TETRA TECH EC, INC.

March 31, 2009
File #: 2282-0096-09-0024

Steven M. Scharf, P.E.
Project Engineer
New York State Department of Environmental Conservation
Division of Environmental Remediation
Remedial Action, Bureau A
625 Broadway
Albany, NY 12233-7015

SUBJECT: US NAVY CONTRACT NO. N62472-99-D-0032
CONTRACT TASK ORDER NO. 96
NAVAL WEAPONS INDUSTRIAL RESERVE PLANT, BETHPAGE, NY
TECHNICAL MEMORANDUM FOR GROUNDWATER MODELING APPROACH REGARDING EXTRACTION WELL RW-3 AND OTHER ASSOCIATED WELLS

Dear Mr. Scharf:

Tetra Tech EC, Inc. (TtEC) is preparing this Technical Memo to present its approach to groundwater modeling related to the groundwater contamination at the GM-38 area. TtEC is preparing a groundwater flow and solute transport model to evaluate the design and capture zone influence of proposed extraction well RW-3 and associated remedial system wells. It is anticipated that the model preparation and detailed evaluation will be completed by May 2009 and the installation of RW-3 will occur some time after this. Concurrently TtEC is constructing the groundwater remedial system at the GM-38 area to address the chlorinated hydrocarbon plume in the local groundwater and anticipate remedial system start-up and operation in May - June 2009 utilizing extraction well RW-1. Extraction well RW-3 will not be installed and on-line in time at the start of remedial system operations.

The original design of the remedial system specified the operation of two extraction wells in the GM-38 area. Two extraction wells designated RW-1 and RW-2 were installed in 2005. Due to pump testing results of extraction well RW-2, Bethpage Water District (BWD) and subsequently, the Town of Oyster Bay required that RW-2 not be used for groundwater extraction because of potential impact on the BWD Plant # 4 potable supply wells. Instead, replacement well RW-3 was proposed, with an approximate location 400 feet west of RW-2. The screen interval depth of RW-3 was proposed to match the screened interval depth of RW-2, at approximately 440 to 510 feet (ft) below ground surface (bgs). It was anticipated that the lithology would be determined with down-hole geophysical testing during well installation. This would then allow the final screen depth of RW-3 to be refined based on site-specific lithology. Based on concerns of BWD, the final screen interval depth of RW-3 (or any pumping well in the area) cannot negatively influence the BWD Plant #4 wells, which are screened between -450 and -516 feet, mean sea level.

In November 2008, Arcadis notified TtEC that the installation details of proposed well RW-3 should be reviewed. This suggestion was based on additional data collected in a vertical profile boring (VPB) investigation conducted from 2006 to 2008 by Arcadis on behalf of Northrop Grumman Corporation. The VPB investigation was conducted over a large area, trending in a southeast direction from the Bethpage Community Park towards GM-38. The VPB furthest from GM-38 was approximately 7,200 feet northwest of the GM-38 system, and the VPB closest to GM-38 was approximately 1,200 feet north of GM-38 (see attached Arcadis Draft Site Plan, Figure 1). Depths of the VPBs ranged from 115 feet bgs in the northwest to depths of greater than 600 feet bgs nearer to the GM-38 area. It is important to note that VPBs were located where groundwater data had not been collected in previous investigations, to the east of the existing monitoring well network, and up-gradient of the GM-38 area.

TtEC is currently developing a site-specific conceptual model (SCM) and beginning the task of developing and calibrating the groundwater flow and solute transport model. Attachment 1 presents details of the current approach and a collection of data sources that will be used to complete the groundwater flow and solute transport model. A brief summary of the objectives and technical approach for the groundwater modeling is presented below.

The current groundwater modeling objectives for the GM-38 area are:

1) Determine RW-3 screen interval (at proposed location);
2) Evaluate capture zones of extraction wells RW-1, RW-2, and RW-3; and
3) Evaluate locations and screen intervals of proposed monitoring wells related to RW-3.

The current groundwater modeling technical approach for the GM-38 area is:

1) Develop the SCM;
2) Build and calibrate a numerical flow model; and
3) Conduct a hydraulic control (capture zone) evaluation with particle tracking and advective transport processes.

Additional modeling may be conducted based on the findings of the groundwater flow model and future objectives for the GM-38 area. This may include an advanced transport model (with processes in addition to advective transport) and three-dimensional plume visualization and animation. It is anticipated that these additional steps are not necessary at this time to meet the current objectives at the GM-38 area.

TtEC will use existing data from and strategies developed by the USGS as well as site-specific data to establish groundwater flow and plume conditions. The technical approaches used in the development of the USGS models (1995, 1997, and 1999) will be used as the foundation for the development of TtEC's groundwater model. In addition, Arcadis' technical approach (1997 model) will also be considered during the development of TtEC's model. The TtEC model will incorporate site-specific data collected in past Tetra Tech investigations in addition to data supplied by Arcadis

from their investigations and model development. The USGS and Arcadis modeling approaches define, but are not limited to, the following:

1) Regional hydrogeologic framework;
2) Numerical codes and model assumptions; and
3) Model geometry, grid spacial descritizations, and boundary conditions, etc.

