following information is needed.

a. Name of individual driving.
b. Year, make, model, color and license plate of the vehicle.
c. Typed letter on company letterhead indicating that the company assumes responsibility for rental, leased or privately owned vehicles.

All access media will be destroyed upon expiration date of contract. If an extension is required a list of employee names and new expiration date must be furnished to the Counterintelligence Division.

Contract extensions must be made prior to the contract expiration date or new Form 268s will be required for each individual that requires an extension.

Traffic Regulations

Traffic Laws, State of New York, apply with emphasis on the following regulations:

Speed Limit:
Controlled Area - as posted
Ammo Area - 5 mph
Limited/Exclusion Area - 25 mph

All of the above are subject to change with road conditions or as otherwise posted.

Parking

AE vehicles (trucks, rigs, etc.) will be parked in areas designated by the Director of Law Enforcement and Security. Usually parking will be permitted within close proximity to the work site. Do not park within 30 feet of a depot fence, as these are clear zones.

Gates

Post 1, Main Gate - NY Highway 96, Romulus, New York is open for personnel entrance and exit 24 hours daily, 7 days a week.

Post 3, entrance to North Depot Troop Area, located at end of access road from Route 96-A is open 7 days a week for personnel and vehicle entrance and exit.

Security Regulations

Prohibited Property

Cameras, binoculars, weapons and intoxicating beverages will not be introduced to the installation, except by written permission of the Director/Deputy Director of Law Enforcement and Security.

Matches or other spark producing devices will not be introduced into the Limited/Exclusion or Ammo Area's except when the processor of such items is covered by a properly validated match or flame producing device permit.

All vehicles and personal parcels, lunch pails, etc. are subject to routine security inspections at any time while on depot property.

All building materials, equipment and machinery must be cleared by the Director of Engineering and Housing who will issue a property pass for outgoing equipment and materials.

AE Employee Circulation

AE employees are cleared for entrance to the location of contract work only. Sight-seeing tours or wandering from work site is NOT AUTHORIZED.

Written notification will be provided to the Counterintelligence Division (Est. 30202) at least 72 hours prior to overtime work or prior to working on non-operating days.

Security Police (Ext. 30448/30366) will be notified at least two hours in advance of any installation or movement of slow moving heavy equipment that may interfere with normal flow of traffic, parking or security.

Unions

Representatives will be referred to the Depot Industrial Labor Relations Officer (Ext. 41317).

Offenses

(Violations of law or regulations).

Minor

Offenses committed by AE personnel which are minor in nature will be reported by the Director of Law Enforcement and Security to the Contracting Officer who in turn will report such incidents to the AE for appropriate disciplinary action.

Major

Serious offenses committed while on the installation will be reported to the FBI. Violators may be subject to trial in Federal Court.

Explosive Laden Vehicle

Vehicles such as vans, cargo trucks, etc. carrying explosives will display placards or signs stating "EXPLOSIVES".

Explosive ladened vehicles will not be passed.

When an explosive laden vehicle is approaching, pull over to the side and stop.

When catching up with an explosive laden vehicle, slow down and allow that vehicle to remain at least 100 feet ahead.

When approaching an intersection where an explosive laden vehicle is crossing - STOP - do no enter the intersection until such time as the explosive carrier has passed thru, cleared the intersection.

When passing a vehicle that is parked, and displaying "Explosive" signs, slow down to 10 miles per hour, and take every precaution to allow more than ample clearance.

Clearing Post

All AE employees are required to return all identification badges, and passes on the last day of employment on the depot. The AE is responsible for the completion of all turn-ins by his employees, and informing the Counterintelligence Division and the depot organization administering the contract, for termination of any employee's access to the depot.

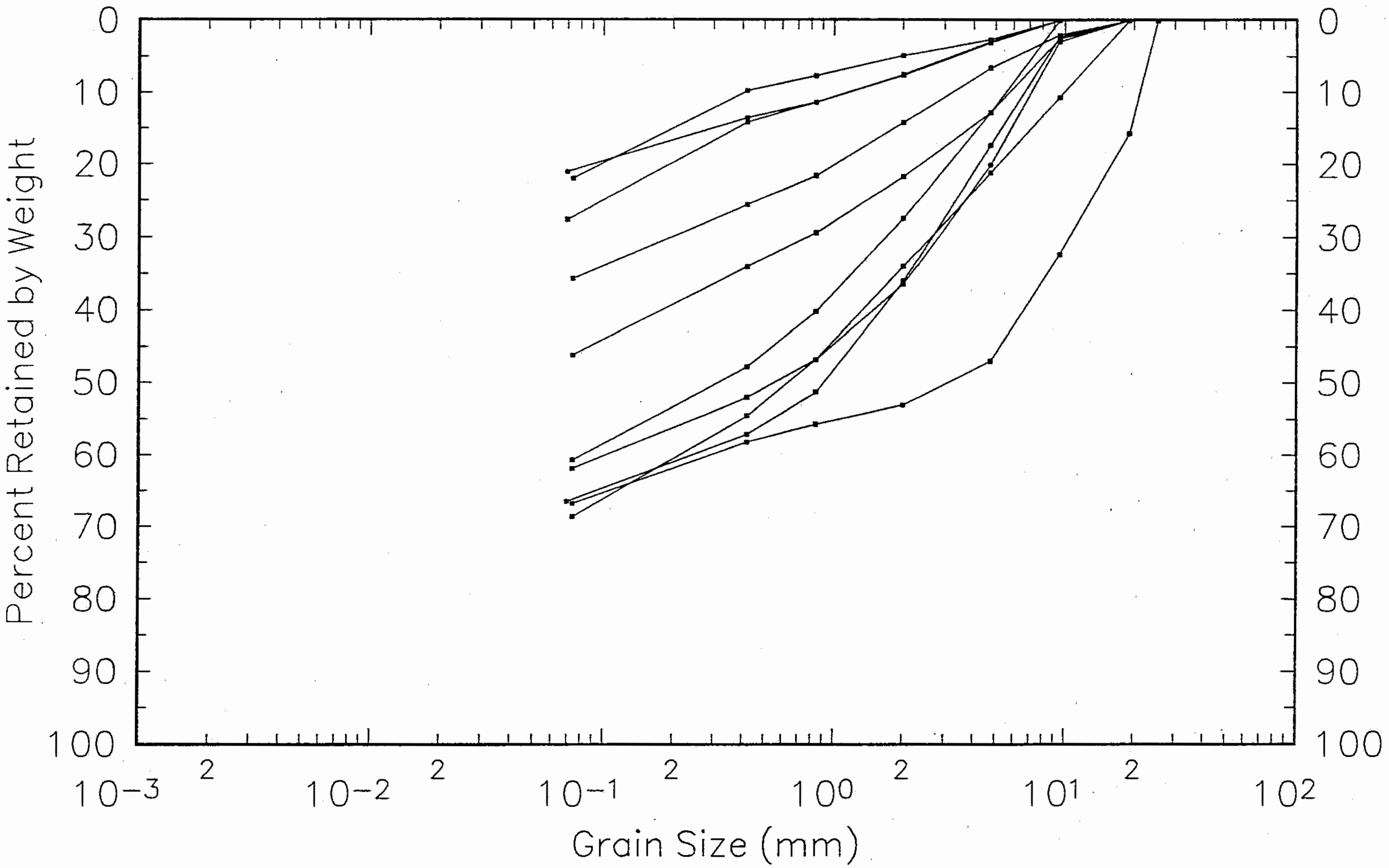
Public Affairs

The subcontractor shall not publicly disclose any data generated or reviewed under this contract. The subcontractor shall refer all requests for information to CEHND. Reports and data generated under this contract shall become the property of the Department of Defense and distribution to any other source by the subcontractor, unless authorized by the Contracting Officer, is prohibited.

APPENDIX C
GRAIN-SIZE ANALYSES FOR SOILS AT THE SENECA ARMY DEPOT ACTIVITY

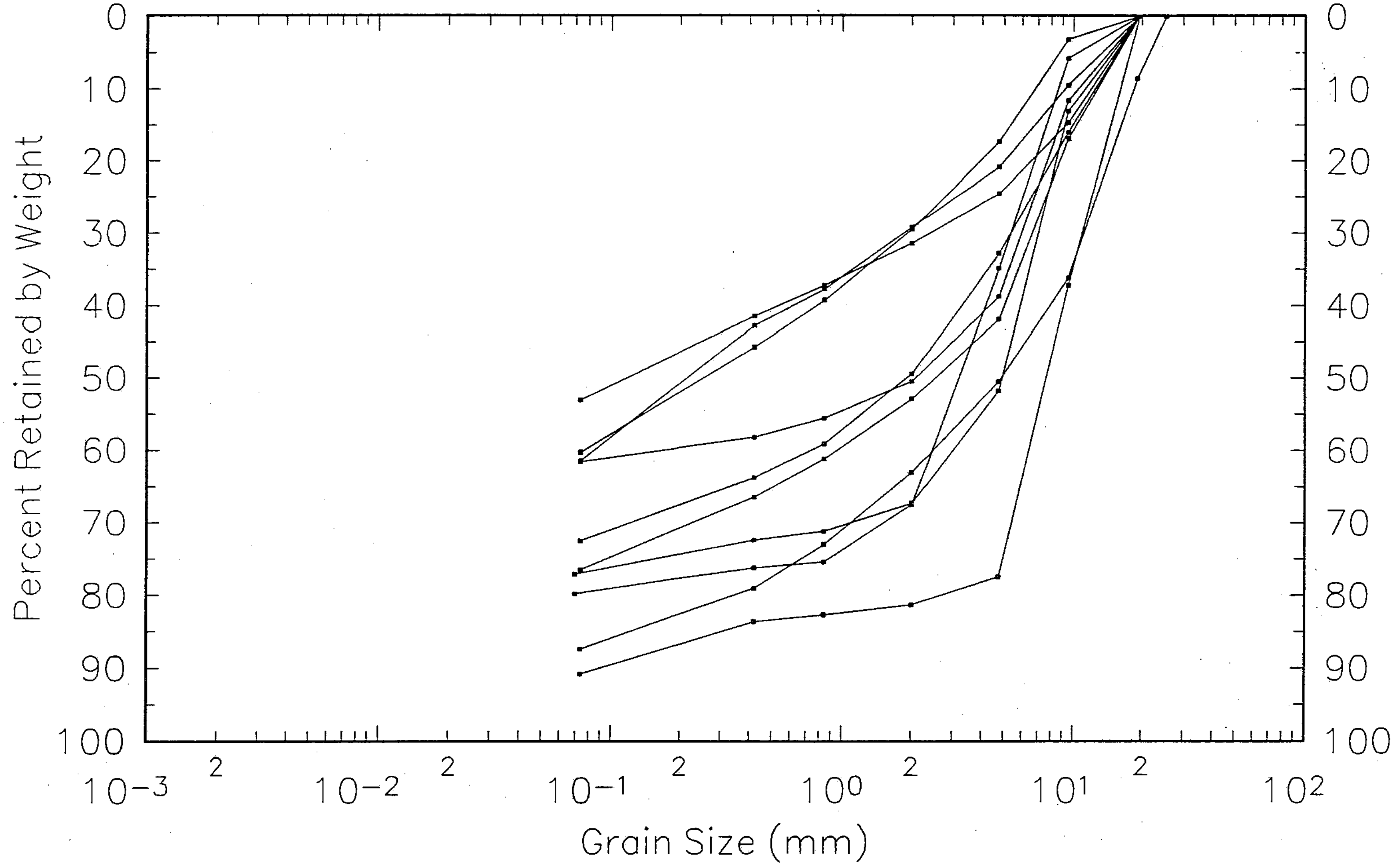
July 22, 1992   8:01:28 AM

GRAIN SIZE DISTRIBUTION CURVES
SENECA ARMY DEPOT TILL SAMPLES



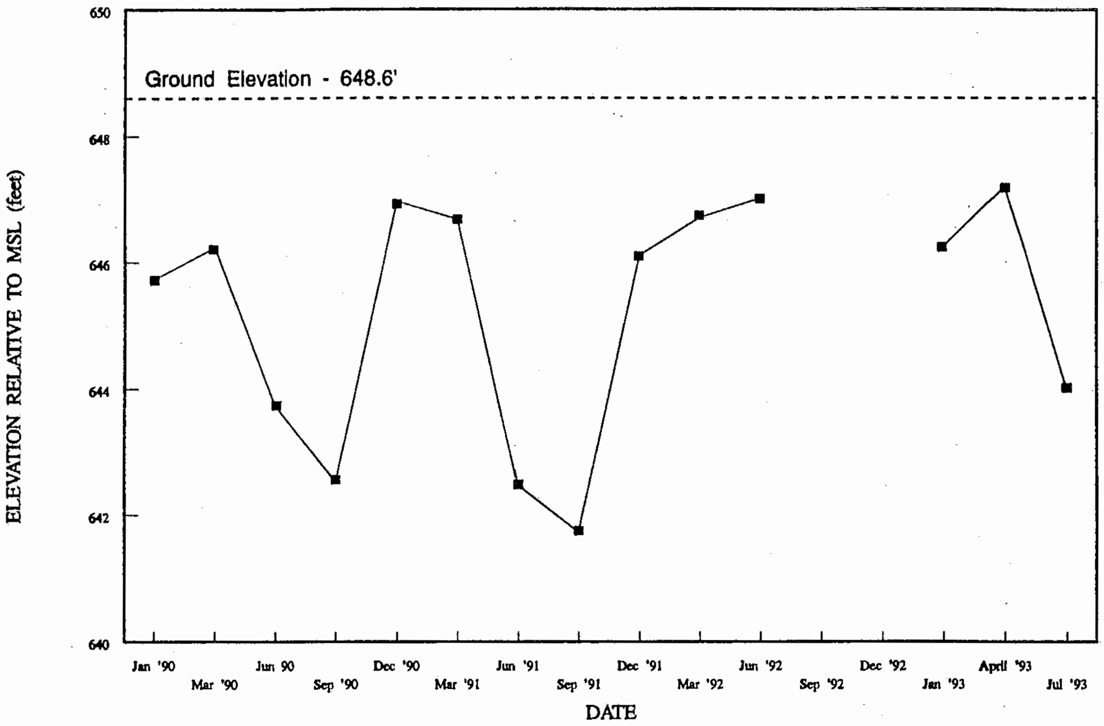
July 27, 1992 12:47:46 AM

GRAIN SIZE DISTRIBUTION CURVES
SENECA ARMY DEPOT WEATHERED SHALE SAMPLES

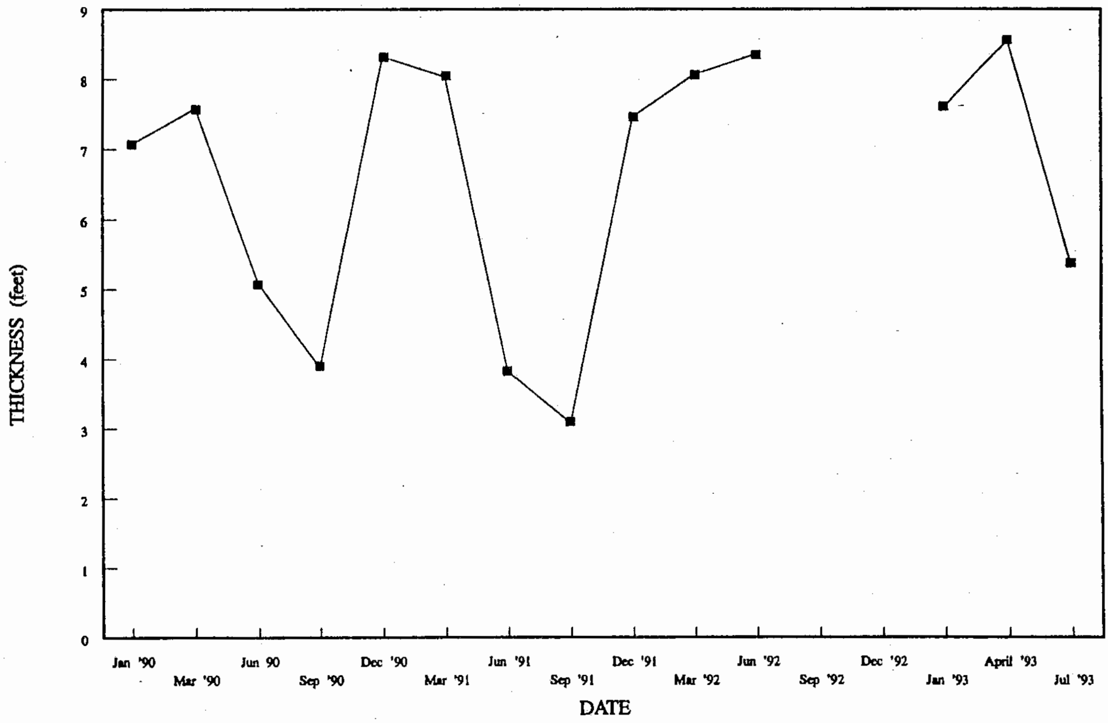


APPENDIX D
SEASONAL GROUNDWATER FLUCTUATIONS AT THE ASH LANDFILL

WATER TABLE ELEVATION PT-12



SATURATED THICKNESS PT-12



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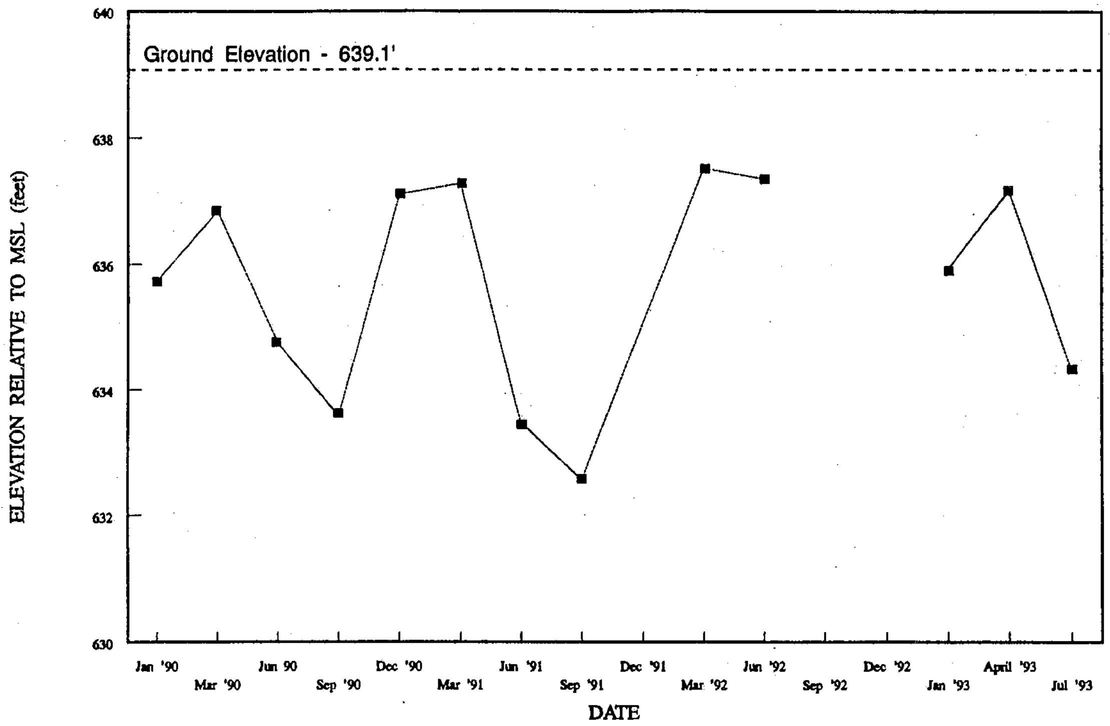

