51-12

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January 6, 1997

Ms. Alicia Allen
U.S. Army Corps of Engineers
Engineering and Support Center, Huntsville
ATTN: CEHMC-PM-ND
4820 University Square
Huntsville, AL 35816-1822

SUBJECT **Groundwater Modeling in Support of the Funnel and Gate Design at the Ash Landfill, Seneca Army Depot Activity, Romulus, New York**

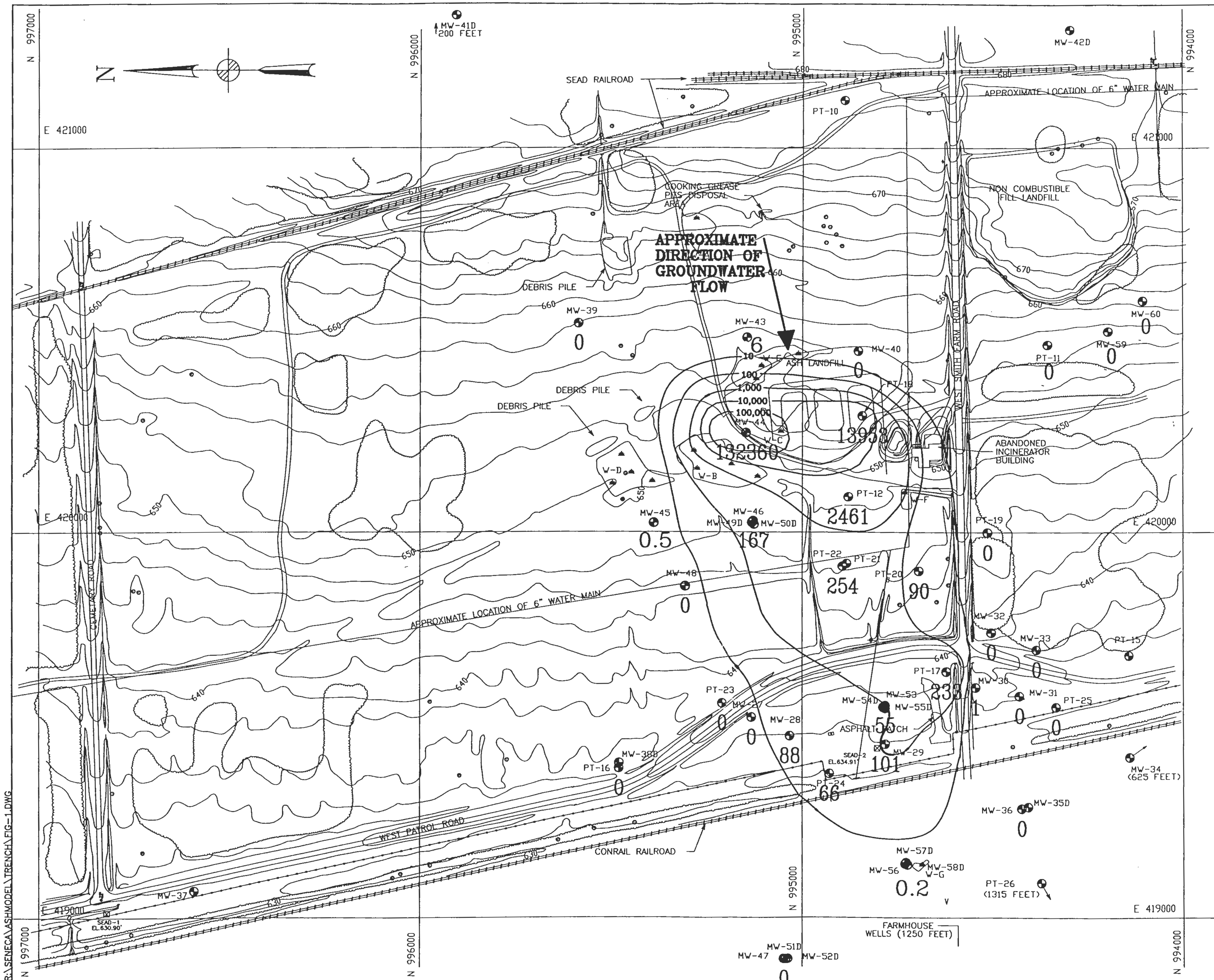
Dear Ms. Allen:

Parsons Engineering Science (Parsons ES) is pleased to provide this letter report describing the results of groundwater modeling, performed to support the design of a planned funnel and gate groundwater collection trench system at the Ash Landfill site. This site is located within the Seneca Army Depot Activity (SEDA), in Romulus, New York. This effort has been conducted in accordance with the requirements of Modification 2 to Delivery Order 31 of the Parsons ES Contract DACA87-92-D-0022.

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.



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)
- GROUNDWATER ISOCONTOUR (ug/L) (—10,000 —)

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.

125 0 125 250
1' = 250'