It is not the intention of TtEC to create a regional flow model or to reproduce existing models, but rather to address the local groundwater flow and the local plume conditions at the GM-38 area, within known regional groundwater conditions. As the model is developed, the approach may be refined to meet the needs of the current objectives. Modifications to the approach will be documented for use in the final evaluation and review of the model.

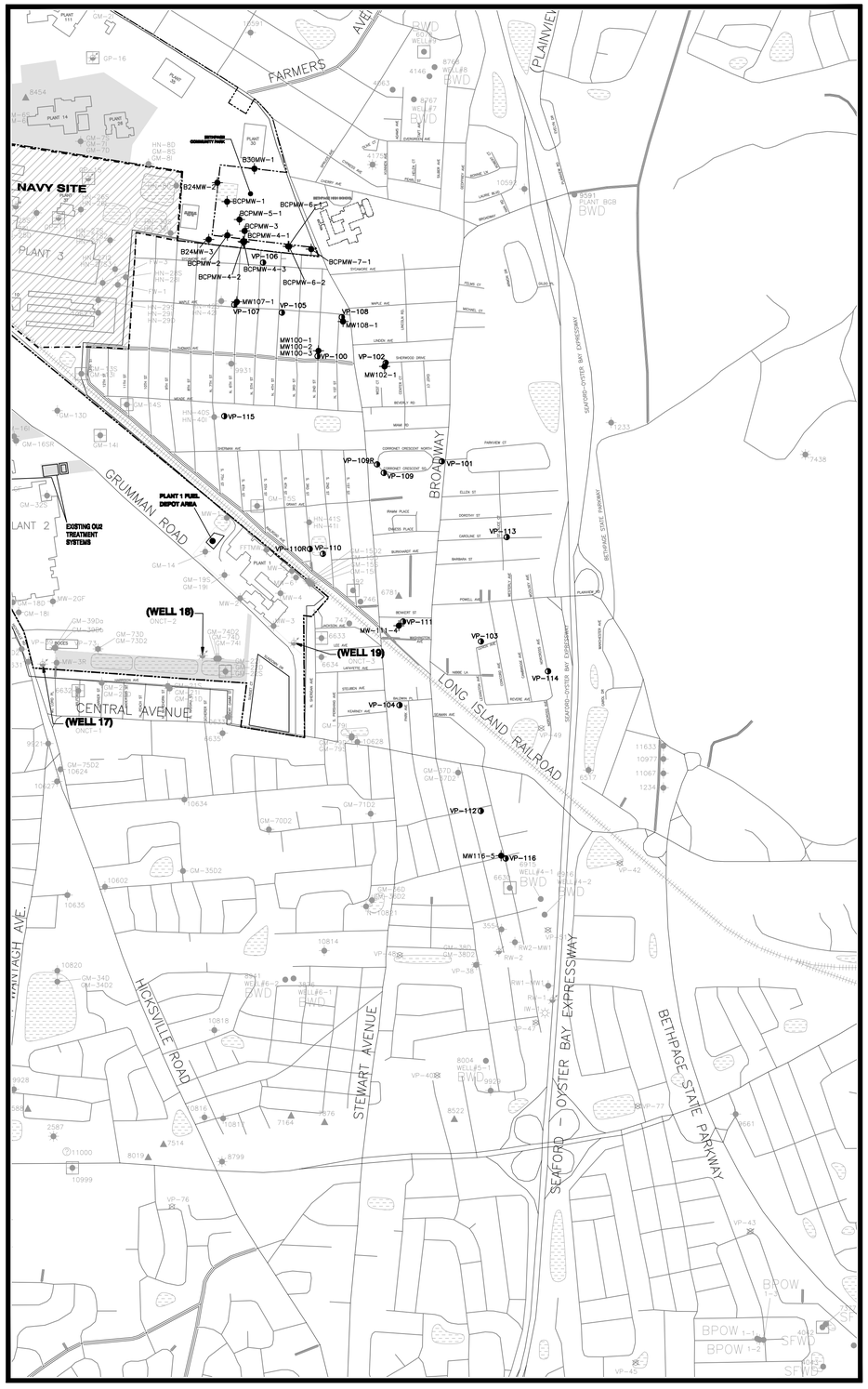
Please do not hesitate to call me at (215) 702-4099 if you have comments or questions.