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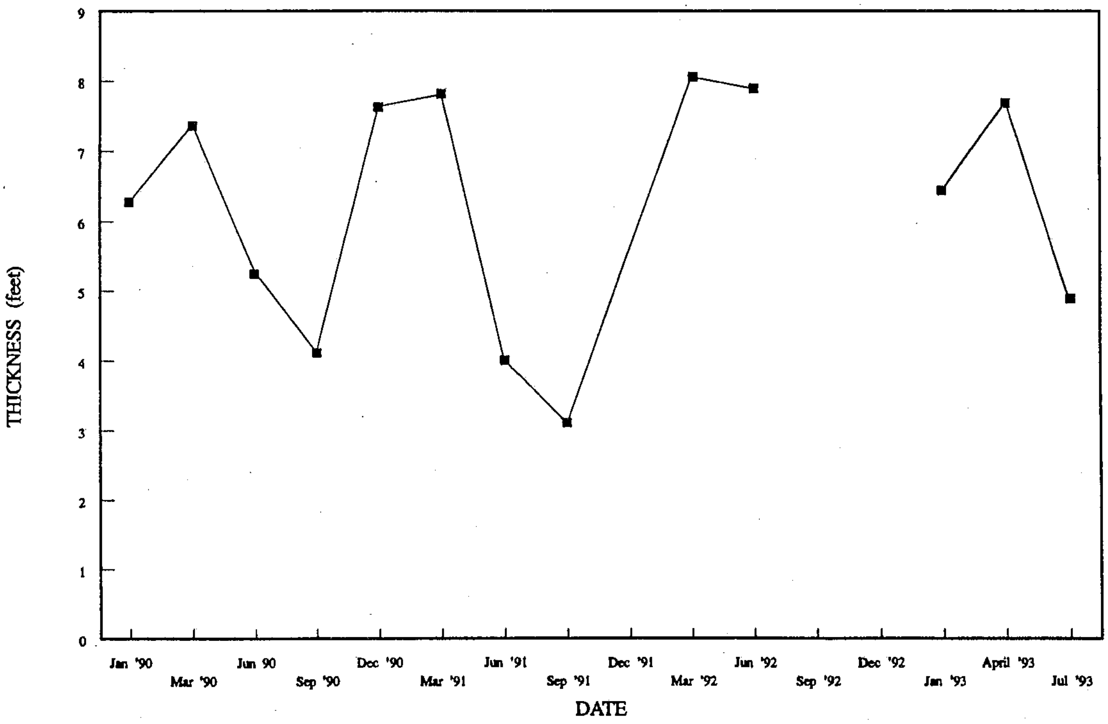
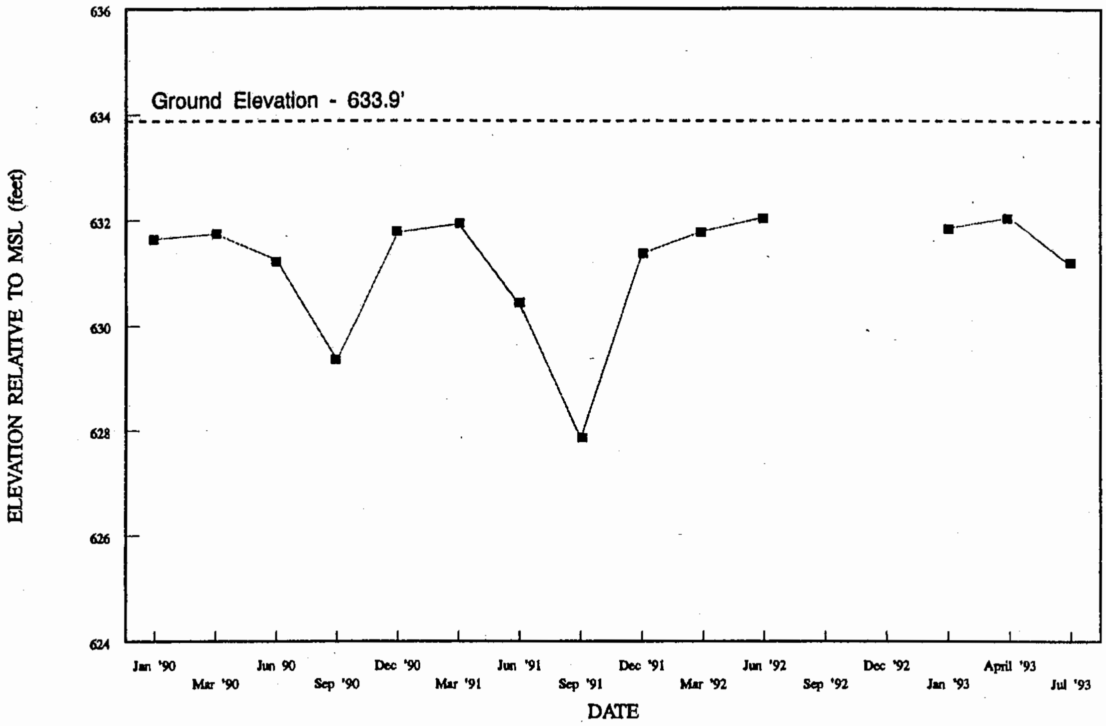


WATER TABLE ELEVATION PT-24



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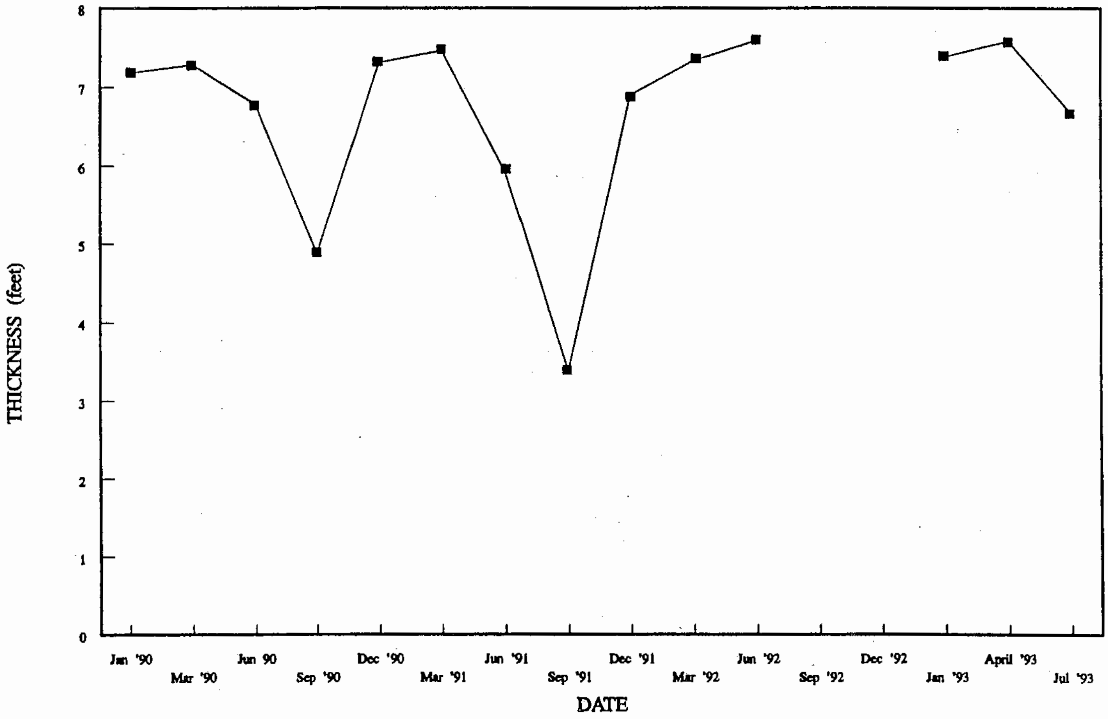
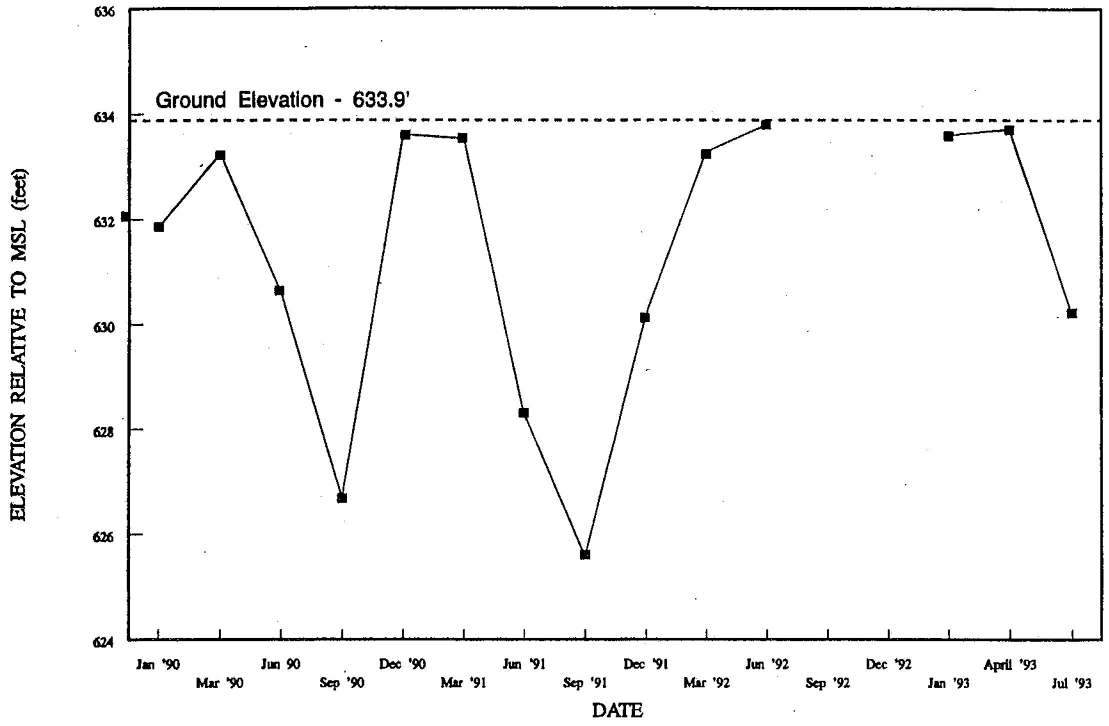


WATER TABLE ELEVATION PT-25



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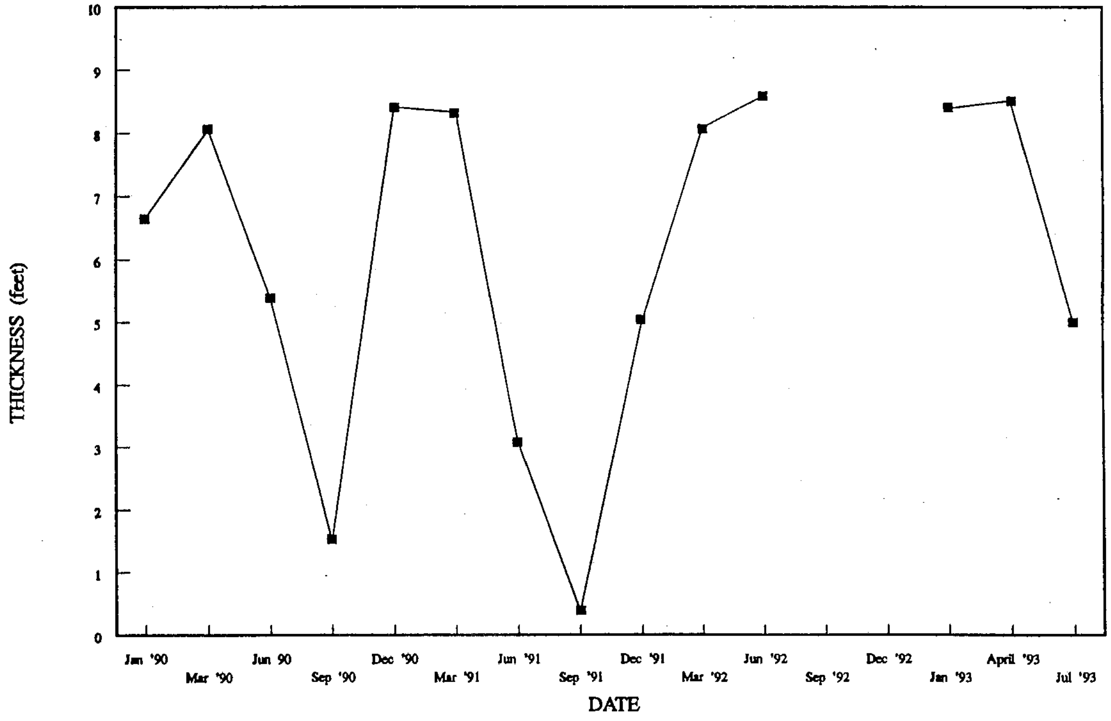
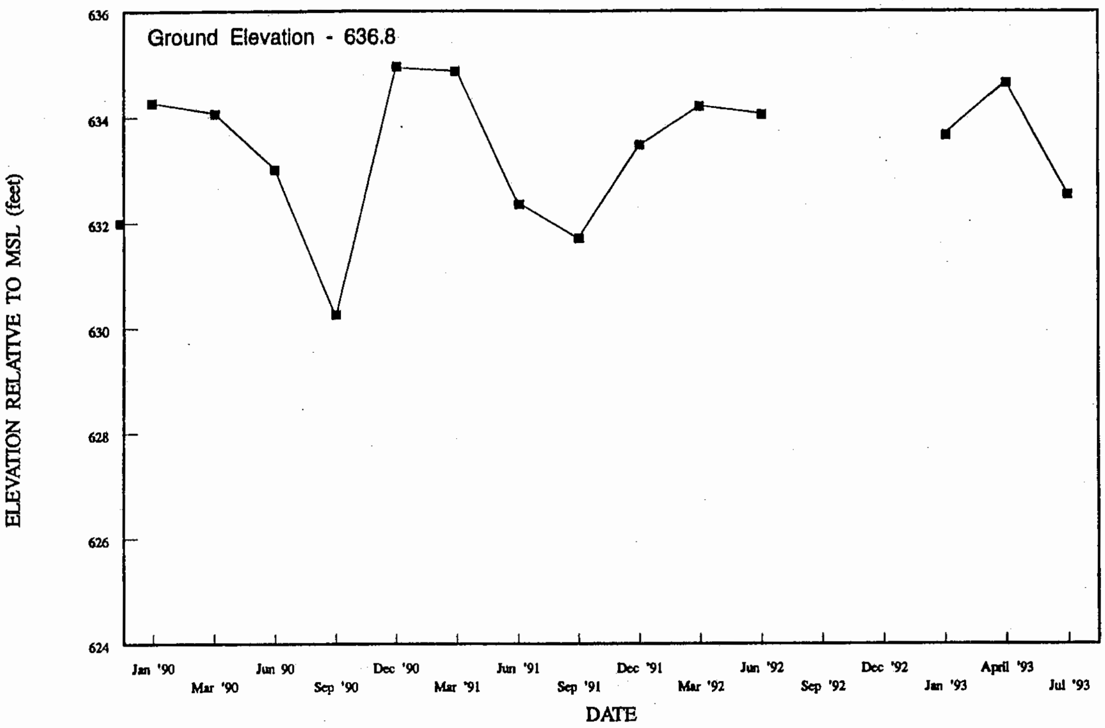


WATER TABLE ELEVATION MW-27



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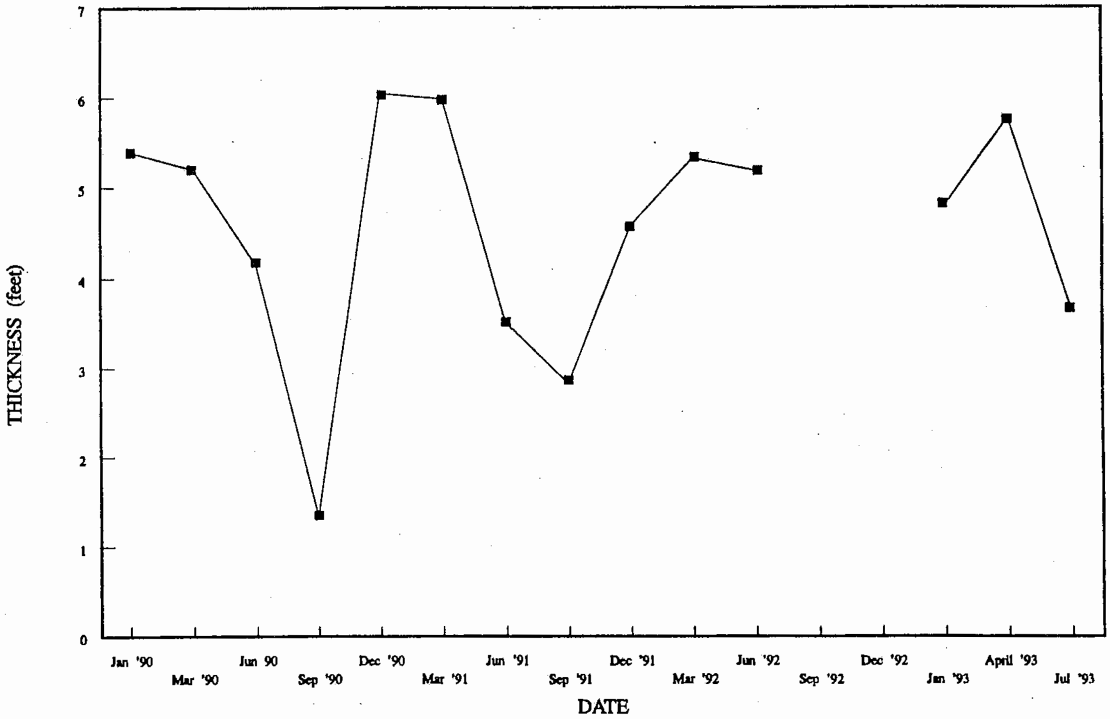
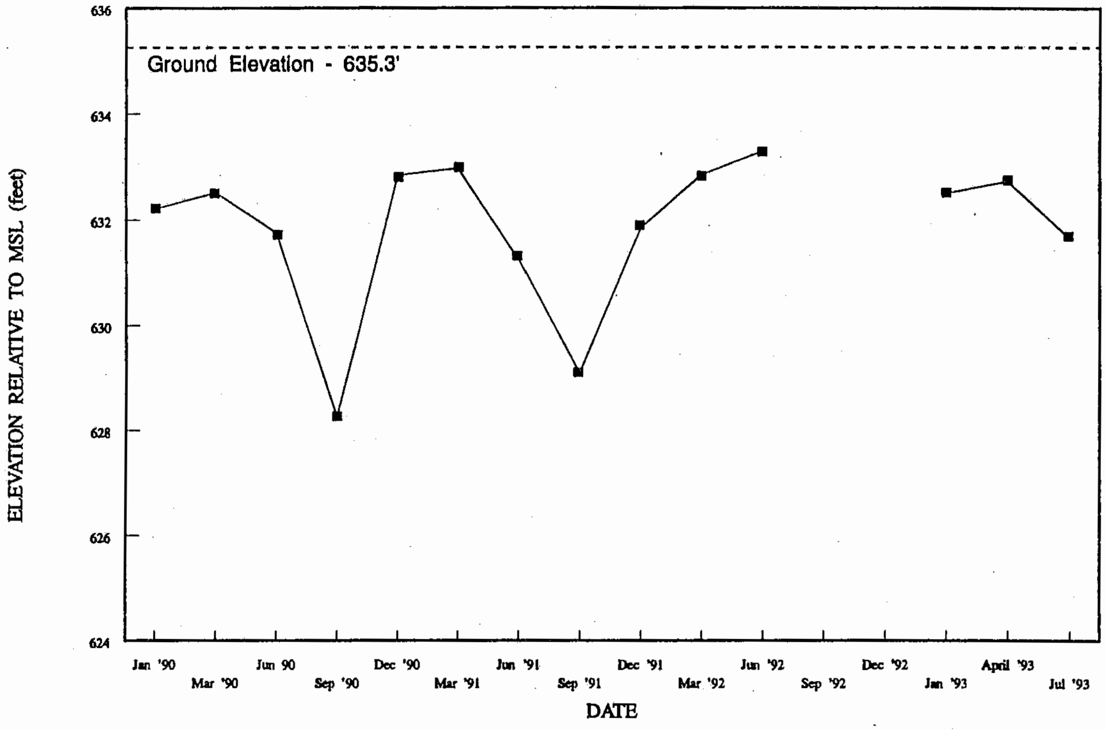
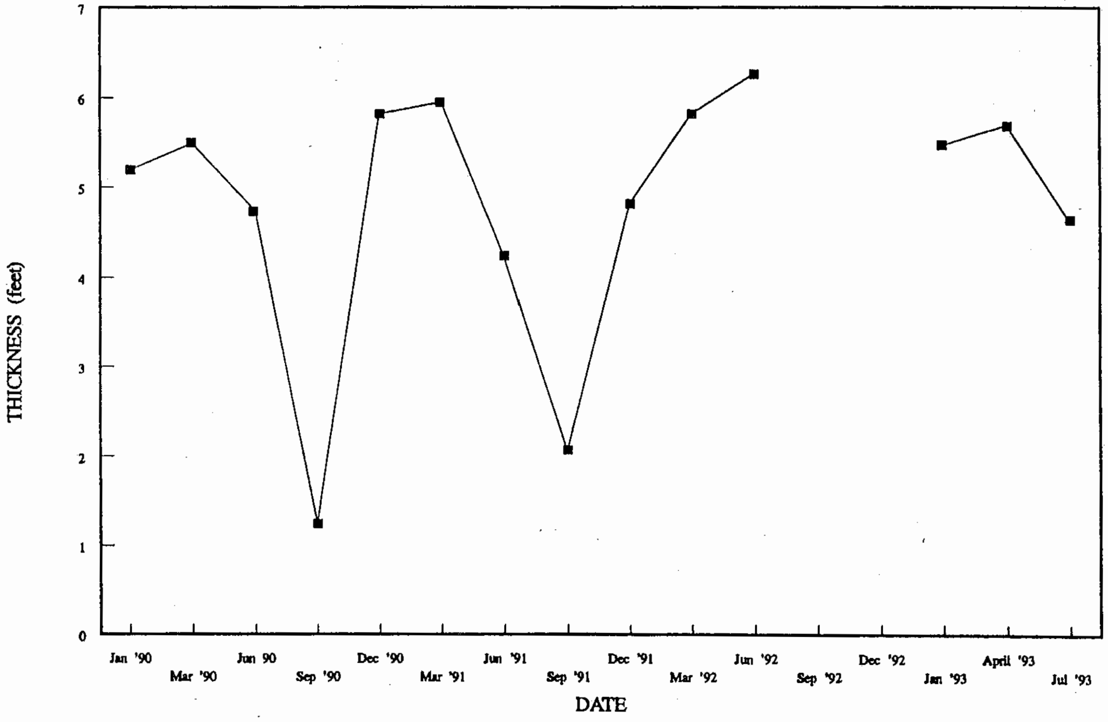