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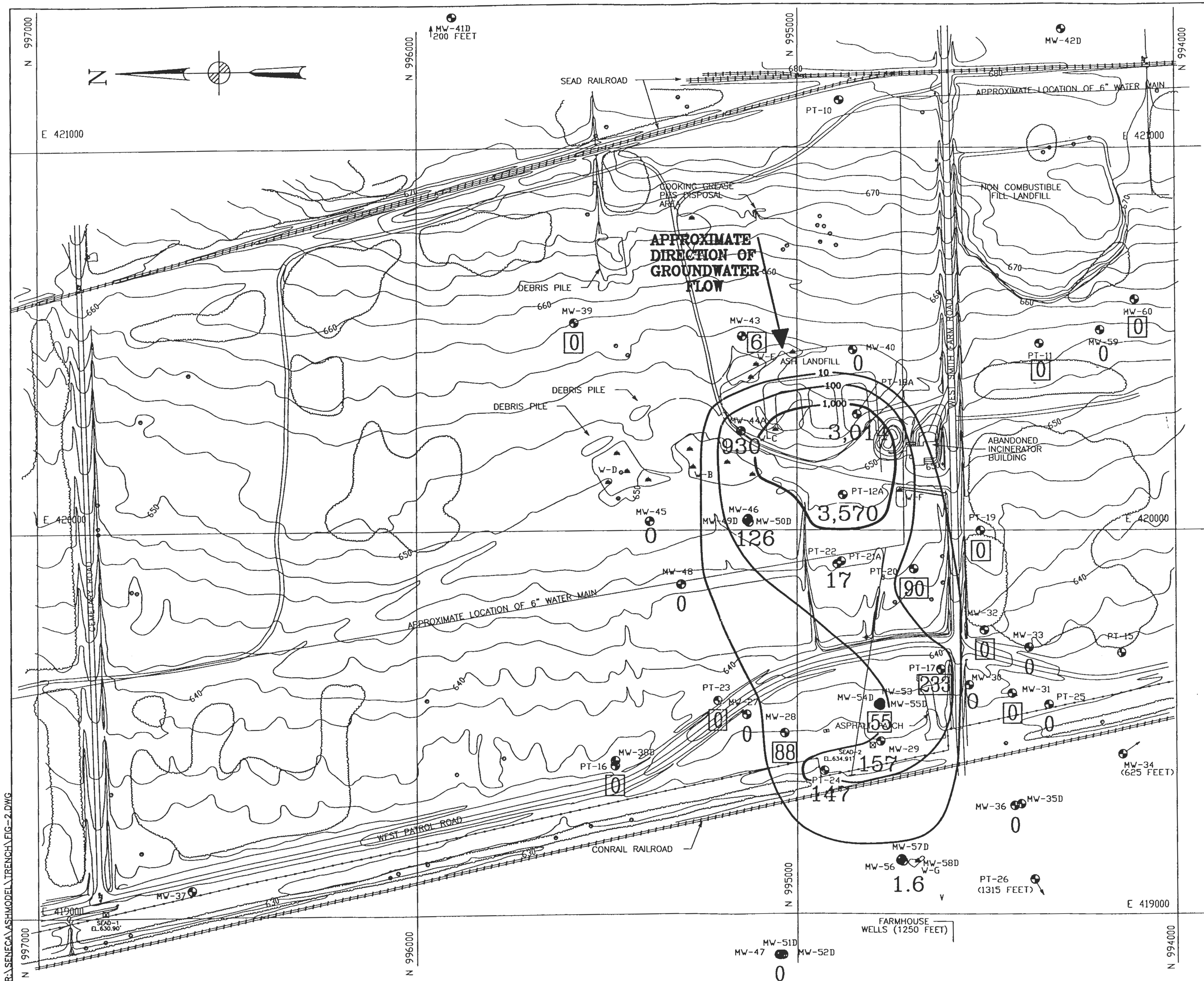
CLIENT/PROJECT TITLE
SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

DEPT. ENVIRONMENTAL ENGINEERING	Dwg. No. 726209-01002

FIGURE 1
ASH LANDFIL SITE MAP WITH VOLATILE ORGANICS PLUME: PRE-REMOVAL ACTION CONDITIONS

SCALE AS NOTED	DATE DECEMBER 1997	REV 0



LEGEND:

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- FUEL OR UNDERGROUND STORAGE TANK
- SURVEY MONUMENT (SEAD-1 EL.630.90')
- MONITORING WELL AND DESIGNATION (PT-22, MW-37)
- —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'

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ASH LADFILL GROUNDWATER MODEL

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

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0

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.

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 has 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.
- Evaluate a groundwater collection alternative using a trench, should a reactive wall configuration be eliminated.

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^{win32} was used for the groundwater flow modeling, and MODPATH Version 3 was used for water particle tracking at the Ash Landfill site.

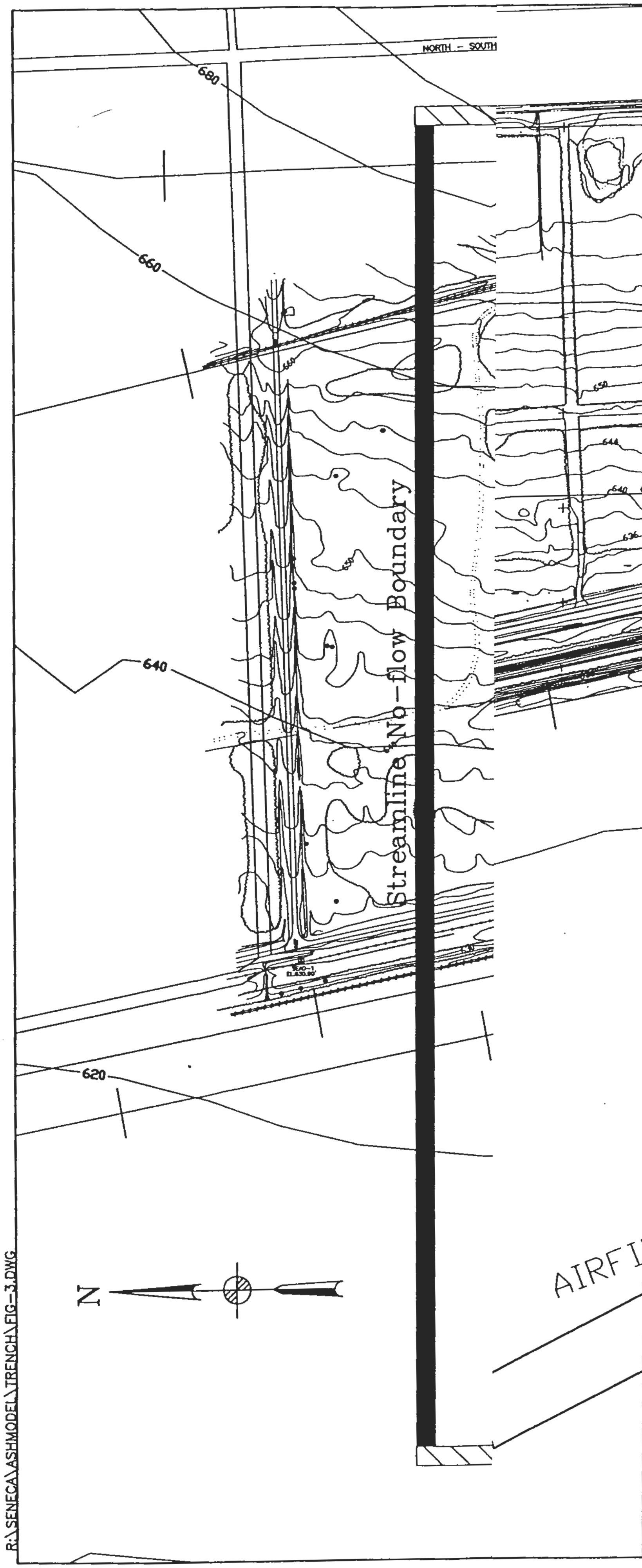
Table 1

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.



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

-400' 0 400'

SCALE: 1" = 400'

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FIGURE 3
MODEL BOUNDARY CONDITIONS

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0

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

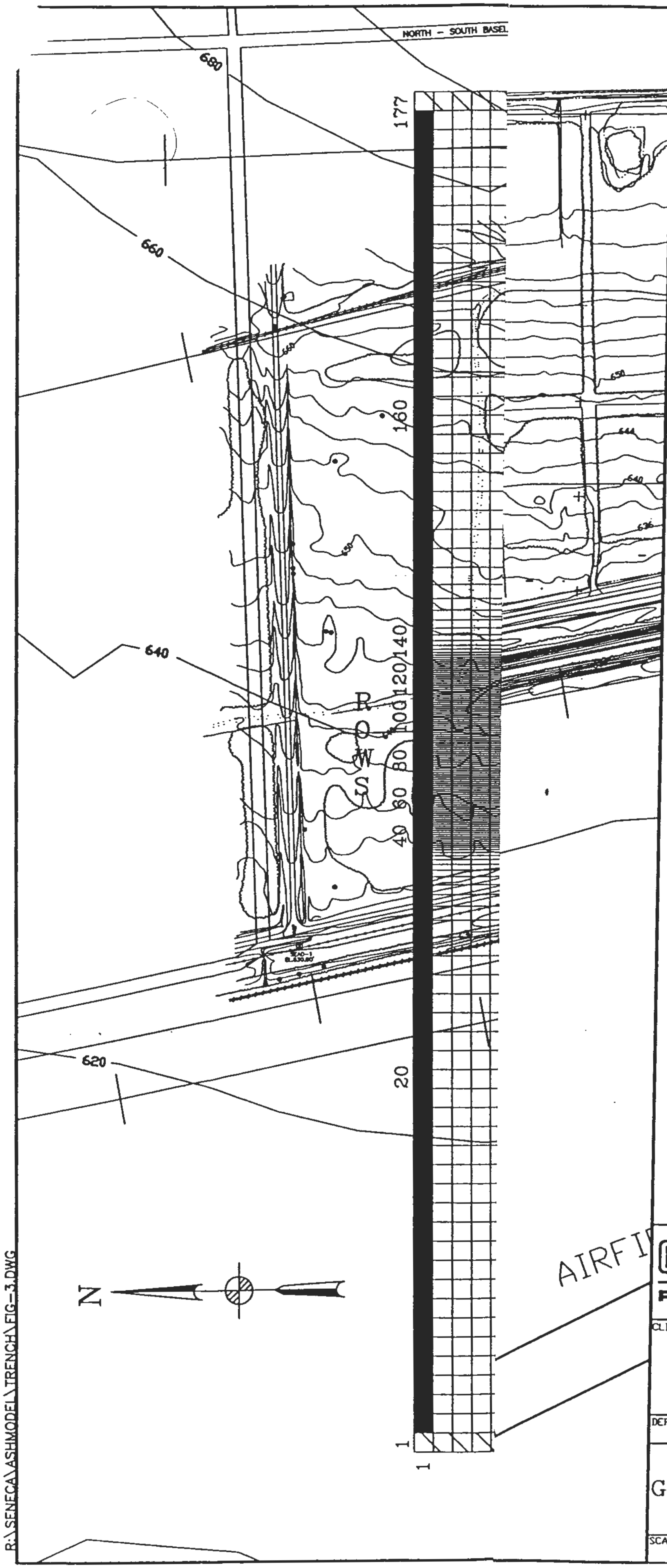
The three flow units that were modeled are:

- 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 1x 10^{-13} cm/sec or 2.8 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.



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)
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- 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
- CONSTANT HEAD BOUNDARY
- STREAMLINE NO-FLOW BOUNDARY
- MODEL GRID

-400′ 0 400′

SCALE: 1″ = 400′

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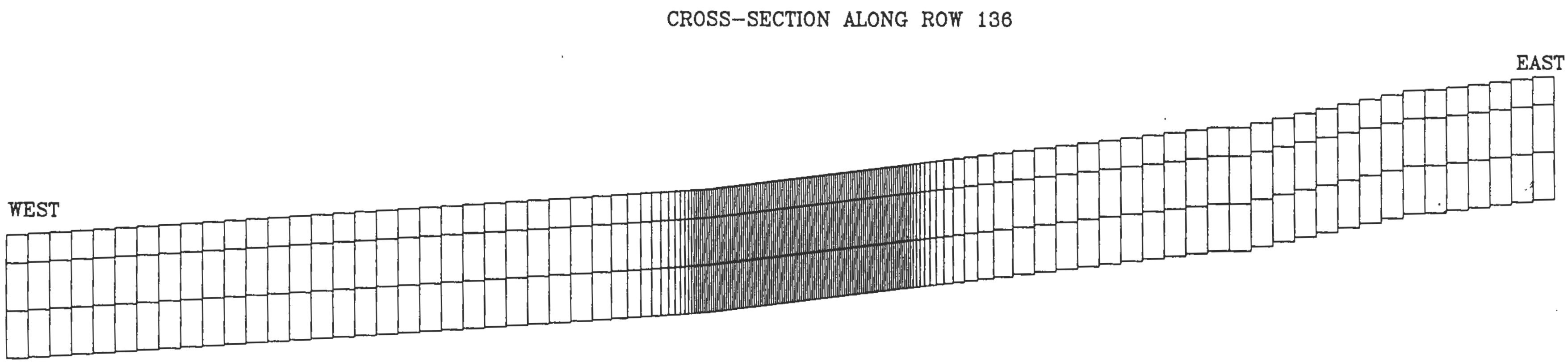
SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

DEPT.	Dwg. No.
ENVIROMENTAL ENGINEERING	726209-01002

FIGURE 4
GROUNDWATER FLOW MODEL GRID AND BOUNDARY CONDITIONS

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0



NOTE:
VERTICAL EXAGGERATION 10X.

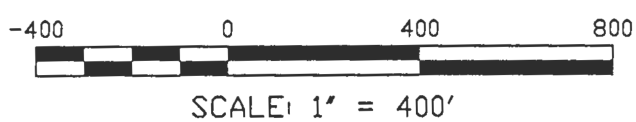


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FIGURE 5
CROSS SECTION OF MODEL GRID

SCALE	DATE	REV
AS NOTED	DECEMBER	0

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

For this simulation, a 1.5-ft thick permeable zone with the conductivity equivalent to a clean sand (1×10^{-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.