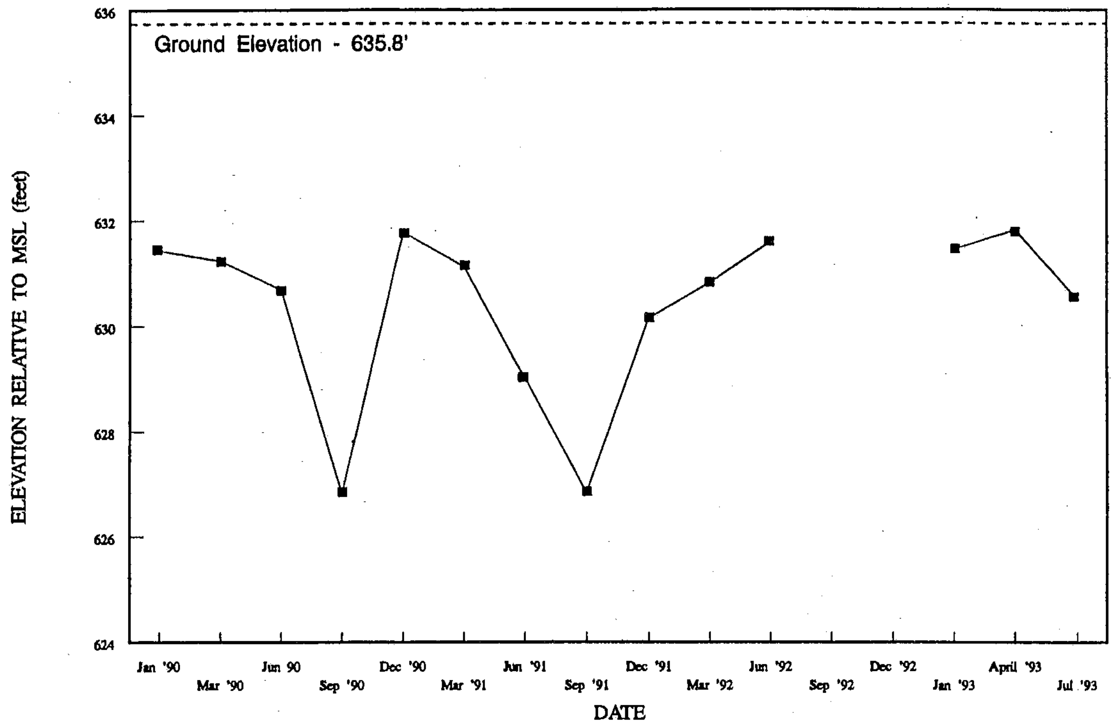


WATER TABLE ELEVATION MW-28

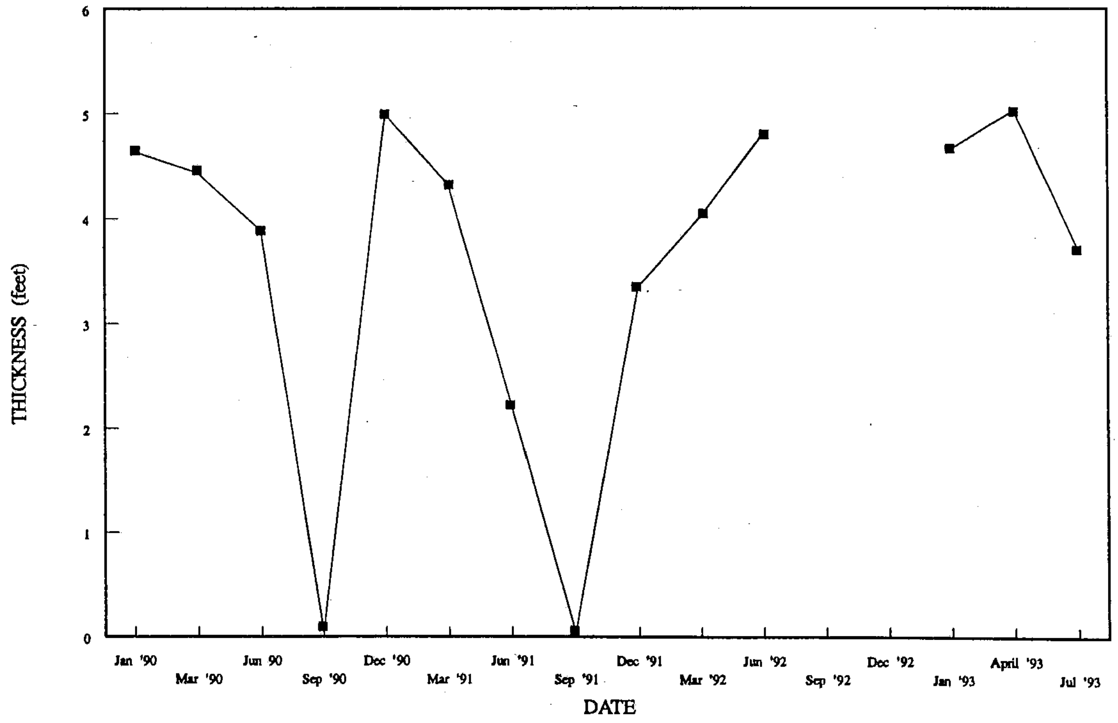


SATURATED THICKNESS MW-28

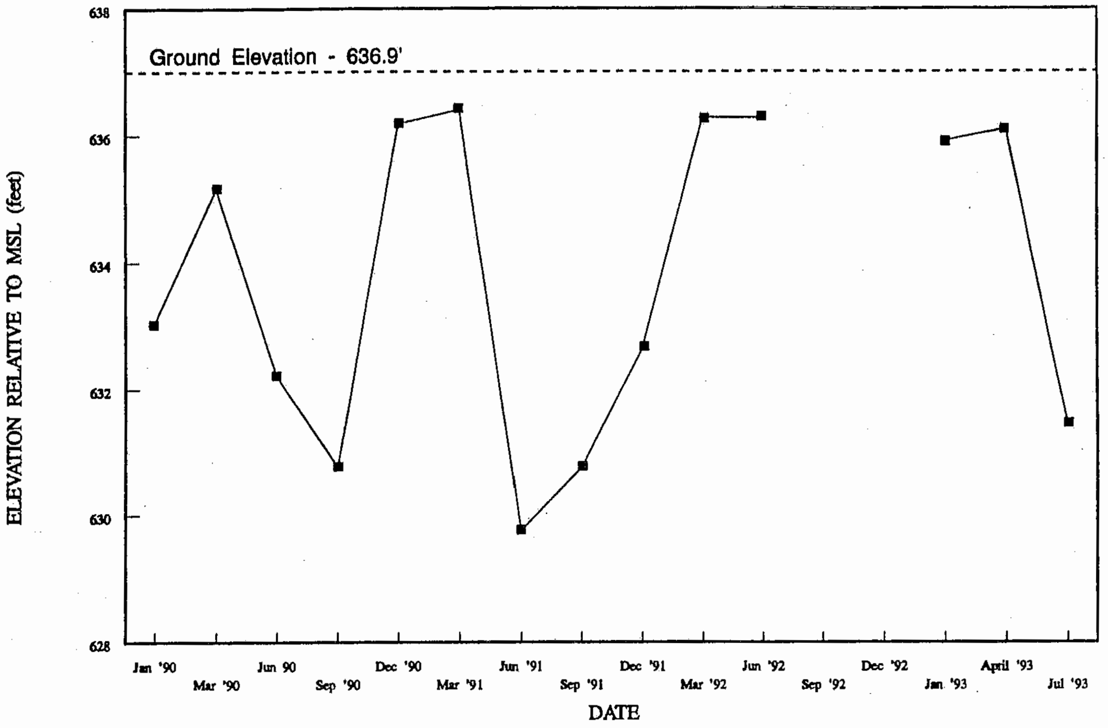
WATER TABLE ELEVATION MW-29



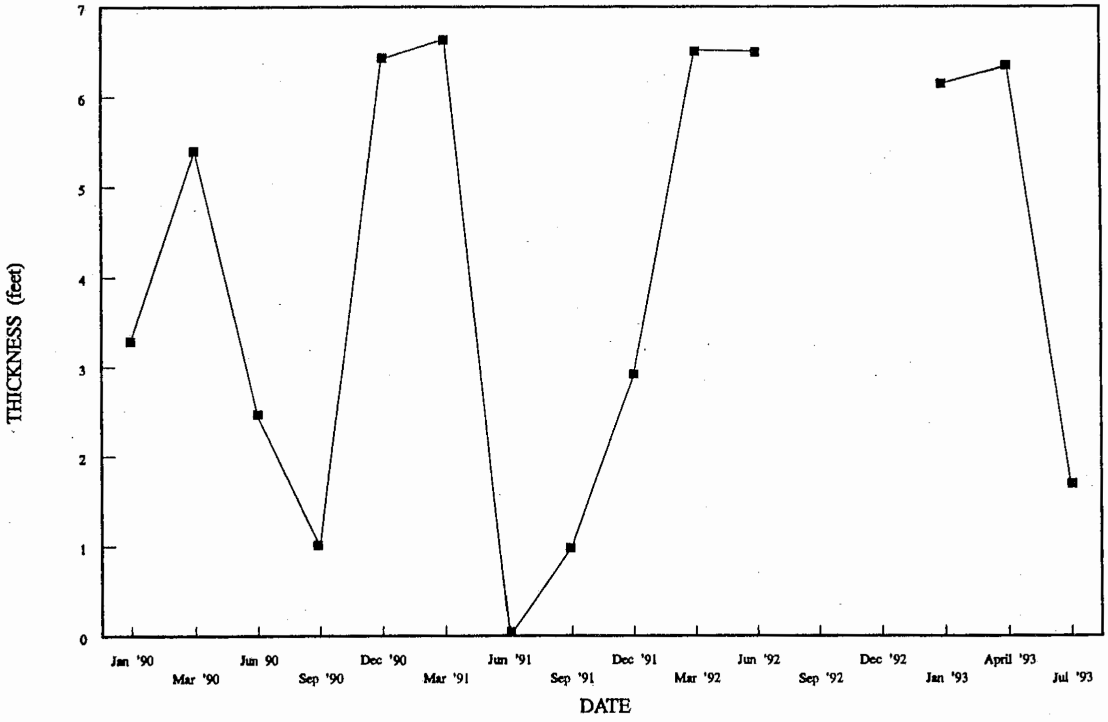
SATURATED THICKNESS MW-29



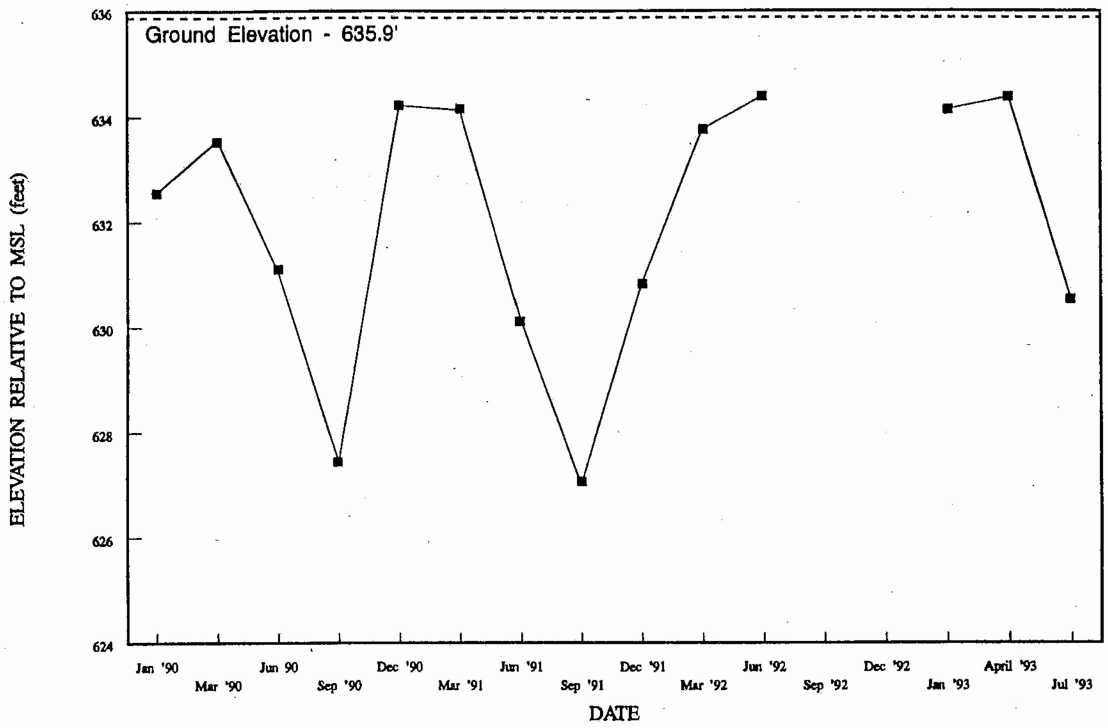
WATER TABLE ELEVATION MW-30



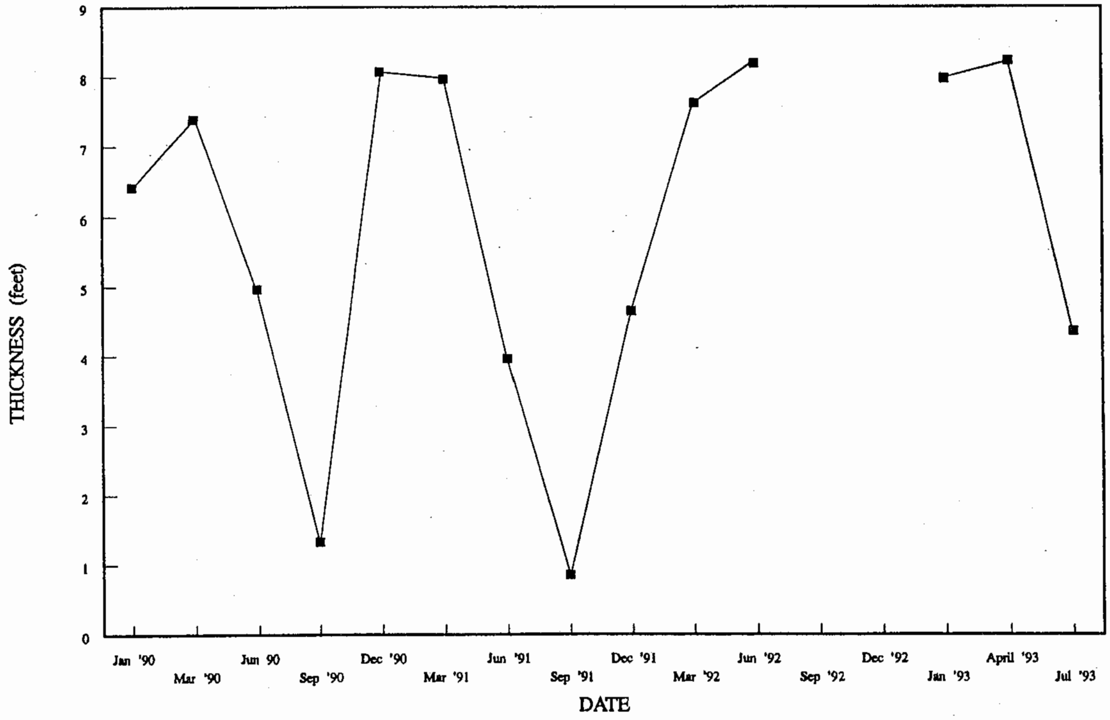
SATURATED THICKNESS MW-30



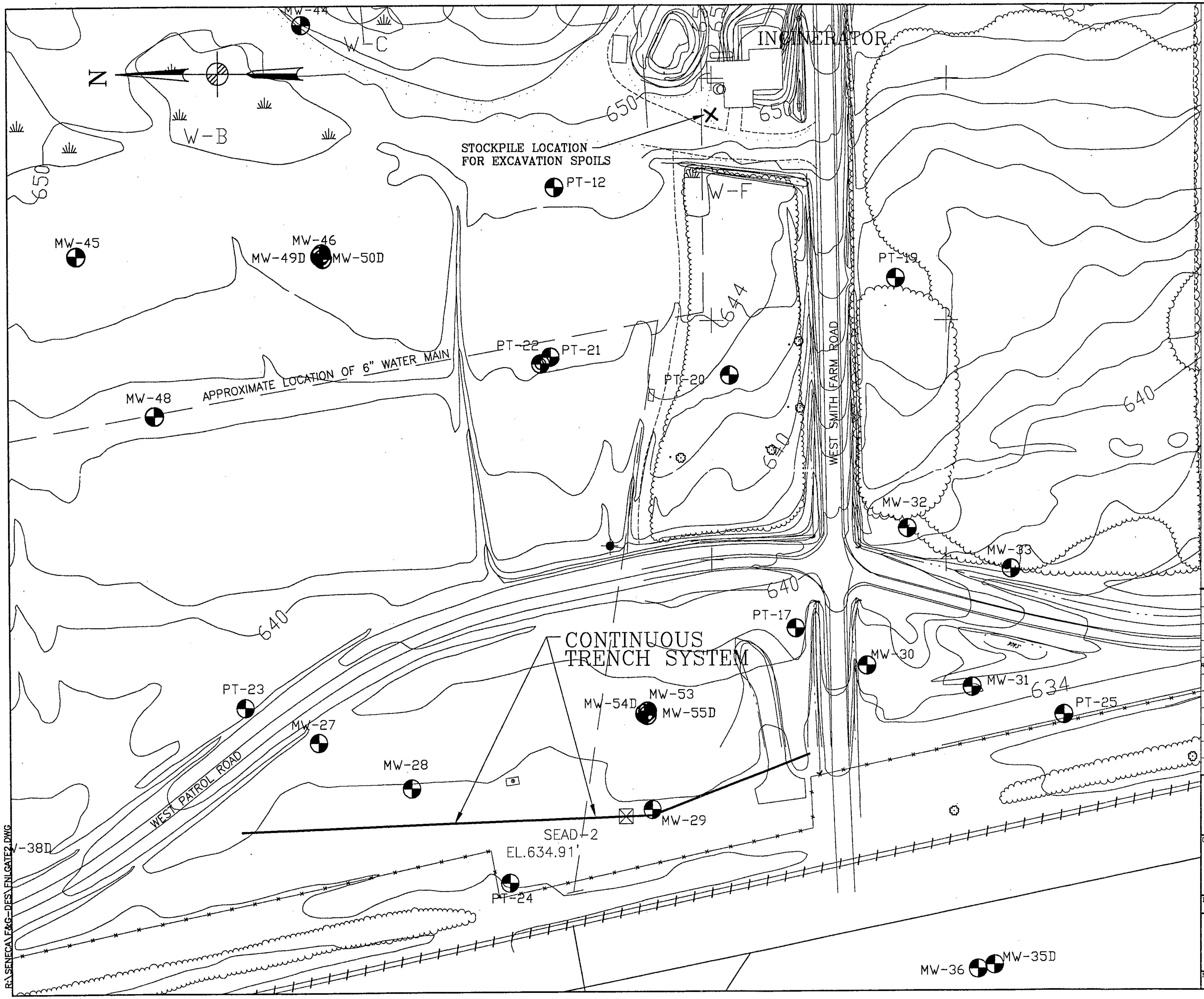
WATER TABLE ELEVATION MW-31



SATURATED THICKNESS MW-31



DRAWINGS



SCALE: 1' = 100'

REV	DATE	DESCRIPTION
D	11/4/98	ISSUED FOR EPA REVIEW
C	10/12/98	ISSUED FOR RE-BID
B	9/16/98	ISSUED FOR BID
A	8/20/98	ISSUED FOR REVIEW

DRAWN BY C. DROWNE
CHECKED BY J. TRAVERS
DESIGN SUPV.
RESP. ENGR.
CHIEF DISC. ENGR.
MGR. OF ENGR.
PROJECT MANAGER M. DUCHESNEAU
MGR. OF PROJECTS J. P. CHAPLICK
IN CHARGE W. D. PATTERSON

DRAWN
CHECKED
DES.SUPV.
RESP.ENGR.
CH.DISC.ENG.
PROJ. MGR.

PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

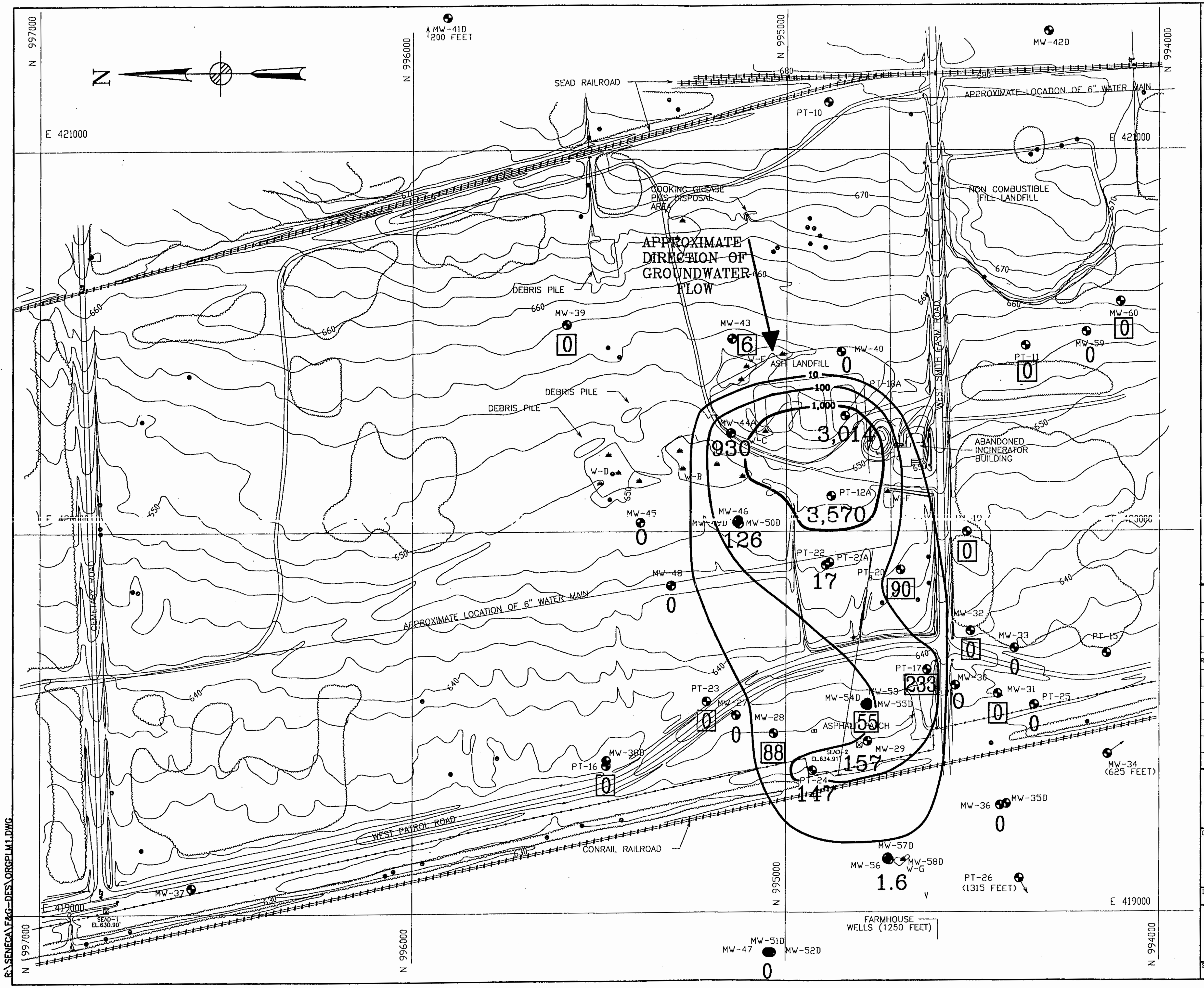
SENECA ARMY DEPOT ACTIVITY

ASH LANDFILL GROUNDWATER TREATABILITY STUDY
USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM

DEPT. ENVIRONMENTAL ENGINEERING
Dwg. No. 726209-01004

FIGURE 1
APPROXIMATE LOCATION OF
CONTINUOUS TRENCH SYSTEM

SCALE 1" = 100'
DATE NOVEMBER 1998
REV D



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LEGEND:

PAVED ROAD
DIRT ROAD
GROUND CONTOUR AND ELEVATION (650)
TREE
WETLAND & DESIGNATION (W-B)
APPROXIMATE EXTENT OF FILL
OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
APPROXIMATE EXTENT OF DEBRIS PILE
BRUSH
CHAIN LINK FENCE
UTILITY POLE
APPROXIMATE LOCATION OF FIRE HYDRANT
FUEL OR UNDERGROUND STORAGE TANK
SEAD-1 EL.630.90' ☒ SURVEY MONUMENT
PT-22 MW-37 MONITORING WELL AND DESIGNATION
—1,000— GROUNDWATER ISOCONTOUR (ug/L)
17 TOTAL VOCs FROM SAMPLE COLLECTED IN JUNE 1997 DURING THE SECOND QUARTER 1997
$\boxed{90}$ TOTAL VOCs FROM SAMPLE COLLECTED IN JULY 1993 DURING THE RI

NOTE:
THE CONCENTRATIONS SHOWN ON THIS FIGURE ARE FOR WELLS SCREENED IN THE TILL/WEATHERED SHALE AQUIFER.

-250′ 0 250′

SCALE: 1″ = 250′

REV	DATE	DESCRIPTION
A	8/20/98	ISSUED FOR REVIEW

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CHIEF DISC. ENGR. J. TRAVERS	MGR. OF ENGR.
PROJECT MANAGER M. DUCHESNEAU	
MGR. OF PROJECTS J. P. CHAPLICK	
IN CHARGE W. D. PATTERSON	

DRAWN CHECKED DES.SUPV. RESP.ENGR. CH.DISC.ENG. PROJ. MGR.

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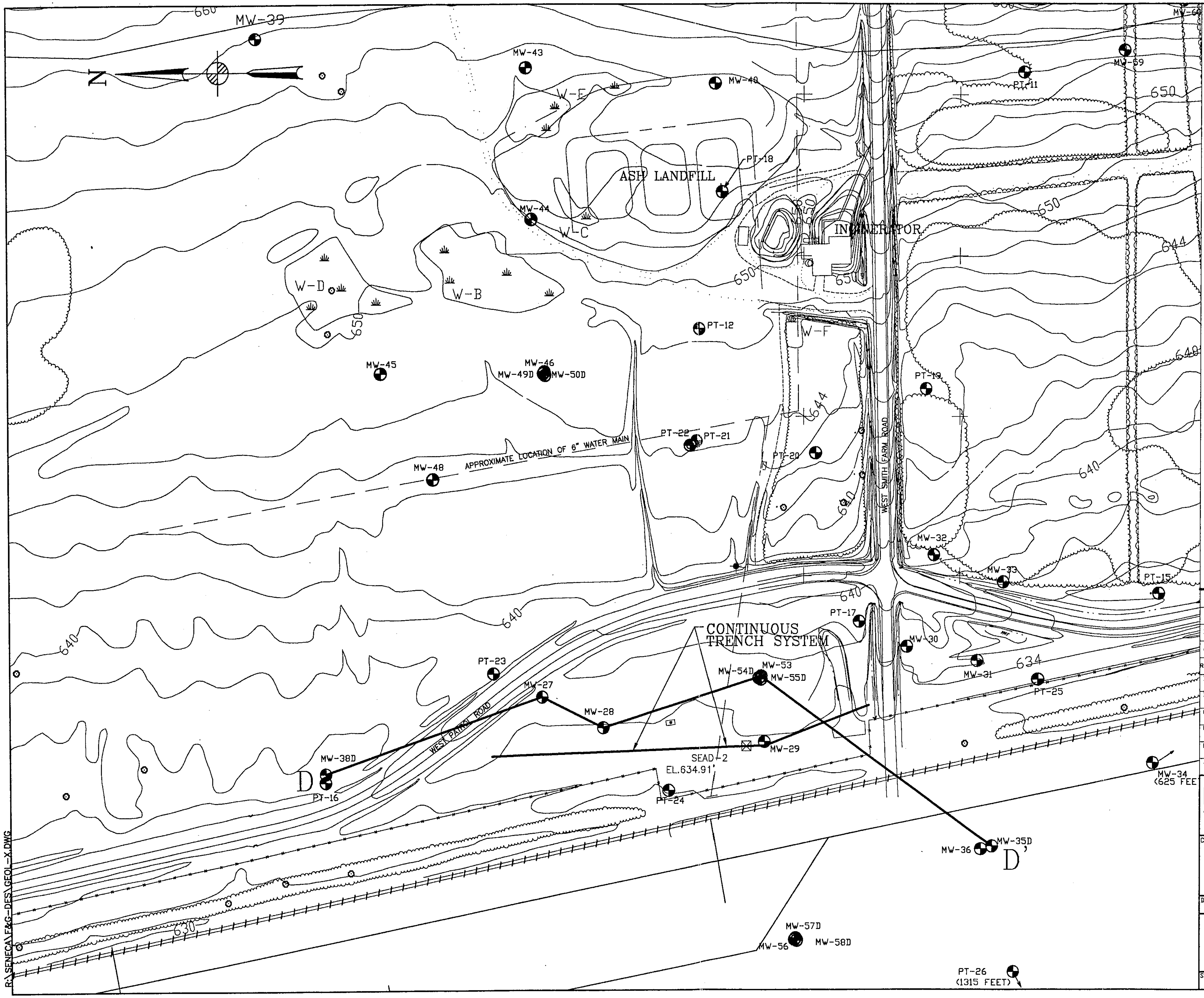
CLIENT/PROJECT TITLE
SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER TREATIBILITY STUDY
USING ZERO VALENT IRON FUNNEL AND GATE SYSTEM

DEPT. ENVIROMENTAL ENGINEERING
Dwg. No. 726209-01004

FIGURE 2
ASH LANDFILL SITE MAP WITH VOLATILE ORGANICS PLUME: POST-REMOVAL ACTION CONDITIONS

SCALE AS NOTED
DATE AUGUST 1998
REV A



LEGEND:

- PAVED ROAD
- DIRT ROAD
- 650 GROUND CONTOUR AND ELEVATION
- TREE
- W-B WETLAND & DESIGNATION
- APPROXIMATE EXTENT OF FILL
- OUTLINE OF FORMER TRASH PITS (IDENTIFIED FROM AERIAL PHOTO)
- APPROXIMATE EXTENT OF DEBRIS PILE
- BRUSH
- CHAIN LINK FENCE
- UTILITY POLE
- APPROXIMATE LOCATION OF FIRE HYDRANT
- FUEL OR UNDERGROUND STORAGE TANK
- ☒ SEAD-1 EL.630.90' SURVEY MONUMENT
- PT-22 MW-37 MONITORING WELL AND DESIGNATION
- D' LOCATION OF SITE CROSS SECTION AND DESIGNATION
- 2 TREATMENT WALL GATE AND NUMBER
- – – – – 6" WATER MAIN

-150' 0 150'

SCALE: 1" = 150'

REV	DATE	DESCRIPTION
B	11/4/98	ISSUED FOR EPA REVIEW
A	8/20/98	ISSUED FOR REVIEW

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CHIEF DISC. ENGR. J. TRAVERS	MGR. OF ENGR.
PROJECT MANAGER M. DUCHESNEAU	
MGR. OF PROJECTS J. P. CHAPLICK	
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CLIENT/PROJECT TITLE

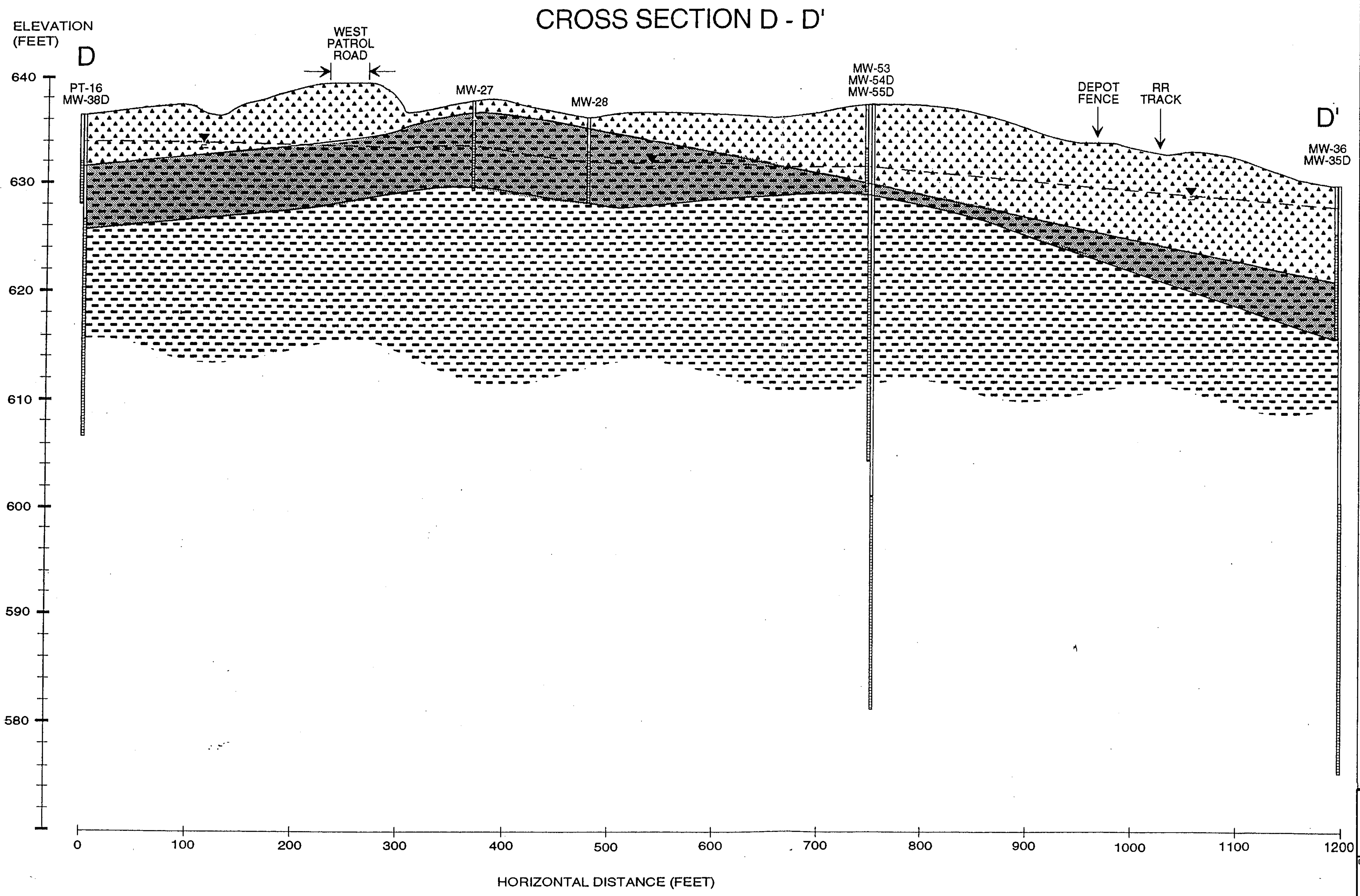
SENECA ARMY DEPOT ACTIVITY

ASH LANDFILL GROUNDWATER TREATABILITY STUDY USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM SYSTEM

DEPT. ENVIRONMENTAL ENGINEERING | Dwg. No. 726209-01004

FIGURE 3
LOCATIONS
GEOLOGIC CROSS SECTION D–D'

SCALE 1" = 150' | DATE NOVEMBER 1998 | REV B



NOTE: ALSO REFER TO FIGURE 5 FOR COMPETENT SHALE TOPOGRAPHY IN AREA OF PROPOSED LOCATION FOR FUNNEL AND GATE SYSTEM

NOTES:

1. Lithologic units are based on descriptions supplied by Engineering-Science, Inc. Interpretations are based on extrapolations between widely spaced boreholes, actual conditions may vary.
2. Groundwater table based on depth to water measurements made in June 1993.