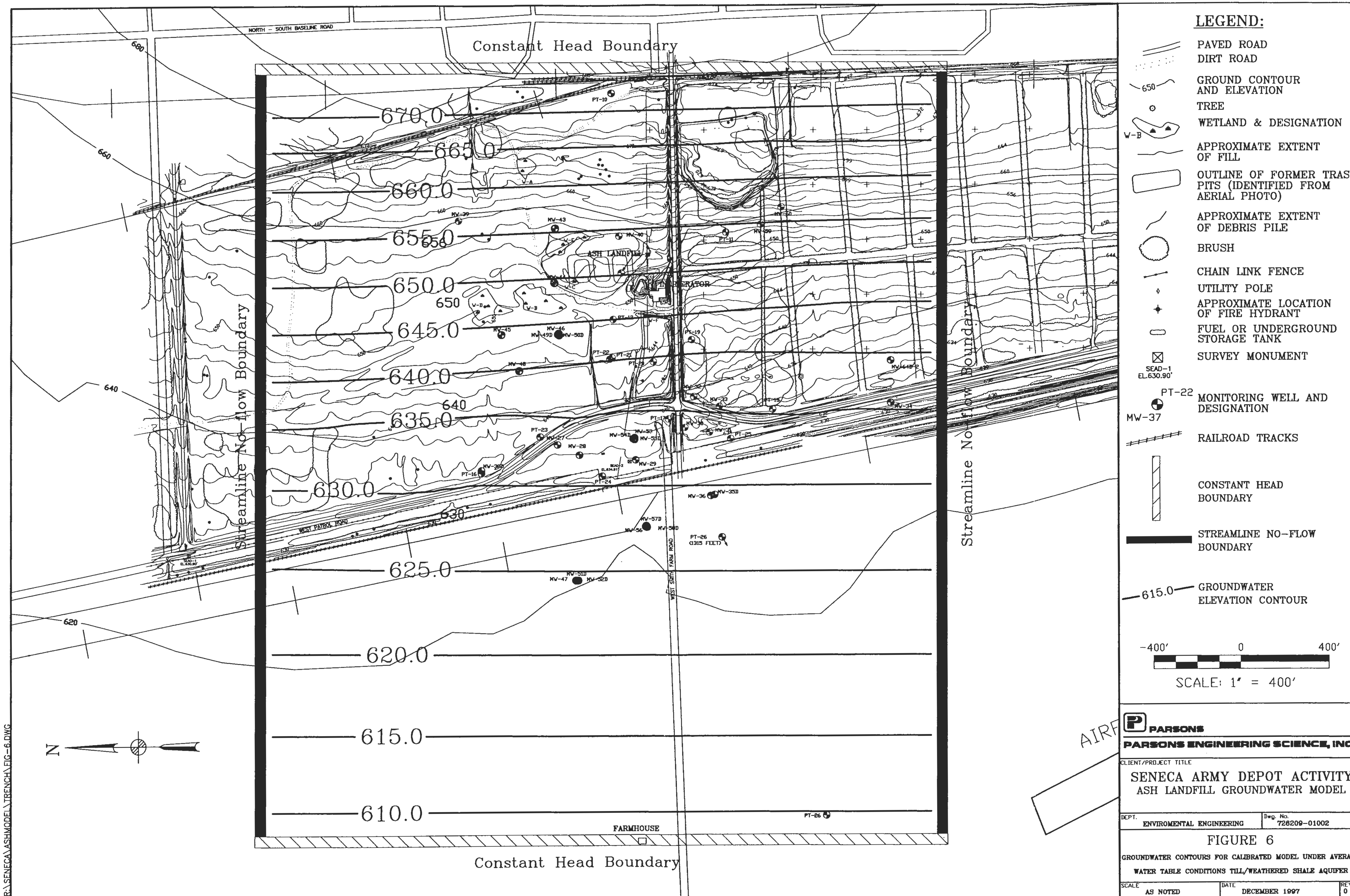


FIGURE 6
GROUNDWATER CONTOURS FOR CALIBRATED MODEL UNDER AVERAGE WATER TABLE CONDITIONS TILL/WEATHERED SHALE AQUIFER

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.

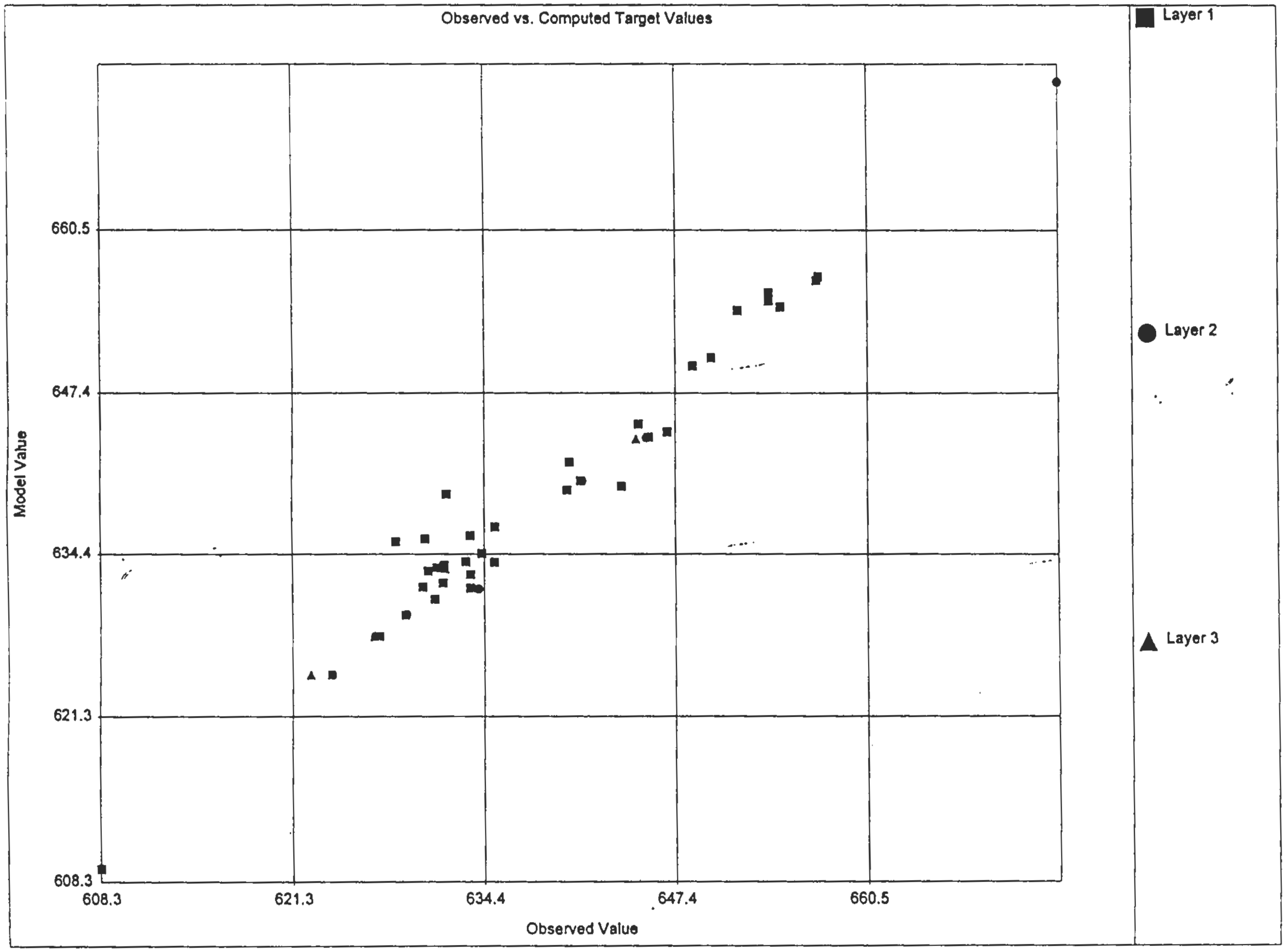
A sensitivity analysis was not performed on this calibrated groundwater flow model because a comprehensive sensitivity analysis was performed on the previous, larger scale model (Parsons ES, 1995). This previous effort provided the justification for the physical aspects and hydrogeologic parameters used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