MW-44

Monitoring Well Designation with Screened Interval

LEGEND:

▨ FILL

▨ TILL

▨ WEATHERED SHALE

▨ COMPETENT SHALE

— ⊻ — GROUNDWATER TABLE

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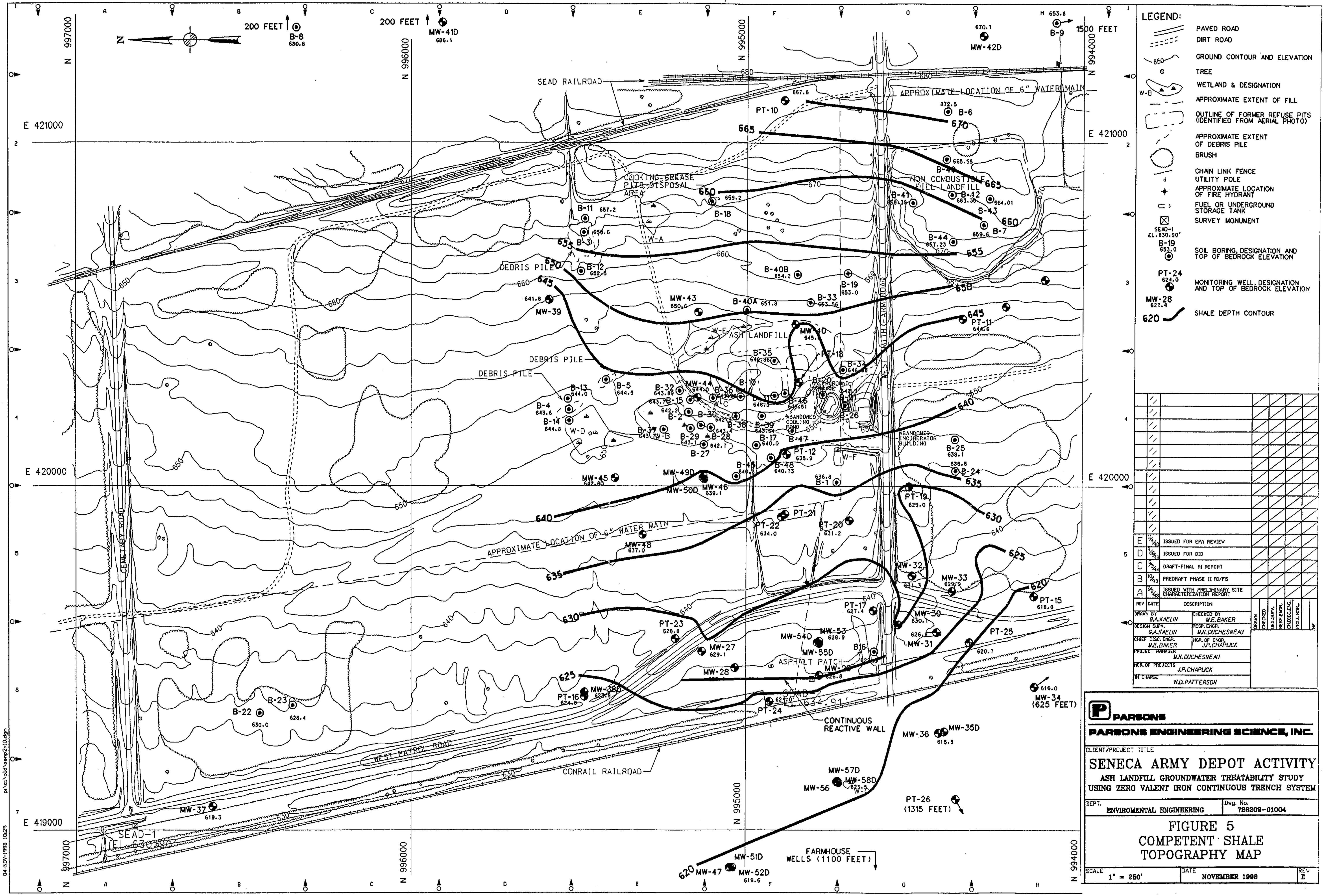
SENECA ARMY DEPOT ACTIVITY

ASH LANDFILL GROUNDWATER TREATABILITY STUDY
USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM

DEPT.	Dwg. No.
ENVIROMENTAL ENGINEERING	726209-01004

FIGURE 4
CROSS SECTION D-D'

SCALE	DATE	REV
AS NOTED	NOVEMBER 1998	



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REV	DATE	DESCRIPTION
E	11/4/98	ISSUED FOR EPA REVIEW
D	9/16/98	ISSUED FOR BID
C	6/3/94	DRAFT-FINAL RI REPORT
B	10/93	PREDRAFT PHASE II RI/FS
A	7/2/93	ISSUED WITH PRELIMINARY SITE CHARACTERIZATION REPORT

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DRAWN BY G.A.KAELIN
CHECKED BY M.E.BAKER
DESIGN SUPV. G.A.KAELIN
RESP. ENGR. M.N.DUCHESNEAU
CHIEF DISC. ENGR. M.E.BAKER
MGR. OF ENGR. J.P.CHAPLICK
PROJECT MANAGER M.N.DUCHESNEAU
MGR. OF PROJECTS J.P.CHAPLICK
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USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM

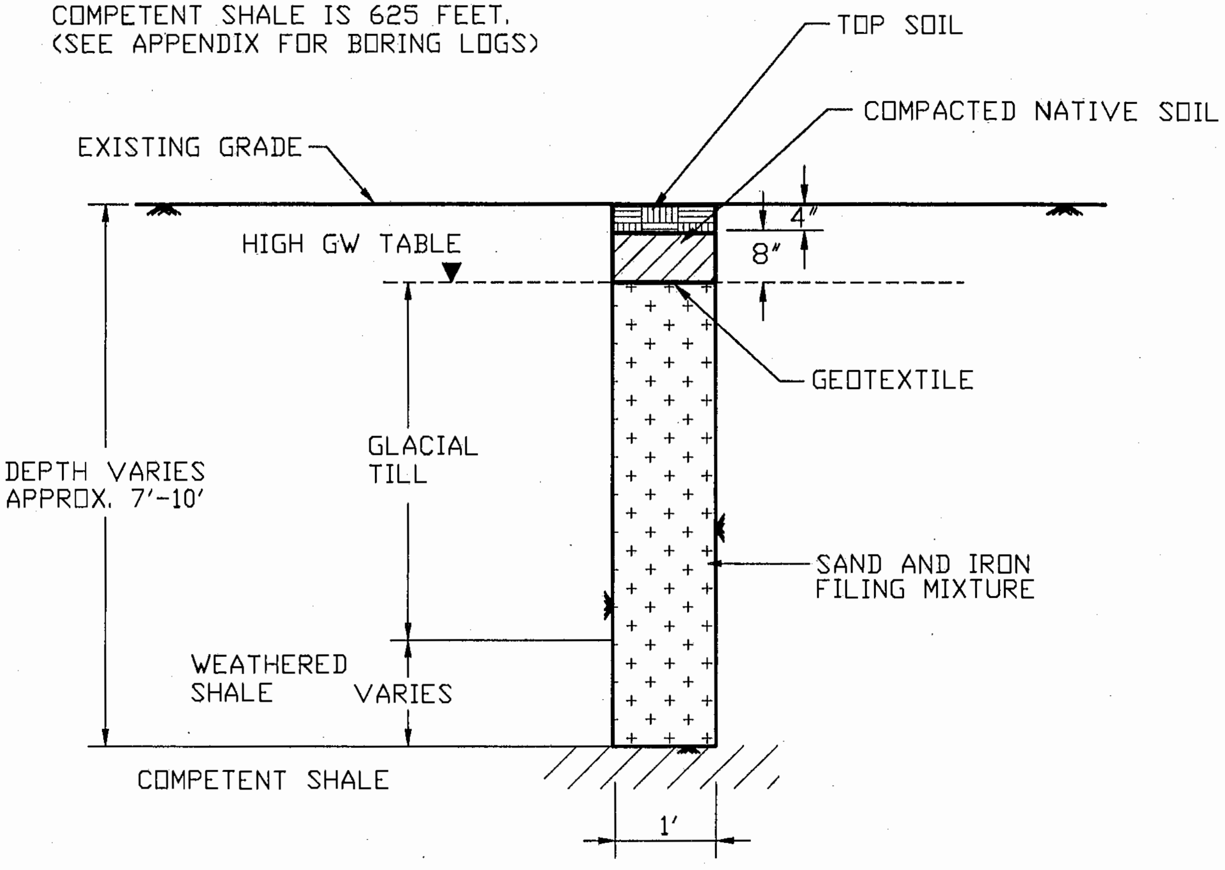
DEPT. ENVIROMENTAL ENGINEERING
Dwg. No. 726209-01004

FIGURE 5
COMPETENT SHALE
TOPOGRAPHY MAP

SCALE 1" = 250'
DATE NOVEMBER 1998
REV E

NOTE(S):

1. EXCAVATION FOR THE TRENCH IS TO BE MADE TO THE TOP OF COMPETENT SHALE. THE TARGET ELEVATION OF COMPETENT SHALE IS 625 FEET. (SEE APPENDIX FOR BORING LOGS)



TYPICAL SECTION

REV	DATE	DESCRIPTION
D	11/3/98	ISSUED FOR EPA REVIEW
C	10/12/98	ISSUED FOR RE-BID
B	9/16/98	ISSUED FOR BID
A	8/20/98	ISSUED FOR REVIEW

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DESIGN SUPV.	RESP. ENGR.
CHIEF DISC. ENGR.	MGR. OF ENGR.
PROJECT MANAGER M. DUCHESNEAU	
MGR. OF PROJECTS J. P. CHAPLICK	
IN CHARGE W. D. PATTERSON	

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CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY

ASH LANDFILL GROUNDWATER TREATABILITY STUDY USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM

DEPT. ENVIRONMENTAL ENGINEERING

Dwg. No. 726209-01004

FIGURE 6
CROSS SECTION
CONTINUOUS REACTIVE WALL

SCALE NOT TO SCALE

DATE FEBRUARY 1999

REV D

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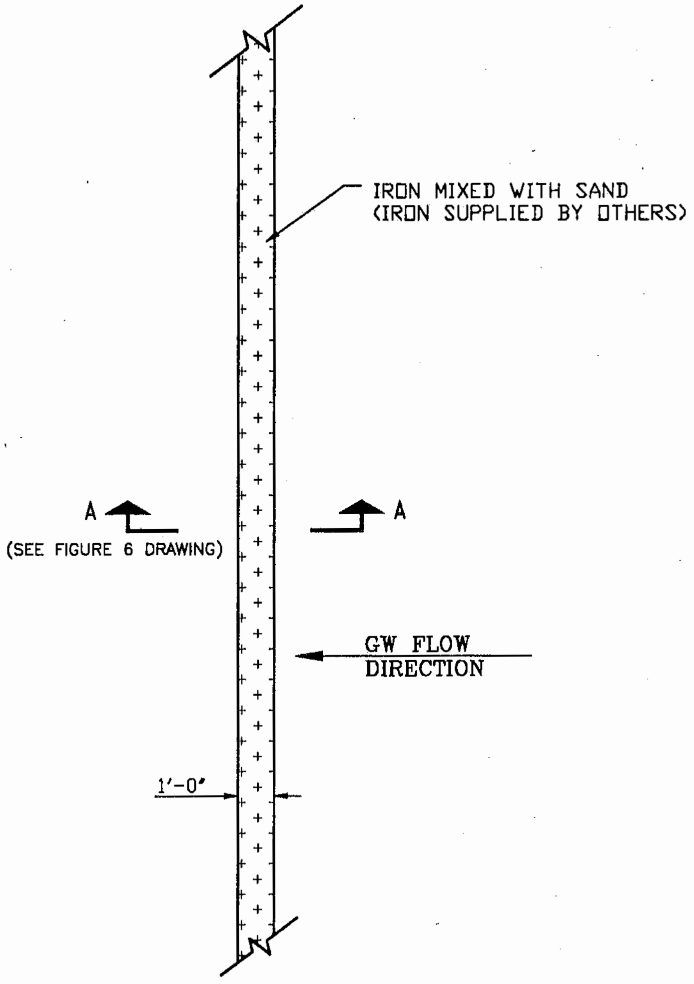

PLAN VIEW

REV	DATE	DESCRIPTION
D	11/3/98	ISSUED FOR EPA REVIEW
C	10/12/98	ISSUED FOR RE-BID
B	9/16/98	ISSUED FOR BID
A	8/20/98	ISSUED FOR REVIEW

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DESIGN SUPV.	RESP. ENGR.
CHIEF DISC. ENGR. J. TRAVERS	MGR. OF ENGR.
PROJECT MANAGER M. DUCHESNEAU	
MGR. OF PROJECTS J. P. CHAPLICK	
IN CHARGE W. D. PATTERSON	

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SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER TRAETABILITY STUDY USING
ZERO LANDFILL VALENT IRON CONTINUOUS TRENCH SYSTEM

DEPT. ENVIRONMENTAL ENGINEERING
Dwg. No. 726209-01004

FIGURE 7
PLAN VIEW
CONTINUOUS REACTIVE WALL

SCALE NOT TO SCALE
DATE FEBRUARY 1999
REV D

R:\SENECA\F&G—DES\RCTVGT2.DWG

Reactive Iron Specifications

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Technical Specification for Granular Iron Used for Treatment of Volatile Organic Compounds in Groundwater

1. Material:
   - (A) The material for use in this application shall consist of granular iron of the grain size range and chemical composition corresponding to the materials supplied for previous laboratory studies and field applications, as specified by EnviroMetal Technologies Inc. and the Engineer.
   - (B) The grain size range for 100% iron shall be similar to the following:

Sieve Size	Approximate % Passing
8	100
16	90
30	25
50	2-4
100	0

   - (C) The material shall be supplied dry.
   - (D) The material shall be free of any oils, greases or other foreign organic substances on its surface.

2. Transport:
   - (A) The material shall be transported in packaging or in bulk as specified by the Engineer. Costs for various shipping methods will be supplied upon request by the Manufacturer.
   - (B) The material must be packaged so as to arrive at the site dry, as specified by the Engineer.
   - (C) The iron shall arrive on-site at a temperature of less than 75 °F.

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Guelph, Ontario
Canada N1K 1S6
Tel: (519) 824-0432
Fax: (519) 763-2378

3. Quality Control During Manufacturing:

(A) The manufacturer will perform grain size analyses on samples collected at 10%, 50% and 90% of the production run and report these analyses to the Engineer.

(B) Additional random sampling of the material shall occur during the production run. The (5 lb) samples will be collected at intervals specified by the engineer. Samples will be delivered to a location specified by the Engineer.

(C) The Engineer reserves the right to visit the Manufacturer during the production run to visually inspect the manufacturing process and collect random samples at that time. The Manufacturer will provide reasonable assistance to obtain these samples.

4. Scheduling:

(A) The Manufacturer will provide a realistic appraisal of the time needed to complete and deliver the order. This includes not only manufacture but also shipment to the site specified by the Engineer.

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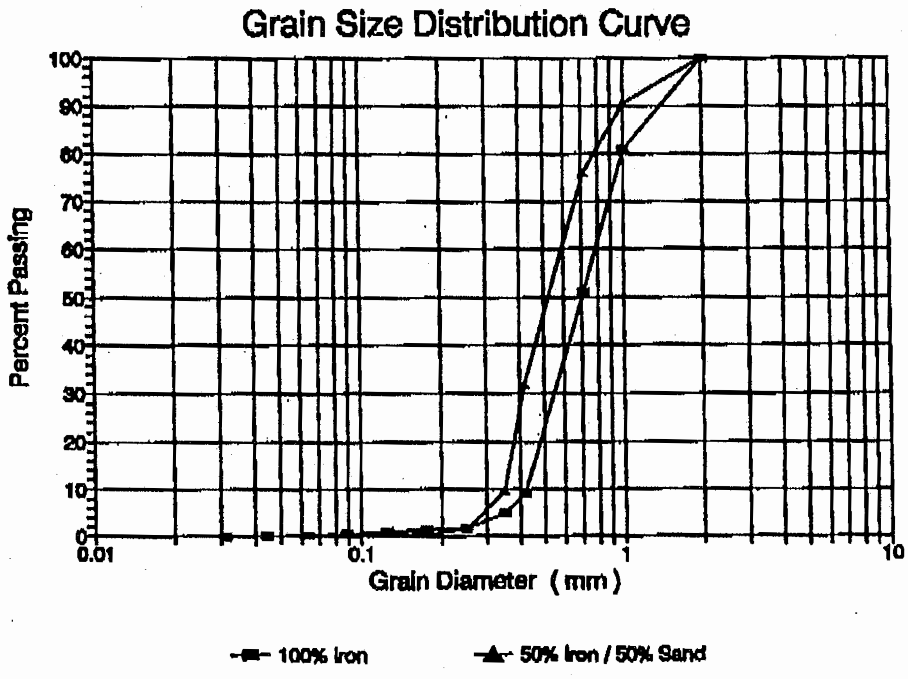
Reactive Material Specifications

The reactive material to be placed in the treatment zone is a granular iron material. The iron has a grain size distribution of approximately –8 to +50 mesh US Std Sieve Size. The figure below shows the grain size distribution curves for a both a 100% iron and a 50% iron / 50% sand mixture. The iron has a field bulk density ranging from 140 to 160 lb/ft^3. It can be shipped to the site in a variety of containers including fiber superbags containing 3,000 lbs or by bulk in trucks. The choice of delivery method may be dependent on the preference of construction contractor selected. The only health and safety issues associated with this granular iron material is the iron dust particles. The appropriate dust masks and safety glasses/goggles are required. Material safety data sheets are available from the iron suppliers. Iron stored on site should be securely covered until required.



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EnviroMetal Iron Suppliers

Iron Supplier	Address / Contact	Product Number	Cost*	Field Installations To Date
Connelly-GPM,Inc.	3154 South California Ave Chicago, Illinois USA 60608-5176 Phone (773) 247-7231 Fax (773) 247-7239 Contact: Stephen Klein	ETICC-1004 (-8 to +50 mesh, US Screen Size)	$350 / ton (US $)	5
Master Builders Inc.	23700 Chagrin Blvd. Cleveland, Ohio USA 44122-5544 Phone (216) 831-5500 Ext 2026 Fax (216)831-6321 Contact: Rod Wells	(-8 to +50 mesh, US Screen Size)	$500 / ton (US $)	6
Peerless Metal Powders & Abrasives	124 South Military Detroit, Michigan USA 48209 Phone (313) 841-5400 Fax (313) 841-0240 Contact: Noreen Warrens	ETI 8/50 (-8 to +50 mesh, US Screen Size)	$350 / ton (US $)	11
Gotthart Maier / Metallpulver GmbH	Gewerbestr 5 D-79618 Rheinfelden Germany Phone 49 7623 4131 Fax 49 7623 40902 Contact: Mr. Maier (Technical Info) Mr. Fischer (Business)	Industrial Iron Filings FG0800/3000 (0.8 to 3 mm)	$550 DM / metric ton	1

*** Shipping Costs extra, vary according to quantity, location and method of shipment.**

Iron/June 1998

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Sand Material and Mixing Specifications

Sand:

The sand should be of similar grain size as the iron and free of debris and other foreign materials. To the extent possible, the sand should be dry. The sooner the iron is used after mixing, the more moisture may be accepted. This means that if there is less moisture, less iron will oxidize by atmospheric oxygen prior to installation and it can be stored for a longer period.

Mixing:

Mixing should be carried out to obtain the desired sand/iron ratio plus or minus some tolerance. The mixing contractor should be made aware of iron handling and storage issues (i.e. keeping it covered and dry), if the mixing is to occur at their facility. The iron/sand mixture should also be stored in a manner similar to the granular iron. All equipment should be clean of foreign materials (e.g. cement mix, soil, stones, etc.) and no water should be used during mixing. During transport and handling, care should be taken to minimize vertical drop and vibration of the finished product to prevent separation/segregation.