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

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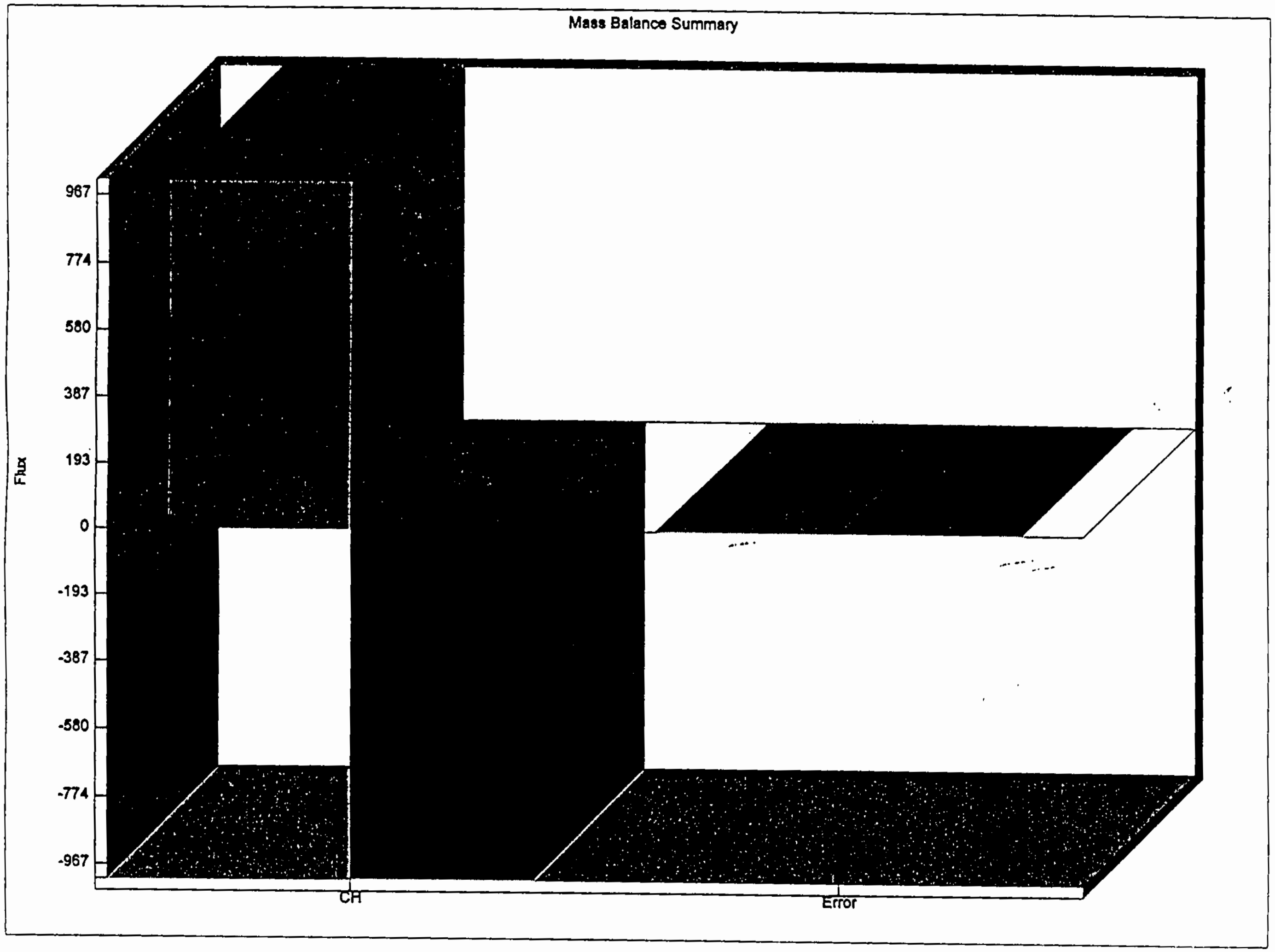
FIGURE 7
OBSEREVED vs. COMPUTED HEADS

SCALE	DATE	REV
AS NOTED	DECEMBER	0



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SENECA ARMY DEPOT ACTIVITY
ASH LANDFILL GROUNDWATER MODEL

DEPT.	Dwg. No.
ENVIROMENTAL ENGINEERING	726209-01002

FIGURE 8
MASS BALANCE SUMMARY
FOR CALIBRATED MODEL

SCALE	DATE	REV
AS NOTED	DECEMBER	0

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

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.

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

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 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.