Appendix E

Supporting Calculations for Quantity of Iron Required in Continuous Reaction Wall

Table C-1

Design of Continuous Reactive Wall for Ash Landfill
Quantity of Iron Required in Trench
Seneca Army Depot Activity

Residence Time (days) (1)	Thickness of 100% Iron at v= 0.2ft/day (2)	Thickness of 100 % Iron with Safety Factor of 2	Volume of Iron Required for Treatment (cu.ft) (3)	Volume of Trench (1'x9'x645') (cu.ft.)	Total Sand cu.ft.	Percentage iron
1.25	0.25	0.5	2,774	5,805	3,032	48%

(1) Residence time is based on results from Envirometals (10/29/98).
(2) The velocity of groundwater is approx.0.2 ft/day (60.5 ft/year).
(3)Volume = thickness of 100% iron required*maximum saturated thickness (est. 8.6')*length (645')

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Memorandum

To: Jackie Travers, Parsons Engineering Science

From: John Vogan, EnviroMetal Technologies Inc.
Denise Burgess, EnviroMetal Technologies Inc.

Date: 29 October 1998

Re: **Residence Time Calculations for the Ash Landfill Site – 31317.88**

I have attached residence time calculations for the data sent to us on October 13, 1998 for wells PT-24, MW-29 and MW-27. Also included in the table are residence times calculated previously using data from wells PT17, MW-28 and MW-53.

Table 1: Residence Time Requirements, Ash Landfill

VOC	MCL (µg/L)	Half Lives (hr)	Well Location and Concentration						
			PT17		MW-28	MW-53	PT-24	MW-29	MW-27
TCE	5	3	260	190	35	4	7	5	nd
CDCE	5	6	53	17	53	51	140	150	nd
VC	2	6	14	--	--	--	--	--	nd
RT (hrs)			30	25	23	21	29	30	--
RT (days)			**1.25**	**1.04**	**0.96**	**0.88**	**1.21**	**1.25**	**–**

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Based on the above table, a residence time of 1.25 days should ensure that all VOCs be remediated to below maximum contaminant levels. For a continuous wall scenario, a residence time of 1.25 days should be used to determine the volume of iron required. As sent to Parsons on October 15, 1998, the volume of iron required for a continuous wall configuration assuming a flow velocity of 0.17 ft/day, a plume width of 800 ft and a saturated thickness of 8.6 ft would be on the order of 1,700 ft^3.

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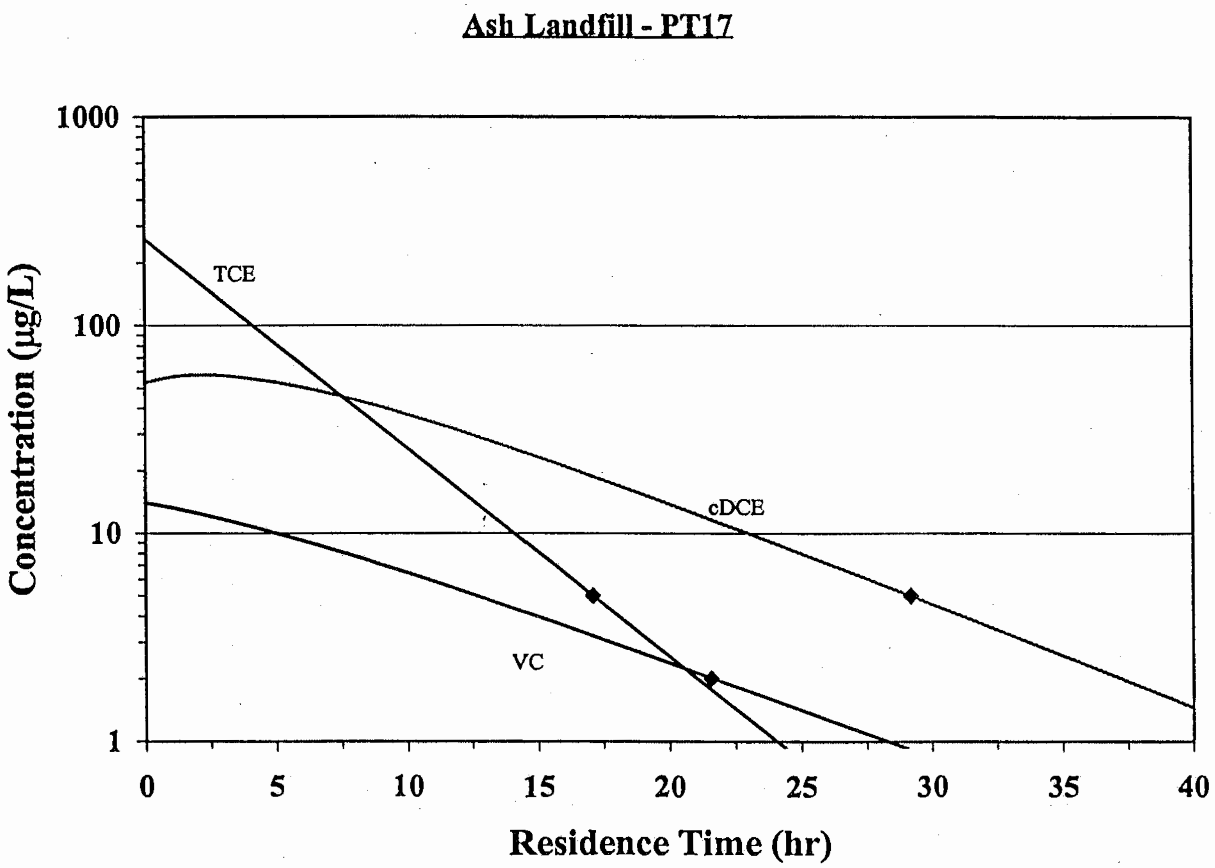

Figure 1: Residence time simulation results using data from well PT17.

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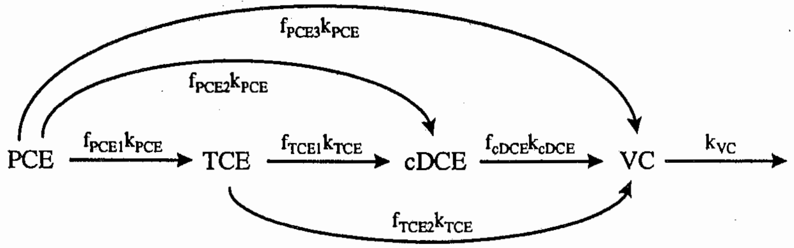
EnviroMetal Degradation Model

The degradation model calculates the volatile organic compound (VOC) concentrations over time, from which, the time required for the VOCs to reach their maximum concentration limits (MCLs) can be determined. The residence time calculation is shown conceptually in Figure 1. In the model, potential breakdown products are concurrently produced and degraded as described by first-order kinetic equations. The equations are similar to those found in many chemical kinetic texts and were adapted by ETI to describe the EnviroMetal Process. The software Scientist® for Windows® Ver 2.0 was used to perform the calculation.

The model is an expression of the chemistry that is observed in the solution phase. For PCE, TCE, cDCE and VC, the model takes the form:



where: f = mole fraction
k = first-order rate constant

In order to determine the VOC concentrations at a given time the following first-order equations are used:

$$d\mathrm{PCE}/dt = -k_{PCE}\mathrm{PCE} \qquad (1)$$

$$d\mathrm{TCE}/dt = f_{PCE1}k_{PCE}\mathrm{PCE} - k_{TCE}\mathrm{TCE} \qquad (2)$$

$$d\mathrm{cDCE}/dt = f_{PCE2}k_{PCE}\mathrm{PCE} + f_{TCE1}k_{TCE}\mathrm{TCE} - k_{cDCE}\mathrm{cDCE} \qquad (3)$$

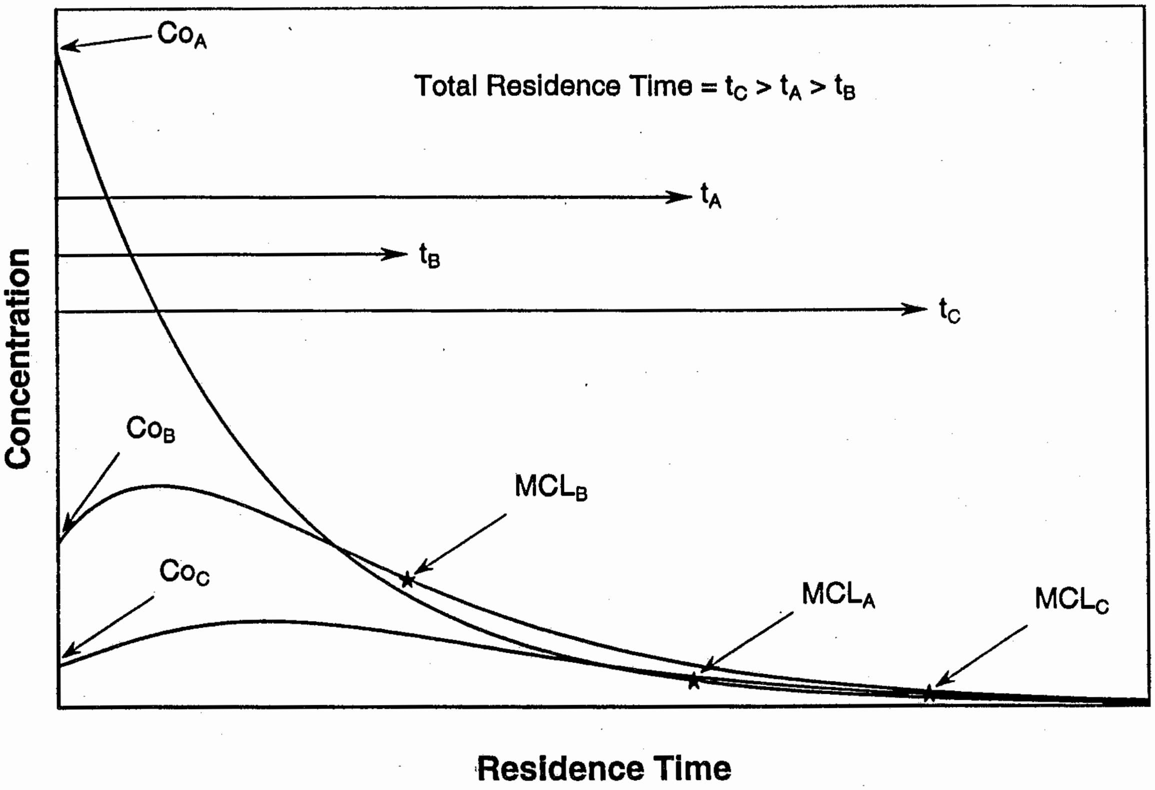
$$d\mathrm{VC}/dt = f_{PCE3}k_{PCE}\mathrm{PCE} + f_{TCE2}k_{TCE}\mathrm{TCE} + f_{cDCE}k_{cDCE}\mathrm{cDCE} - k_{VC}\mathrm{VC} \qquad (4)$$

These equations can be used directly in Scientist® which can integrate them, or their integrated form may also be used. As an example, integration of equation 1 yields the more familiar form of the first-order equation for parent compounds:

$$PCE = PCE_0 e^{-k_{PCE} t} \qquad (5)$$

where: t = time
PCE = PCE concentration at time t
PCE_0 = PCE concentration at $t = 0$

$$A \rightarrow B \rightarrow C$$



t - **Time**
C_o - **Initial Concentration**
MCL - **Maximum Contaminant Level**

Figure 1: Illustration of determining residence time using the first-order kinetic degradation model.

Appendix F

Standard Operating Procedure for Collecting Groundwater Samples Using Direct Push Sampling Technology

STANDARD OPERATING PROCEDURE
FOR COLLECTING GROUNDWATER SAMPLES USING DIRECT PUSH SAMPLING TECHNOLOGY

1. OBJECTIVES

The objective of this document is to define procedures and methodologies to be followed during the collection of groundwater samples using direct push sampling technology. Direct push sampling technology is defined as the advancement of small-diameter casing either by hydraulic push probe systems mounted on light vehicles (e.g., Geoprobe) or by hand operated percussion hammer (e.g., slide hammer) to collect groundwater samples.

2. EQUIPMENT

1. Truck or van mounted hydraulic push probe system or drive system
2. 2.5-inch diameter casing
3. Stainless steel bottom point
4. 1-inch PVC wire wrapped well screen (0.010-inch slot size)
5. Bentonite pellets
6. #3Q-ROC filter pack
7. Small diameter bailer (7/16 inch OD x 20 inches long) or polyethylene tubing with bottom check valve
8. Organic vapor meter with calibration and zero air gas cylinders and regulators
9. Detergent (e.g., Alconox)
10. 40 ml glass VOA vials with teflon sealing caps
11. Labels
12. Notebook

3. PROCEDURE

3.1 GENERAL PROCEDURES

1. Inspect all drilling equipment.

2. Decontaminate small pieces of field equipment (e.g., casing, samplers, bailers, tubs, tools, etc.) prior to starting the work and between each use. Inspect all equipment to ensure that residual oils, asphalt, grease, grout, soil, etc. has been removed.

3. Go to the boring location and set-up and configure the hydraulic push system over the sample location, (if this system is being used). Initiate the boring by driving casing using either the hydraulic push system or by hand held slide hammer.

4. Casing will be advanced to a predetermined depth or refusal. The final depth of the borehole will be verified by the Field Inspector. The final depth is calculated by adding the lengths of casing, measuring the length of sample tube used, or by sending a graduated tape, such as a water level indicator down the open casing. The final depth is recorded in the field log book.

5. Label sample containers.

6. Spoils management will conform to procedures identified in the Generic Installation RI/FS Work Plan.

7. Field clean (decontaminate) samplers, casing, and tools between consecutive samples in accordance with Generic Installation RI/FS Work Plan.

8. Mark the boring with a stake or flagging so that its location can be surveyed (if necessary) and label the stake or flagging with the location ID.

3.2 GROUNDWATER SAMPLING

1. Attach a stainless steel bottom point to the lead casing and drive the point to the bottom of the required sampling interval adding casing lengths as necessary to reach the desired depth. Well point will be installed as close as possible to the downgradient wall of the aquifer material within the reactive iron material.

2. Insert 1-inch PVC well screen into borehole and thread into bottom point. These wells will be screened from 3 feet above the water table to the top of competent bedrock as outlined in the Generic Installation RI/FS Work Plan.

3. Place sand pack as outlined in the Generic Installation RI/FS Work Plan.

4. Remove outer casing, leaving well point intact.

5. Place bentonite seal and outer protective casing as outlined in the Generic Installation RI/FS Work Plan. Bentonite seal shall be placed within the top soil layer (not within the reactive media), no greater than one foot from the surface.

6. Develop well as specified in Generic Installation RI/FS Work Plan.

7. Lower dedicated bailer or polyethylene tubing with bottom check valve down the rods to one foot above well point bottom. Purge well point by withdrawing approximately one well volume as defined as the interior volume of the well point from the water table to the bottom of the well point. Allow the well point to refill with water and collect water samples.

8. Collect the water sample directly into sample containers in accordance with the Generic Installation RI/FS Work Plan.

9. Record the sample collection information in the log book.

Appendix G

Response to EPA/NYSDEC Comments

Response to the NYSDEC Comments on the Treatability Study Work Plan for Zero Valence Iron Continuous Reactive Wall at the Ash Landfill

Comments dated December 21, 1998

General Comment #1, Paragraph #1 : A basic premise offered in the argument for a continuous wall design is that "according to ETI, iron which is subjected to unsaturated conditions show negligible oxidation..." We are unwilling to accept this without evidence. Anecdotal information regarding other projects raises concerns that iron which is subjected to wet dry cycles in the presence of oxygen may experience significant oxidation. If the iron becomes oxidized and the wall becomes less permeable, channel flow within the wall will lead to increased groundwater flow velocities and decreased residence time for the groundwater within the treatment system. This could lead to breakthrough of contamination. A less permeable wall may also increase the head differential across the wall also leading to contaminant breakthrough.

Parsons ES's Response to General Comment #1, Paragraph #1 : We are unaware of the anecdotal information that NYSDEC is referring to that have had iron clogging due to premature oxidation and therefore cannot fully address the specific problems that this site may be experiencing. Since the technology is relatively new, there are relatively few documented evaluations of reactive barrier wall to address the concern regarding the long-term behavior of the reactive material. Since ETI is the only licensee of this technology data, ETI is one of the best sources of available data that can be used to address the long-term effectiveness of this technology. The effect of a fluctuating water table was discussed with ETI on several occasions and was not identified by ETI as being a significant cause of iron fouling. ETI's experience at other sites suggests that fouling of the iron bed is predominated by calcium carbonate precipitation, not oxidation of the reactive iron. Since the iron is buried and not exposed to strong oxidizing conditions, the rate of oxidation appears to be less than what would be expected. Perhaps water with low dissolved oxygen is less problematic than iron placed at the surface, which would be attacked by water with high dissolved oxygen content.

Parsons ES has reviewed dissolved oxygen (DO) data measured recently as part of the third quarter groundwater monitoring at the Ash Landfill for 1998. The DO levels in several monitoring wells were generally low, ranging from 0.8 mg/L to 3.55 mg/L. Most DO was in the 1 mg/L range, with only two wells above 2 mg/L. Total alkalinity, as calcium carbonate, ranged from 212 mg/L to 656 mg/L during this last round of monitoring. ETI provided recent studies, performed by ETI, to support their position. O'Hannesin and Gillham (1998), has provided long-term monitoring data, including core samples, for a site in Borden, Ontario (see Groundwater Vol. 36, No.1, January-February 1998). During this study, core samples were obtained from a continuous, permeable, reactive barrier wall after four years of operation. Trace amounts of iron oxides, as well as iron and calcium carbonates were found in the first few millimeters of the upgradient face of the reactive wall but there was no evidence of cementation or precipitation. The report concluded that after four years of successful chlorinated organic treatment, continual performance should be maintained for at least another five years.

The water table at this site varied seasonally between about 2 and 3 meters below the ground surface. Dissolved oxygen at the Ontario site was similar to the Ash Landfill site, ranging at the Ontario site from between 2.5 and 5 mg/L. Upgradient of the reactive wall, the DO was determined to be 3.4 mg/L. The upgradient alkalinity concentration, expressed as calcium carbonate, was determined to be 277 mg/L.

More recent data was prepared and presented at The First International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 18-21, 1998. Vol. C1-6, Battelle Press, Columbus, Ohio, entitled "Inorganic and Biological Evaluation of Cores from Permeable Iron Reactive Barriers" by ETI. ETI obtained reactive iron core samples from two sites where reactive iron trenches that have been operating for approximately 2 years. One of the trenches evaluated was in New York State. The investigation observed that a decrease of approximately 10% porosity in the reactive media was noted in the first few cm of the media, declining sharply over the first 0.3 m to below 2%. The reactive barrier was expected to perform adequately for several more years before replacement was considered necessary. As with the previous study, some calcium and iron carbonate precipitation was determined to be present but no significant reduction in effectiveness due to oxide precipitation was noted. Since these two sites have similar groundwater chemistry, cementation of the reactive iron was not expected to cause poor performance at the Ash Landfill any more than it had at the Ontario site or the New York site.

Since the effort at the Ash Landfill is a treatability study, the goal of the program is to collect the data that will determine the effectiveness of the reactive barrier wall. Factors that may adversely affect the reactive wall performance, such as oxidation, will be observed in either the chemical data or groundwater piezometeric head data.

ETI's Response to General Comment #1 Many of the 36 field installations, over the past 4 years, contain iron in the zone of groundwater table fluctuation. This includes a pilot-scale installation near Syracuse, New York, which was cored by ETI and the site consultant 26 months after installation (Vogan et al. 1998). Both vertical and angled cores of the iron material were taken to examine oxidation and inorganic precipitate formation. No evidence of significant oxidation and/or cementation of the iron grains were observed in the zone of fluctuating watertable or elsewhere in the cores. The iron in the fluctuating watertable zone was visually inspected at the time of coring and appeared granular and black in colour, similar to the original iron place in the ground. The back colour is due to a maghemite (Fe_2O_3) coating on the iron surface which is also present on the surface of unused iron. Groundwater flow measurements and VOC analyses were performed during the same period prior to coring. These results indicated that the iron was performing the same as when the system was first installed.