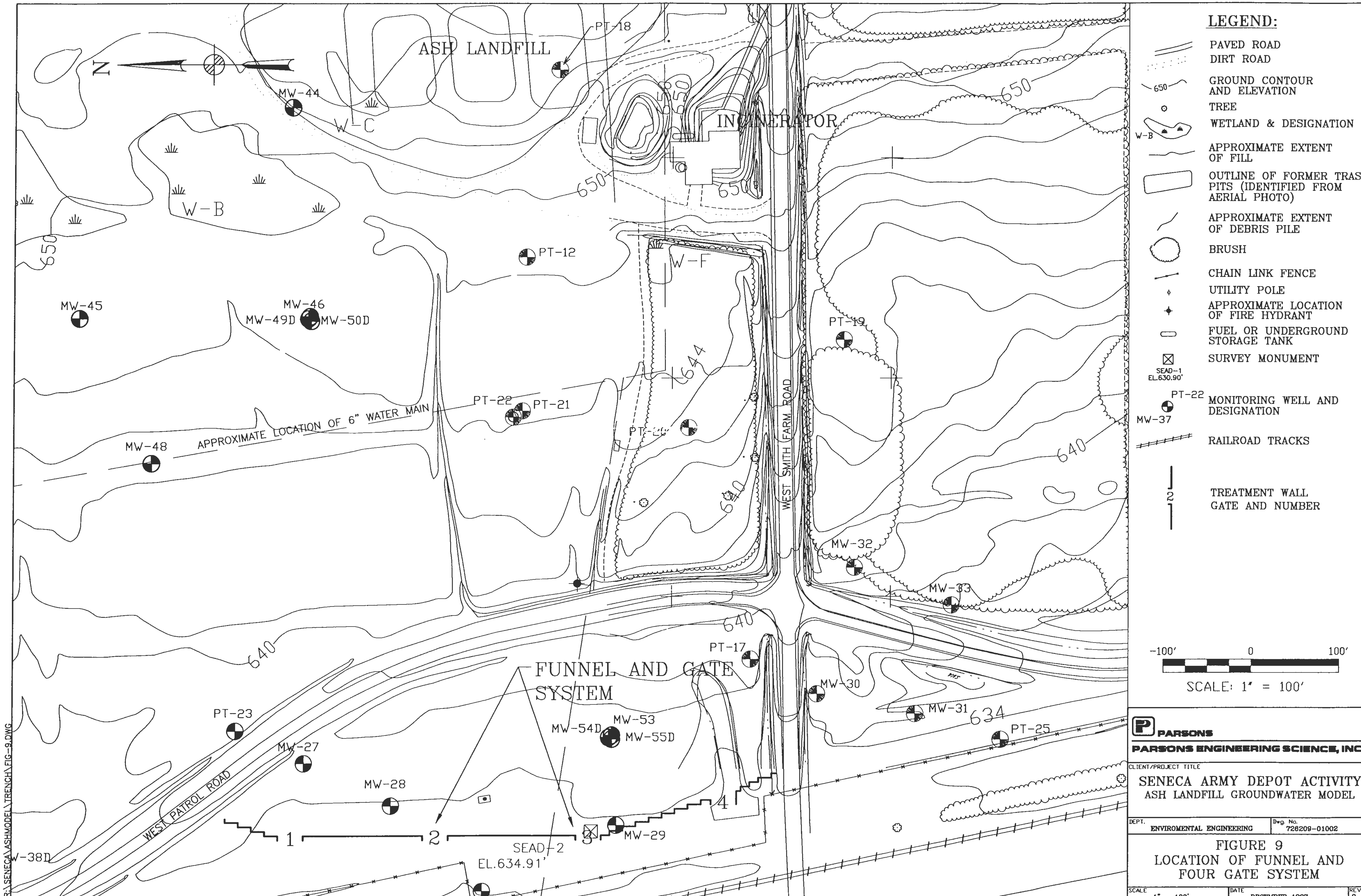
The results from the MODPATH simulations indicate that the travel time for a particle of groundwater to reach the treatment gates after release from the eastern (upgradient) end of the plume ranged from 10.7 years to 12.5 years. The average travel time for the particles was 11.8 years.

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 (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.



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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

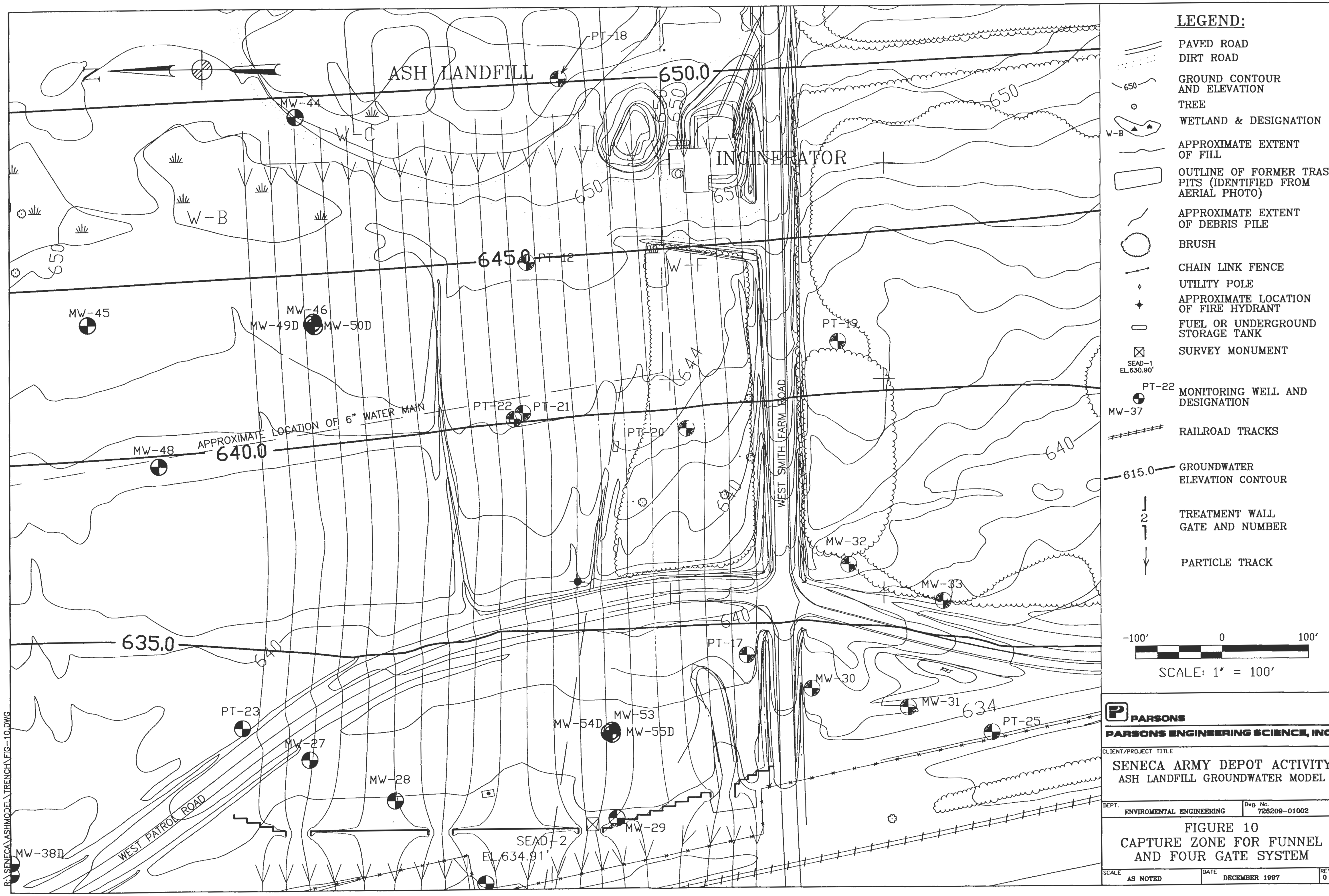

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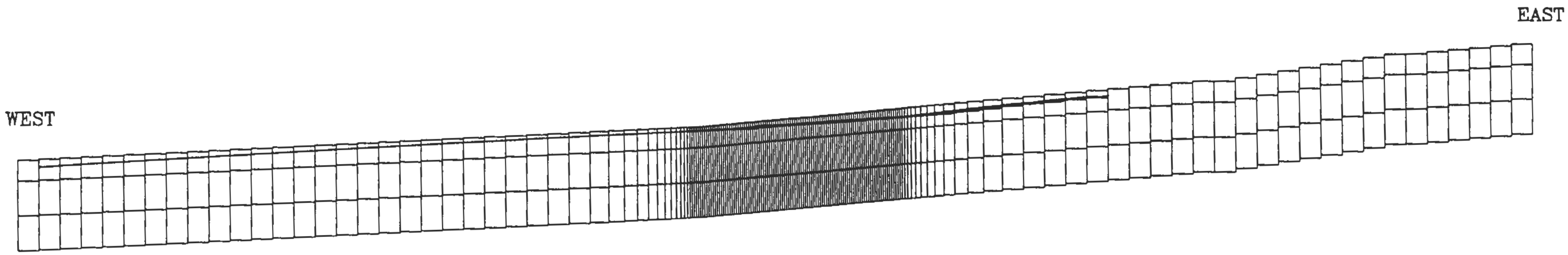
FIGURE 10
CAPTURE ZONE FOR FUNNEL AND FOUR GATE SYSTEM

SCALE	DATE	REV
AS NOTED	DECEMBER 1997	0

CROSS-SECTION ALONG ROW 136



NOTE:
VERTICAL EXAGGERATION 15X.

-400 0 400 800

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

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.

The treatment technologies used in the gates are anticipated to be zero valence iron. Since the constituents of concern are volatile, air sparging is another feasible alternative, should zero valence iron prove to be ineffective. If necessary, zero valence iron could be removed from the gate and replaced with sparging points. This is not easily done for a continuous permeable wall configuration.

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 ALTERNATIVE GROUNDWATER COLLECTION DESIGN

Consideration has been given to an alternative groundwater collection scheme using a trench, backfilled with permeable material such as gravel or washed sand, placed upgradient of an impermeable layer. This alternative design would capture the plume by using on or more pumping wells on the upgradient side of the cut-off wall, increasing the hydraulic gradient, and causing groundwater to flow toward the pumping well(s). Thus, the well(s) would create a zone of influence that extended to the plume boundary. Modeling was used to determine the optimum number and placement of pumping wells, and to establish the approximate pumping rates needed to capture the plume. Because of the relatively low conductivity of the till/weathered shale aquifer, it is likely that the pumping wells will use relatively low flow rates to prevent the aquifer from being pumped dry. This limits the extent of the cone(s) of depression.

This configuration also considered a downgradient permeable sand layer that would be used to distribute treated groundwater back to the aquifer on the western, downgradient, side of the wall. For this simulation, extraction wells were placed in the permeable sand zone on the upgradient side of the cut-off wall.

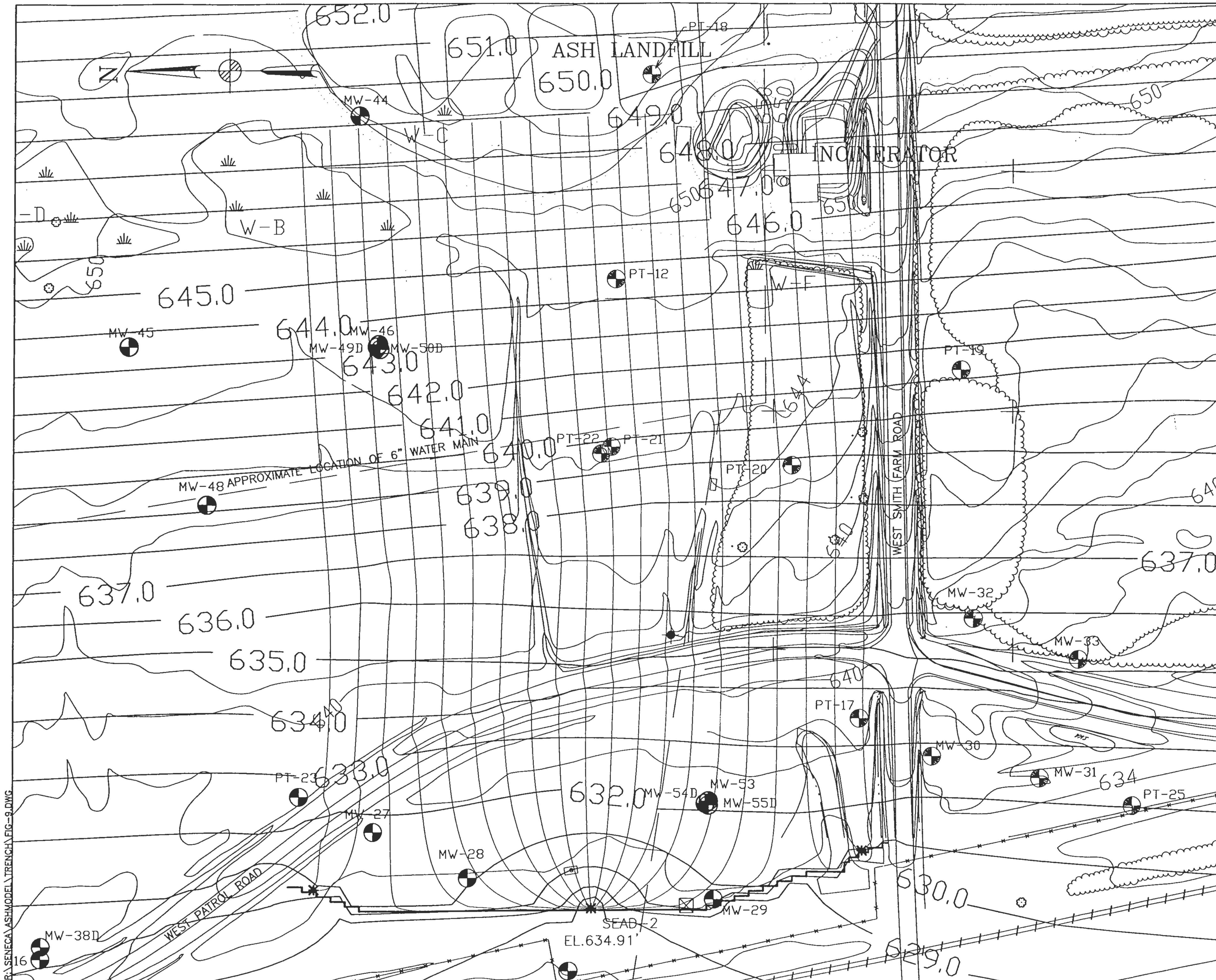
The modeling results showed that a minimum of three wells are needed on the upgradient side of the 525-ft funnel to ensure that the VOC plume is captured (Figure 12). One of the three wells was located in the center of the cut-off wall and the other two were located approximately 30 ft from the northern and southern ends of the wall. The center well had a pumping rate of 0.44 gallons per minute (gpm) or 634 gallons per day (gpd) with the wells on the northern and southern ends pumping at rates of approximately 0.1 gpm. Higher pumping rates caused the aquifer in the areas of the wells to go dry.