It is also worth mentioning supplementary testing of sample of iron from an iron pile that was not used during construction of the pilot treatment system. This iron pile was left unprotected at ground surface. During one of ETI's trips to the site, about 15 months after installation, a sample of this iron was brought back and tested in the laboratory at the University of Waterloo. Batch tests indicated that this "exposed" iron was still reactive in degrading VOCs. Odziemkowski and Gillham (1997) explain that maghemite (Fe_2O_3) produced by oxidation of iron can undergo autoreduction to magnetite (Fe_3O_4) and that magnetite is broadly excepted as a good electron conductor which should not adversely influence the rate of VOC degradation. Iron covered by soil should be exposed to considerably less atmospheric oxygen than iron at ground surface.

Groundwater modeling of continuous permeable walls indicate that even treatment walls which are a few order of magnitude lower in hydraulic conductivity that the native aquifer are effective in capturing and treating groundwater plumes. For example, Garon et al (1998) showed that a 700 ft long by 1 ft wide PRB with a hydraulic conductivity two orders of magnitude less than the native aquifer would capture a plume 600 ft wide. Thus only groundwater within about 50 ft of either end was diverted around the system. Considering that groundwater will flow through the path of least resistance and that the entire treatment system depth at the Ash Landfill is 11 ft or less, it is likely that in the worst case no more than about 10 to 20 feet of groundwater on either end would be diverted around the treatment system. This is because the iron that is fully saturated over the entire year should be more permeable than the iron in the fluctuating watertable zone.

General Comment #1, Paragraph #2 : Review of available guidance for permeable barrier walls, including the document referenced in Section 5.0, has revealed the importance of site specific designs including batch and column studies involving the groundwater and the specific iron ore to be used for construction of the wall. While granting that ETI is expert on this technology, we are concerned with the lack of detailed support for the design parameters offered in the work plan. For example, Battelle notes in *Design Guidance for Application for Permeable Barriers to Remediate Dissolved Chlorinated Solvents, February 1997*, that "observations at a test site in New Jersey have shown that the degradation rate (of TCE) declines by a factor of 2 to 2.5 at temperatures of 8 to 10 degrees Centigrade compared with laboratory rates." (Page 41). When calculating the residence time needed, did ETI allow that the Ash Landfill plume, at the shallow depth in a cold region, is likely to have a low temperature for significant portions of the year?

Parsons ES's Response to General Comment #1, Paragraph #2 : Batch and column studies were not necessary as the groundwater conditions were not deemed to be beyond what could be modeled or what would be a concern from previous experiences. Parsons ES, in consultation with ETI, believes that the numerous ETI applications of this technology was sufficient to justify the ETI design model that has been correlated to numerous batch, column and field studies. This model was to determine the reactive iron volume and the required retention time. The ETI model has been used as the basis for numerous successful reactive wall configurations. Site-specific groundwater chemistry and flow data, including alkalinity and hardness data, was provided by Parsons ES to ETI for their review. ETI determined that the concentrations of the constituents such as alkalinity were not unusual compared to other experiences. There was no technical justification to incur the added costs and schedule delays for conducting such studies.

The guidance referred to in the comment also indicates that "Caution should be exercised in interpreting the results of accelerated column tests. Equating 100 pore volumes at 20 feet/day in the laboratory with 1,000 pore volumes at 2 feet/day in the field may not provide an exact estimate, because the lower residence time in the accelerated column test may underestimate the amount of precipitation." For these reasons, a batch and/or a column study was not proposed, instead actual data collected from one trench at the toe of the plume was felt be more valuable in determining the actual performance of the technology.

The affect of temperature on the rate of reaction was considered by ETI in the modeling, as is described in their response to this comment below. Although temperature changes of the groundwater may be a factor that could decrease the effectiveness of the reactive material, a safety factor has been incorporated it the design to account for this. Actual temperature variation in the groundwater at the Ash Landfill has not been well documented but generally the temperature of groundwater, below the frost line, remains consistently between 45°F and 55°F.

ETI's Response to General Comment #1 : ETI provided information and guidance for both the ITRC (ITRC, 1997) and Battelle (Gavaskar et al. 1998) documents. While we agree that at many sites bench-scale testing is important, it is also important to recognize that these documents are guidance documents. Site specific design and monitoring plans should be based on the judgment and experience of the design team at the site. In addition, it is important to recognize that the Battelle document was originally drafted in February 1997. At that time, only 11 of the current 36 pilot and full-scale systems using the iron technology had been installed with only about two years of operation at the first site. Since February 1997, several full-scale systems (including the Seneca Army Depot system) did not have bench-scale testing performed as part of the design. The knowledge and application of the iron technology and other in-situ technologies has grown tremendously in the past two years.

The half-lives chosen to determine the residence time needed to degrade the VOCs at the Seneca Army Depot were representative values from ETI's database of over 100 column tests of commercial site waters. These bench-scale half-lives were doubled to account for lower field temperatures of about 10°C (Battelle, 1998). The water temperature in this above-ground reactor in New Jersey was 6° to 12°C and was influenced by the surrounding ambient temperatures measured at between -6° and 11°C (US EPA, 1997). In-situ the groundwater should not decline in temperatures as low as an above-ground system. Therefore, a temperature correction of two is generally applied at most sites.

General Comment #1, Paragraph #3 : The proposed placement of the new monitoring wells will leave approximately 200 feet of reactive wall between each well cluster. Because of the above concerns, additional monitoring points are needed to confidently determine that the reactive wall is performing as required throughout its length. At a minimum, an additional cluster appears needed between MW-29 and the southern extent of the trench, as this location of the trench appears most likely to encounter elevated levels of contamination. Other monitoring locations may be designed with an eye toward also gathering necessary hydraulic information (see Specific Comment below regarding Section 5.0).

Response to General Comment #1, Paragraph #3 : The known plume, as depicted by Figure 1 of the workplan, identifies a zone of groundwater with concentrations above 100 ug/L. Although the overall plume direction is east to west, following the established groundwater gradients, this zone of higher concentration does have a slight southerly trend. The monitoring well network will be modified by moving the southernmost cluster of three wells to the south, to within the lobe of the plume of higher concentrations. The northernmost cluster of three wells will also be moved to the south, to the centerpoint of the plume at a location near the edge of the zone of higher concentration. Characterization of the reactive wall's effectiveness will be obtained from the two-upgradient and downgradient clusters. To minimize additional costs, one additional well cluster, placed to the north of the two others (see Figure 3 of the revised work plan), will be sufficient to provide assurance that the trench is providing sufficient destruction. This location is within the portion of the plume that is of lesser concentration than that shown to the south.

Each upgradient and downgradient monitoring well will be installed as close as possible to the reactive wall without disturbing the zero valence iron. We anticipate that each well will be placed to within 2.5 feet of the reactive material.

We agree to modify the placement of the monitoring wells as follows: one well cluster will be moved to the south to a location that will monitor the highest zone of groundwater contamination. The second cluster will be placed within the midpoint of the trench. One additional well cluster will be added to the north.

Finally, we propose to move the three upgradient and three downgradient monitoring wells closer to the trench, by approximately 2.5 feet. This will decrease the travel time necessary before changes in concentrations can be observed.

General Comment #1, Paragraph #4 : Core samples of the iron wall should be taken shortly after installation and periodically thereafter. The initial cores will provide construction quality assurance to confirm the quantity and distribution of iron throughout the wall as well as to establish a baseline against which to measure the later core samples. The later cores will provide information as to whether the physical properties of the wall are changing with time and exposure (e.g.; oxidation of the iron, fouling of the wall with precipitates, etc.) in ways detrimental to the system's required performance.

Parsons ES's Response to General Comment #1, Paragraph #4 : While we agree that core samples can be collected after the trench has been operating for a year, we disagree with the need to collect iron core samples shortly after the installation or periodically thereafter. Monitoring of the installation process was closely watched and we did not experience "bridging" of the sand/iron mixture as evidenced by the volume of iron that was placed in the trench. We believe that since the wall is only 14 inches thick, core samples can affect the hydraulic performance of the wall. We would consider coring if there is a drop in the hydraulic behavior of the wall. At this point there would be a good indicator of cementation or clogging and coring would be used to confirm that such a condition does exist.

ETI's Response to General Comment #1, Paragraph #4 :

Initial coring of the permeable reactive barrier could be done to verify the dimensions and distribution of the iron. Additional coring could be performed every few years to determine the accumulation of precipitates. However, data obtained from strategically placed monitoring wells may be more cost effective and allow for more frequent observation of wall performance. For instance, slug tests performed in the iron zone could be conducted to evaluate significant permeability changes (if any) over time. Changes in flow gradients from perpendicular to the PRB to some angle parallel to the PRB could also indicate changes in permeability.

Specific Comments

Section 3.0: It is stated that the entity which holds the license design for this technology, ETI, "has provided a summary of similar projects" and "these reports have provided useful information pertaining to the design and construction of the continuous wall system". The work plan should include the "useful information pertaining to the design and construction" of this treatability study, as appropriate. This section also notes that zero valence technology has been recently installed and successful "at a site in New York". As the reference apparently is intended to support the use of this technology, the document should provide at least basic information such as the name of the site and a summary of evidence.

Response: Agreed. The reference material will be added to the Work Plan in Appendix B.

Section 4.1: Placing potentially contaminated soil from the excavation onto the constructed wall may lead to percolation of contaminated water into the trench in a manner which may not allow for adequate residence time within the trench before exiting. This could lead to contaminated water getting past the trench. Another concern is that infiltration of heavy rains and snowmelt through the relatively porous top of the constructed wall may cause mounding and an increase in the groundwater flow velocities within the trench. This may also lead to contaminant breakthrough and flow of contaminated water around the ends of the trench. To prevent this, an impermeable barrier should be placed above the zero valence iron wall.

Parsons ES's Response: The soil, which was excavated during construction and used as backfill for the trench, was analyzed for TCL Volatile Organic Compounds prior to placing the soil into the trench. A 24-hour turnaround time from the laboratory was required to avoid delaying the progress of the construction. The results indicated that TCE was present at levels of approximately 160 ug/kg. Soil was backfilled as the concentration was less than the TAGM value of 700 ug/kg. Soil that was not backfilled was stockpiled, under cover, until a reuse can be found.

Backfill material for the trench was placed above the reactive media following the placement of a geosynthetic filter fabric above the reactive media. The soil excavated during the construction of the trench, consisting of clayey till, was compacted and reused for this purpose. Parsons ES does not believe that an additional impermeable barrier was necessary, since there was no reason to assume infiltration above the trench will be greater at the trench than at any other location at the site. Since the entire area is covered with thick grass and shrubs, migration of surface water over the land to the reactive barrier trench was not deemed likely. An impermeable barrier of bentonite was placed above the trench in the location where the trench crossed the drainage ditch at West Smith Farm Road. A drainage culvert was also placed above the impermeable barrier to further divert and control surface water away from seeping directly into the trench.

It was felt that the added cost of placing the impermeable barrier over the top of the entire 650 feet of the wall was unnecessary. Water that would have been diverted from moving vertically into the trench would move horizontally, beyond the limits of the impermeable barrier, and then move vertically through the adjacent natural soil. Eventually, the infiltrating water will combine with groundwater and seep into the trench. The placement of an impermeable barrier above the reactive media would not remove water from infiltrating, only divert the water. This could be a problem if the trench was expected to be subjected to a large surface water flow but, other than the drainage ditch, this was not considered to be likely. The amount of rainfall acting on the 14 inch wide strip of soil above the reactive material is not considered to be enough to cause a significant mounding affect in the trench beyond what increases in groundwater elevations will occur over the site as precipitation infiltrates. Infiltrating water that seeps into the trench will be expected to be of a lower concentration than the migrating groundwater. When mixed with the existing groundwater the concentration of the groundwater will may have less of an effect on the reactive material.

Section 4.2: The wall is apparently designed to address contaminant levels detailed in Table 1 of the work plan. It should be explained why the design does not address levels of contamination at the Ash Landfill that are significantly higher. Should we expect contaminant breakthrough of the trench if wells immediately upgradient of the trench reach twice the levels listed in Table 1? Are the upgradient contamination concentrations, which are high enough to cause contaminant breakthrough of the trench, not expected to reach the wall?

Parsons ES's Response: While some long-term increases may be observed, there is little evidence to suggest that the concentration in the area of the trench would significantly increase. Quarterly groundwater monitoring in this area has not determined a consistent significant increase in VOC concentrations over the years that monitoring has occurred. For example, the data for PT-24, located downgradient of the trench along the fenceline, has been monitored since January, 1990. The concentration of TCE in December, 1992 was 6.7 ug/L, whereas the concentration of TCE in September, 1998 was 5 ug/L. The concentration of total DCE in December, 1992 was 110 ug/L, whereas the concentration of total DCE in September, 1998 was 96 ug/L. Groundwater modeling, performed by Parsons ES in 1996, suggested that following elimination of the source material, the concentration of VOCs at the fenceline should not increase beyond the variability of the existing database, assuming an overall degradation rate of 0.033 per year.

Elimination of the source of groundwater contamination in 1996 has resulted in notable reductions of VOC concentrations in groundwater at the source of approximately two orders of magnitude, from approximately 130,000 ug/L to 1,000 ug/L. Since the new source concentrations of 1000 ug/L is over 1500 feet away from the location of the reactive barrier wall, the time of travel for TCE to reach the trench is approximately 40 years. During that time of travel, reductions in concentration due to various geochemical factors such as dispersion, attenuation, volatilization and degradation are expected to occur. Since the current concentrations at the reactive barrier wall traveled from the same source through the same aquifer, it is reasonable to expect some future reductions at the location of the reactive wall. Thus, since the source has been reduced, to the point that the current source concentrations are only 1,000 ug/L and some reductions will be likely realized due to geochemical factors the future concentrations at the trench will be less than 1,000 ug/L.

The design considered the actual known concentrations of VOCs in the vicinity of the where the trench was to be placed, since the study was intended to be of a one-year duration. The integration of the reactive barrier wall into a final remedial action has yet to be determined. If this study is successful, the existing trench may serve as the final barrier to off-site migration and may be combined with one or two additional trenches to prevent higher concentrations from adversely affecting the reactive material. The life expectancy of the reactive material is considered to be approximately 10 years. Since no other reactive barrier wall application has reached the 10 year plateau of operation it is hard to determine with certainty what the life expectancy of the reactive material will be. Suffice to say that the trench material has a finite lifespan and therefore the reactive material will eventually require replacement. If the movement of TCE from the source area to the trench is 40 years, then trench material will have to have been potentially replaced 4 times. If projections show increases of VOC concentrations to levels above what the reactive material can destroy, then additional iron can be placed into the trench during the replacement to account for the increases of VOCs in the groundwater.

Finally, factors of safety were applied that will be able to account for various factors, such as concentration increases, that could affect the effectiveness of the reactive wall material. ETI, using their reaction kinetic model and experience, determined a residence of 1.25 days would be required, based upon existing groundwater concentrations. Using a groundwater velocity of 40 ft/yr, (0.11 ft./day), the minimum required trench width to yield this retention time, if the trench was completely filled with reactive iron, would be 0.14 feet. The installation technique involved the use of a continuous trencher that was limited to a minimum 14 inch trench thickness. To avoid unnecessary reactive iron costs, the design trench width, which was achieved during installation, utilized a 50/50 mixture of iron to sand. It is possible to calculate a reactive iron Safety Factor (SF) which would be the ratio of the actual amount of reactive iron to the required amount of iron. Expressed mathematically the SF would be: (0.5 X 1.2 feet)/0.14feet = 4.3. Considering a groundwater velocity of 60 ft/yr (0.17 ft/day), the SF would be: (0.5 x 1.2 feet)/0.21feet = 2.9. Therefore, sufficient amounts of reactive iron above what is required was placed in the trench to account for fluctuations in either groundwater concentrations or groundwater velocity.

ETI's Response: The residence time used in the design is based on VOC concentrations upgradient of the PRB. The highest concentrations, and thus the longest residence time, assumed were from well PT17 (TCE = 260 ug/L, cDCE = 53 ug/L and VC = 14 ug/L). Using these VOC concentrations a residence time of 30 hr was determined for 100% iron to reduce the VOCs to below 5,5, and 2 ug/L for TCE, cDCE, and VC, respectively (Figure 1). It is our understanding that the highest VOC concentrations observed at the site are more likely around 1,000 ug/L. Figure 2 shows that a residence time of 55 hours would be required to degrade 1000 ug/L of each of TCE, cDCE, and VC.

Based on about 50% iron by volume and a flow through thickness of 14 inches the effective thickness of 100% iron is 7 inches. Assuming an average linear groundwater velocity of -.11 ft/day, this thickness would give a residence time required for VOC concentrations upgradient of the system and over 2 times greater than that required to treat VOC concentrations of 1000 ug/L. Thus, the treatment system, as designed, has the capacity to degrade higher VOC concentrations than those immediately upgradient.

Section 5.0: Although the document states that the monitoring plan was based upon the referenced ITRC document, the monitoring does not seem adequate and does not agree with our copy of the ITRC document. Enclosed is Table 6-1, Permeable Barrier Monitoring Frequency, from the ITRC's December 1977 Regulatory Guidance for Permeable Barrier Monitoring Frequency, from the ITRC's December 1997 Regulatory Guidance for Permeable Barrier Walls Designed to Remediate Chlorinated Solvents. We request that the parameters and frequencies listed be adhered to for this project unless modifications are adequately rationalized. There is no piezometeric monitoring of the groundwater proposed. The work plan should be revised to include a groundwater level monitoring program per the guidance in the above document.

Parsons ES's Response: The ITRC document was considered as a guide for establishing a project specific monitoring plan. Parsons ES, in consultation with ETI, considered groundwater movement and flushing of residual soil water as factors that would tend to limit the expected changes to groundwater concentrations in the months shortly after the installation. The average velocity of groundwater has been estimated to be between 60ft/year (5ft/mo) and 40 ft/year (3.3 feet/month), depending upon the effective porosity value that is assumed. We consider 40 ft/year to be a reasonable value for this calculation. Assuming a retardation factor for TCE of 1.5, the retarded velocity of TCE in the aquifer is approximately 2.2 feet/month. The total travel distance will also include the width of the trench, making the distance 11.2 feet. Initially, Parsons ES had proposed to place monitoring wells at a location five feet upgradient and five feet downgradient of the barrier wall requiring approximately 5 months for groundwater to move from the upgradient point to the downgradient point. However, to observe the changes in as short a timeframe as possible, we propose to place the upgradient and downgradient monitoring wells 2.5 feet from the boundary of the trench. If, as we expect, the upgradient influent concentrations will remain constant over the monitoring period, the time necessary to observe a change in downgradient concentration will be approximately 2.8 months, i.e. 6.2 feet/ 2.2 feet/month. Initial monitoring of the wells more frequently will not be expected to yield changes due to the slow movement of groundwater. Expected decreases in concentration at the downgradient monitoring points will be further lessened as the barrier wall effluent water is mixed with the residual aquifer groundwater that would be similar to the upgradient concentrations. Changes in concentration may also be affected as the water table fluctuates, due to the infiltration of uncontaminated precipitation. This will reduce both the concentrations at the upgradient and downgradient locations. For these reasons, three sampling events are proposed during the first year after trench installation. The timing of these events has been modified slightly from what was originally proposed to space these sampling events out evenly. Sampling will be performed initially after installation of the wells, four months after installation and nine months after installation.