The modeling predicted that the center well, pumped at 0.44 gpm, produced the greatest amount of drawdown, and the largest cone of depression. The maximum drawdown in this well was 5.43 feet, relative to average groundwater conditions. The extent of the cone of depression on the upgradient side of the cut-off wall for this well was approximately 160 ft, with 75 percent of the incoming water being captured by this well. The wells on the northern and southern flanks produced drawdowns of 0.91ft and 1.22 ft respectively. Although the wells on the northern and southern edges of the cut-off wall removed groundwater at minimal rates, they were necessary to ensure the complete capture the edges of the plume.

The results from the MODPATH simulations predicted average travel times for water particles to reach the pumping wells of 11.1 years; the actual travel times ranged from 10 years to 14.8 years. These times represented the longest travel time for a water particle, released from the furthest eastern (upgradient) end of the plume, to be captured by the extraction well. Solute transport would be longer due to adsorption and interactions with saturated soil. A retardation factor of 1.2 was previously derived from the groundwater modeling performed for evaluation of natural attenuation. Average solute travel time would be approximately 13.3 years.

Treatment times for the funnel and four gate design, and the continuous reaction wall were not significantly different from each other. The treatment wall designs both rely on capturing the plume under a natural hydrologic gradient, and thus the treatment time is directly related to the time required for VOC-impacted groundwater to flow to the treatment wall. The funnel and four gate treatment wall design at the "toe" of the plume required on average 11.8 years for the groundwater particles to reach the treatment wall; the travels times ranged between 10.7 years and 12.5 years. Using the average travel time of 11.8 years and a retardation factor of 1.2, the solute travel time is approximately 14.2 years. The continuous reaction wall required an average of 11.4 years for the groundwater particles to reach the wall, and applying the same retardation factor, the solute travel time is approximately 13.7 years.

Pore volume flushes are generally required to reduce volatiles to target level. Assuming three flushes are required, the total time of treatment using the funnel and gate system and the continuous reaction wall would be approximately 42.6 years and 41.1 years, respectively.



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
- PARTICLE TRACK
- CUT-OFF WALL
- PUMPING WELL ON UPGRADIENT SIDE OF CUT-OFF WALL
- 615.0 GROUNDWATER ELEVATION CONTOUR

-100' 0 100'

SCALE: 1" = 100'

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FIGURE 12
CAPTURE ZONE FOR PUMP AND TREAT SYSTEM WITH CUT-OFF WALL

SCALE	DATE	REV
1" = 100'	DECEMBER 1997	0

Modeling results for the extraction and treatment system predicted travel times were only slightly faster than those estimated using the treatment wall designs. The pump and treat design relies on capturing the plume by increasing the hydraulic gradient and increasing flow toward the pumping well(s), located on the upgradient side of the cut-off wall. Particle velocities increase within the zone of influence of the pumping well(s) and will shorten the time it will take for groundwater to flow to an extraction well(s). The pump and treat design required an average of 11.2 years for the groundwater particles to reach the wells. The particle travel times ranged between 10 years and 14.8 years. The previous solute transport modeling effort utilized a retardation factor of 1.2, therefore the expected average solute travel time to the extraction well would be approximately 13.4 years.

Assuming that three flushes would be required to remove the VOCs from the aquifer, the total time of treatment is estimated to be 40.2 years.

These treatment times can be increased by adding more treatment/collection areas in upgradient locations of the plume. The treatment time at the Ash Landfill site could be reduced by half by adding a second reactive wall system or groundwater collection trench and reducing the travel time by half.

9.0 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 system or a pump and treat system.

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.

The modeling results showed that for the pump and treat system, a minimum of three wells are needed on the upgradient side of the 645-ft funnel to ensure that the VOC plume is captured. One well was located in the center of the cut-off wall and the other two on the flanks of the wall. The pumping rate in the center well was determined to be 0.44 gpm (634 gpd) and at the wells on the flanks the rates were estimated to be approximately 0.1 gpm.

Treatment times for the systems did not vary significantly. 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. While the pump and treat system does decrease the time required for clean-up due to the influence of active pumping wells, the decree in time was only slightly less, estimated to be 40.2 years. The low hydraulic conductivity of the till/weathered shale is responsible for the low pumping rates in the wells, which resulted in a relatively small cone of depression. These treatment times can be increased 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.

Parsons ES appreciates the opportunity to provide this modeling report. Should you have any questions regarding this report, please do not hesitate to call me at our new office location in Canton MA at (781) 401-2492.

Sincerely,

PARSONS ENGINEERING SCIENCE, Inc.

Michael Duchesneau, P.E
Project Manager

MD/pfm
Attachments

cc:
Mr. Stephen Absolom, SEDA,
Mr. Randall Battaglia, CENAN,
Mr. Kevin Healy, CEHNC,
Mr. John Buck, AEC,
Mr. Edward Agy
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List of Tables

List of Figures