ETI's Response: An in-situ iron PRB is passive once installed. Since there are no moving parts or energy requirements a catastrophic failure is highly unlikely. More likely a failure would occur as a gradual change over time. Thus, monitoring frequencies should be designed based on site and technology specific parameters. A change in VOC concentration and inorganic parameters can be expected at the downgradient interface following installation. However, due to desorption of VOCs, diffusion of constituents out of low permeability zones and the buffering capacity of the aquifer, these changes are more gradual the further downgradient of the PRB the monitoring well is placed. Given a flow velocity of 0.2 ft/day and assuming the downgradient monitoring wells are located about 5 ft downgradient for the PRB, one sampling event after two months might provide some early indication, however, quarterly and semi-annually monitoring are likely sufficient. It is important to remember that for these early sampling events, VOC concentrations in the downgradient wells could likely be above regulatory criteria due to desorption of VOCs from aquifer sediments and migration out of low permeability zones.

Section 5.1: The work plan should detail action to be taken if contamination is found during the monitoring of side-gradient wells MW-T7 or MW-T8. We anticipate discovering bypassing contamination would require a design modification and/or a re-mobilization to extend the wall.

Parsons ES's Response: This effort is a treatability study to determine the effectiveness of the system, future additions or modifications to the system may be required. Since the type of modifications will depend upon the problem to be addressed it is premature and beyond the scope of the workplan to speculate on what the modification would be. However, the goal of the final action will be to completely capture the entire plume. This may include extension of the reactive wall if it is determined that additional contamination is not captured by the wall.

ETI's Response: In the event contamination is detected side-gradient of the PRB the source of contamination should be investigated. If the PRB is diverting flow around the ends of the system then measures to increase the permeability of the PEB maybe required. This could include scarification of the PRB using augers to break-up any crusting/cementation caused by precipitation/oxidation. If the PRB is not diverting flow around the system, then extending the PRB may be required.

Section 6.0: Soil removed from the trench should be assumed to be contaminated unless proven otherwise. The soil should be placed upon an impermeable surface and covered with a tarp; any water leaving the soil should be considered contaminated. Analysis of the soil should be for TAL/TCL. "Totals" analysis, not just TCLP, for proper future handling determinations.

Parsons ES's Response: Agreed. The soil which was excavated from the trench during construction was stockpiled near the Ash Landfill incinerator and covered with a tarp. Two soil samples were collected from the excavated soil and sent for VOC analysis. One soil sample will be collected from the soil which will be used for backfill and analyzed with a 24-hour turnaround time. The trench will not be backfilled until the results of the analyses are received from the laboratory.

Appendix B, Section 02221: References are made to a water line which intersects the trench. All efforts should be made to prevent the bedding of this pipeline to be a preferential pathway for groundwater moving both into and out of the trench. Either of these cases will cause more rapid localized water flow leading to decreased residence times and a higher potential for contaminant breakthrough. As the figures show this water line to terminate a short distance past the proposed trench location, consideration should be given as to whether this line should be abandoned and/or removed so that its potential to compromise this remedial effort is eliminated.

Response: Agreed. If the water line had been encountered during the construction of the trench, a bentonite seal would have been packed around the section of the water line that crosses the trench. However, the water line was not encountered and this was never an issue.

Appendix B, Figure 6: As the design calls for a continuous reactive wall treatment trench, this figure is mislabeled "Cross Section, Funnel System", and Figure 7 is mislabeled as "Reactive Gate".

Response: Agreed. Figures 6 and 7 are mislabeled.

References:

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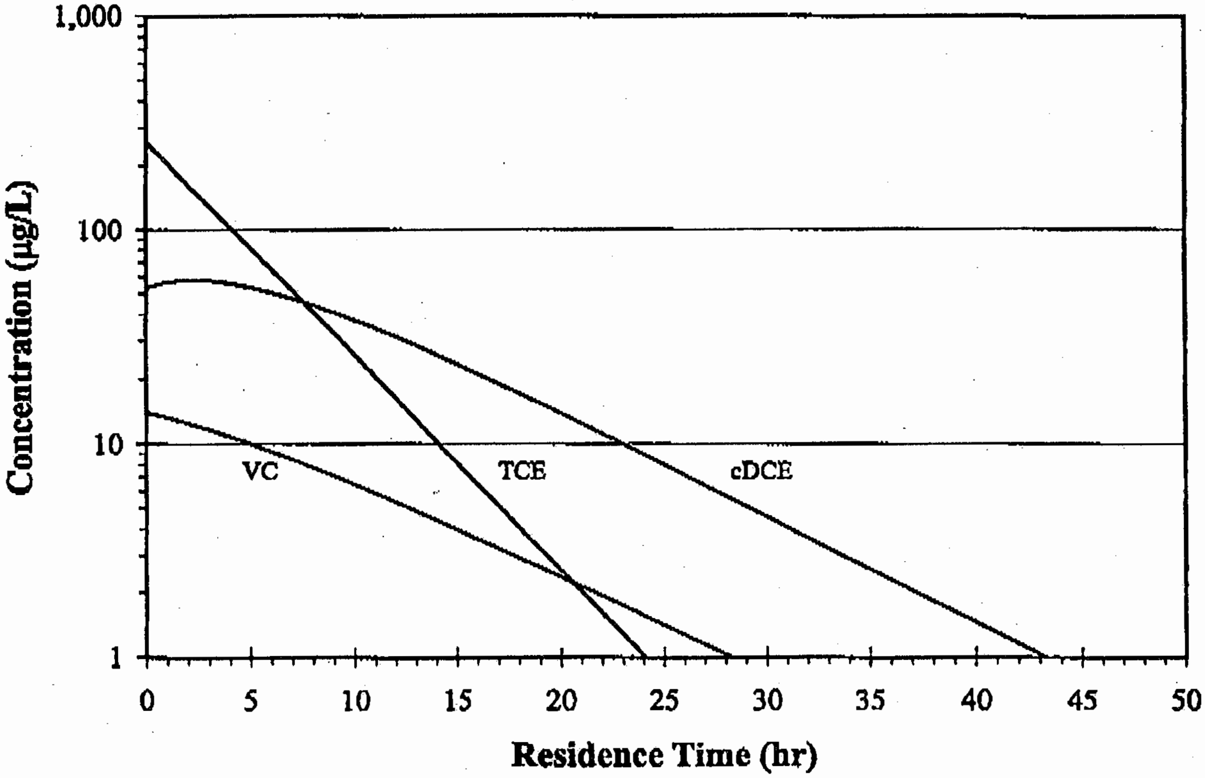


Figure 1: EnviroMetal process degradation model results. (TCE_o = 260 µg/L, $cDCE_o$ = 53 µg/L and VC_o = 14 µg/L).

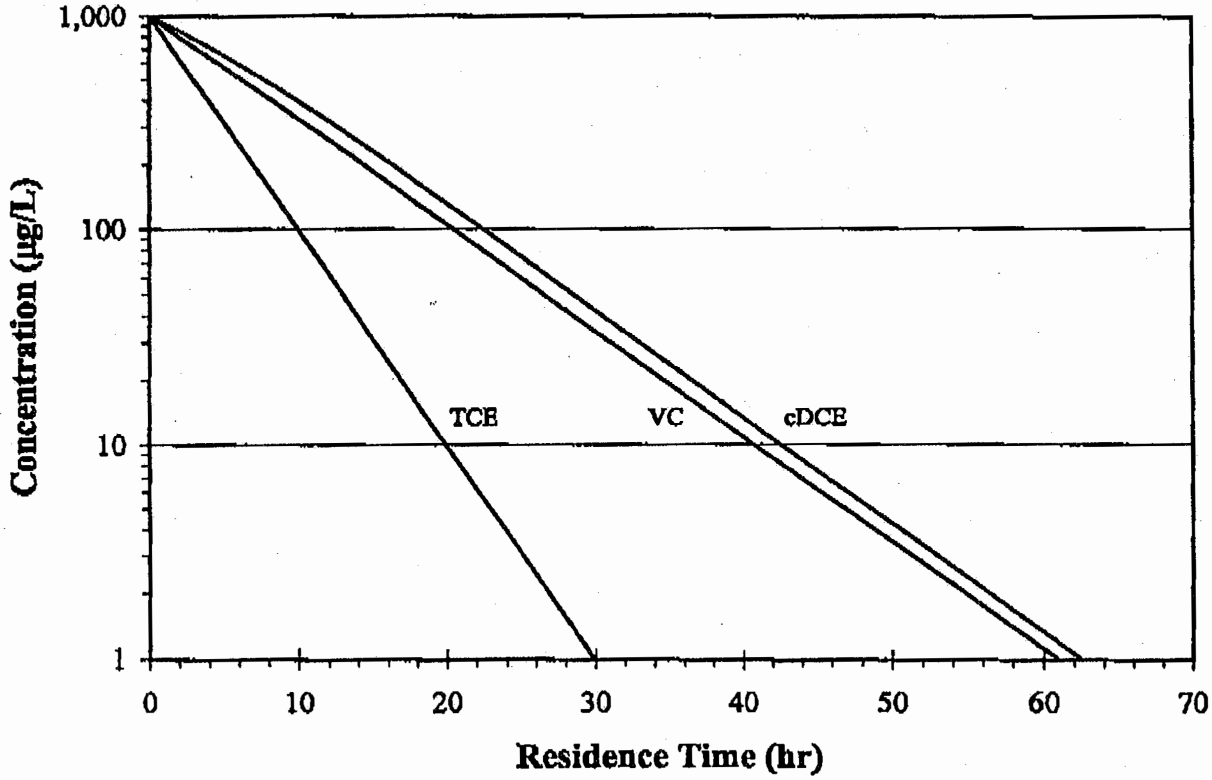


Figure 2: EnviroMetal process degradation model results. (TCE_o = 1,000 µg/L, $cDCE_o$ = 1,000 µg/L and VC_o = 1,000 µg/L).

Response to the EPA Comments on the Treatability Study Work Plan for Zero Valence Iron Continuous Reactive Wall at the Ash Landfill
Comments dated January 22, 1999

General Comments: The technical specifications presented in the appendix do not match the method of installation for the trench presented in the text of the Work Plan. Parsons Engineering Science, Inc. stated that the specifications have been changed to reflect the method of installation in the field. The new specifications have not been submitted.

Response: The technical specifications which were distributed for bidding purposes incorporated methods for installation of the trench using conventional excavation equipment, since bids initially were solicited from contractors having conventional excavation equipment. Since a contractor having continuous trenching equipment was finally selected, Technical Specification 02221 (Excavation and Filling) had been tailored for the use of this equipment. The modified specification has been substituted in Appendix D.

Specific Comments

Page 4, Section 2.3: The text in this section states that MW-44 is located in the source area, however, a review of Figure 1 shows that there is no MW-44 in the plume, but there is a MW-44A. Text should be added to the document explaining which well is being discussed. The text in this paragraph also states that VOCs range from 10 ug/L to 100 ug/L; however, a review of Figure 1 shows a maximum concentration of 157 ug/L. The text should be corrected to reflect this maximum concentration.

Response: Agreed. MW-44 was located in the source area before the removal action took place at the Ash Landfill. The concentrations referenced in this section from MW-44 were detected prior to the removal action. Since MW-44 was located in the source area which was removed, MW-44 was removed and later replaced with MW-44A in the same location. The text has been modified to clarify that MW-44, the monitoring well from which the referenced data were collected, was located where MW-44A currently exists in Figure 1.

The text has been revised to state that VOCs range from 10 ug/L to 200 ug/L so that the concentration detected at MW-29 is incorporated in this range of values.

Page 5, Section 3.0, p1: The text references a groundwater model completed as part of the treatability study, this model should be presented in this document so the reader may review the appropriateness of the selected configuration of the reactive wall.

Response: The groundwater modeling study has been presented in Appendix C. This study found that both a funnel and gate system using four gates and a continuous wall system would be effective in capturing the contaminant plume without unreasonable upgradient mounding effects. The continuous wall system was selected for the following reasons: 1) a continuous wall system raises no hydraulic concerns with respect to groundwater mounding. Although the degree of mounding for the funnel and four gate system was shown to be reasonable in the modeling study, some mounding would occur. 2) Recent studies discussed in our response to NYSDEC's General Comment #1 showed that there are negligible effects on the reactivity of the reactive iron when subjected to unsaturated conditions. Therefore, the increased liklihood of unsaturated conditions in a continuous wall system may not impact the performance of the system; and 3) the continuous system is more cost effective to install.

Page 7, Section 5.1, p2: The purpose of MW-T8, i.e., to monitor for migration of contamination around the reactive wall, will be compromised because the well is located within the plume which is shown on Figure 1. Based on this, the wall should be extended further to the south, and should extend to a point almost directly west of monitoring well MW-30.

Response: The plume contour lines on Figure 1 may not accurately reflect the southern extent of the plume due to the presence of West Smith Farm Road. Contour lines indicate estimated concentrations based on the groundwater monitoring data shown and do not take into account the physical barrier that West Smith Farm Road may be providing as well as the topographic high point of competent shale which was observed to occur near this road during construction (based on trench bottom topography - see Figure G-1 attached). As we discussed during our conference call on December 8, 1998, except for MW-30, there is no evidence that the plume has migrated across this road. As USEPA pointed out, there have been occasional detections of TCE in MW-30 at concentrations hovering above the detection limit and below NYSDEC GA Standards. These detections have not been consistent. Because we are not convinced that the plume extends across the road, it was decided not to extend the wall across this road. Monitoring well MW-T11 (previously called MW-T8 in the earlier version of the treatability study work plan) will be located in the road at the southern end of the trench. If chlorinated solvents are detected in this well, the final remedy at the site will need to address this extension of the plume. However, for the purposes of this treatability study, monitoring from this well will occur before further action is taken.

Page 7, Section 5.2.2: The method of well installation within the reactive wall should be changed from the methods presented in the Generic Plan. The suggested method of well installation in direct push or drive casing, these methods will minimize the disturbance to the reactive materials during well installation.

Response: Agree. The text has been changed to reflect that the three groundwater monitoring points to be installed within the trench by direct push methods. The SOP for installation and sampling of these monitoring points is provided in Appendix G.

Page 7, Section 5.3.1, p1: The text in this section states that sampling will be conducted in June and December 1999; however, a review of Table 2 shows that the sampling will be conducted in March and December, this discrepancy should be corrected.

Response: Agreed. Samples for indicator parameters will be collected in March, June and December 1999. Both the text and Table 2 has been corrected to reflect this.

Page 8, Section 5.3.2, p1: The text implies that field parameters will only be recorded after stabilization has occurred, the text should be corrected to state that readings will be recorded more frequently to document stabilization of the field parameters.

Response: Agreed. The text has been changed to reflect that field parameters will be recorded periodically to document stabilization of field parameters.

Page 8, Section 6.0: Additional detail should be presented in this section as to the length of time the materials will be stored prior to disposal.

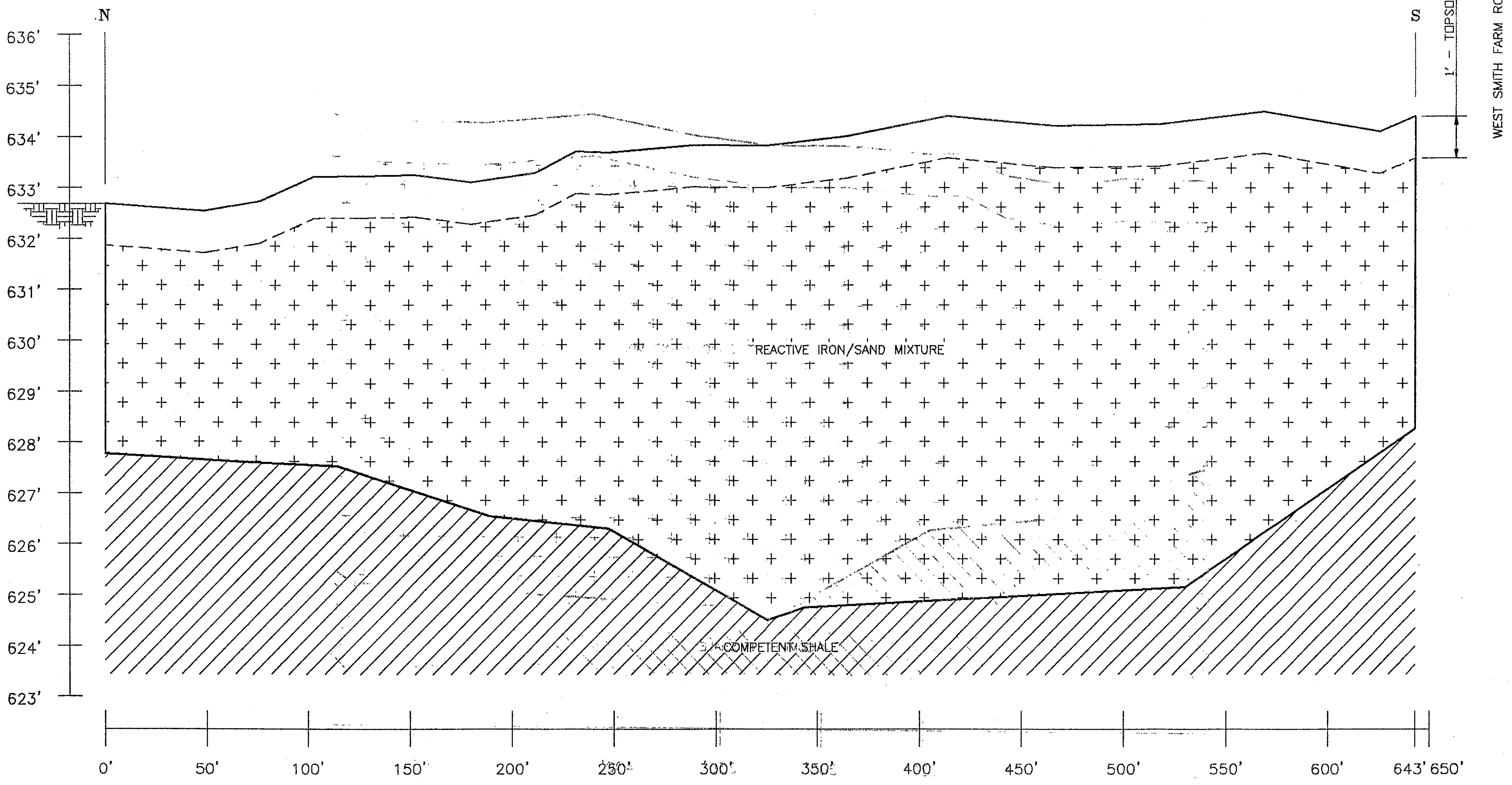
Response: Agreed. The text has been changed to reflect the following. Soil from the excavation has been stockpiled at the Abandoned Incinerator Building. The soil was tested for total VOCs at a frequency of every 100 CY, rather than for TCLP VOCs every 200 CY, as previously noted in the text. Soil results indicated that the highest concentration of TCE was 160 ug/kg, well below the TAGM of 700 ug/kg. Soil from this stockpile may be considered by SEDA as fill at other sites at SEDA. This soil will remain at the Abandoned Incinerator Building until used elsewhere on the site. The contractor was responsible for their own PPE. Decon water will be tested and disposed by SEDA in a timely manner.

Figure 1: The reactive wall presented in this figure does not extend through the width of the plume, the wall should be extended to the south to capture and treat the plume.

Response: Please refer to the response to your comment on Page 7, Section 5.1, p2 above.

Table 2: The inorganic parameters should be collected and analyzed every quarter of sampling. Additional sampling, beyond the one year of sampling presented in the work plan, should be conducted to show that the downgradient monitoring wells are showing reducing concentrations.

Response: The inorganic parameters will be collected during each of the three sampling events proposed (initially after well installation, four months after installation, and nine months after installation). The need for additional sampling will be assessed once the first year of monitoring is completed and evaluated. This assessment will be made in the treatability study report to be issued after the first year of data have been collected.



PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER TREATABILITY STUDY
USING ZERO VALENT IRON CONTINUOUS TRENCH SYSTEM

DEPT. ENVIRONMENTAL ENGINEERING
Dwg. No. 726200-01004

FIGURE G-1
REACTIVE WALL
CROSS SECTION

SCALE AS NOTED
DATE FEBRUARY 1999
REV A

R:\SENECA\FIG-DES\X-TRENCH.DWG