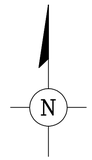
Sincerely,

Project Manager

Attachments
Figure 1 Draft Arcadis Site Plan
Attachment 1 Groundwater Flow and Solute Transport Study Proposed Approach

cc: Lora Fly, US Navy
David Li, TtEC
Christine Joblon, TtEC
File





EXPLANATION

- PROPERTY BOUNDARY OF THE FORMER GRUMMAN AEROSPACE SITE
- PROPERTY BOUNDARY OF U.S. NAVY SITE
- LONG ISLAND RAILROAD
- DENOTES NORTHROP GRUMMAN OWNED PROPERTY (AS OF 2003)
- DENOTES U.S. NAVY OWNED PROPERTY (AS OF 2003)
- RECHARGE BASIN
- LIMITS OF BETHPAGE HIGH SCHOOL MAIN BUILDING
- 10592 OBSERVATION, MONITORING WELL
- 6781 INDUSTRIAL WELL
- 9591 PUBLIC SUPPLY WELL
- 4175 IRRIGATION WELL
- WELL-17 NORTHROP GRUMMAN OR NAVY PRODUCTION WELL
- ABANDONED WELL
- VP-49 COMPLETED OU2 VERTICAL PROFILE BORING
- VP-100 COMPLETED OU3 VERTICAL PROFILE BORING
- BCP-MW-2 COMPLETED OU3 MONITORING WELL OR WELL CLUSTER
- BWD BETHPAGE WATER DISTRICT
- VPB VERTICAL PROFILE BORING
- RI REMEDIAL INVESTIGATION
- OU2 OPERABLE UNIT 2
- OU3 OPERABLE UNIT 3

GENERAL NOTES:

1. THIS FIGURE INCLUDES LOCATIONS OF PUBLIC SUPPLY WELLS BASED ON INFORMATION RECEIVED BY ARCADIS IN RESPONSE TO A SEPTEMBER 2001 LETTER TO WATER DISTRICTS.
2. BASIN LOCATIONS OBTAINED FROM USGS TOPOGRAPHIC MAPS (HUNTINGTON, HICKSVILLE, FREEPORT AND AMITYVILLE QUADRANGLES) AND INFORMATION PROVIDED BY NORTHROP GRUMMAN.
3. NORTHROP GRUMMAN PROPERTY HOLDINGS BASED ON DATA PROVIDED IN JUNE 2003.
4. LOCATIONS OF MONITORING WELLS INSTALLED BY DVIRKA & BARTILUCCI (D&B) AT PLANT 1 (i.e., MW-1 TO MW-6) ARE APPROXIMATE BASED ON D&B SITE PLAN, PROVIDED ON DECEMBER 19, 2002.

0 800' 1600'
SCALE IN FEET

DRAFT

ALL COORDINATES REFERENCED TO NORTH AMERICAN DATUM 1983

NORTHROP GRUMMAN SYSTEMS CORPORATION
BETHPAGE, NEW YORK
OPERABLE UNIT 3
(FORMER GRUMMAN SETTLING PONDS)

SITE PLAN SHOWING COMPLETED VPB AND MONITORING WELL LOCATIONS

ARCADIS

FIGURE 1

ATTACHMENT 1

DRAFT

NWIRP Bethpage
GM-38 Area
Groundwater Flow & Solute Transport Study
Proposed Approach

Long Island, New York

by
Tetra Tech EC
March 17, 2009

Objectives

- Understand flow systems
  - Both regional & site-specific flow conditions
  - Lateral and vertical flow components
- Site-specific goals
  - Determine RW-3 screen interval (at proposed location)
  - Capture local plumes in GM-38 area
  - Evaluate capture zones of extraction wells RW-1, RW-2, and RW-3
  - Evaluate locations and screened intervals of RW-3 related monitoring wells
- Evaluate transport processes (may not be completed as part of this scope)
  - Site-specific conditions of plumes in GM-38 area
  - Chlorinated hydrocarbon plumes
    - May use compound-specific or average VOC concentrations
- Plume Visualization & Animation (may not be completed as part of this scope)
  - Detailed mass & volume estimates
- Groundwater flow modeling (and transport simulation)
  - Used to study (evaluate) hydraulic responses from RW-1, RW-2, and RW-3 on plume control (capture) at GM-38.
  - Numerical flow and transport models will be developed and calibrated to steady-state flow field with averaged hydrogeologic conditions.

Approach

- Review & adopt USGS models (1987, 1991, 1997, 1999, etc.)
- Develop a site-specific conceptual model (SCM)
  - With lithology/chemical data, & Vertical Profile Borings (VPBs), etc.
- Step 1-Build & calibrate numerical flow model
  - Steady-state or transient
  - Hydrogeologic conditions averaged years 2000 through 2008
- Step 2-Hydraulic control (capture zone) study
  - RW-1, RW-2, and RW-3
  - Particle tracking method
  - Advective transport process
- Step 3-Build & calibrate transport model (in addition to advection)
  - Other processes (dispersive, decay, and chemical reactive, etc .)
  - Re-construct plumes
  - Calibrate plume configurations/concentrations
- Step 4-Plume visualization & animation
  - 3D interpolation of chemical data (USEPA method)
  - Mass & volume estimates for supporting transport model
- Steps 1 and 2 to be completed to meet current objectives for the GM-38 area. Steps 3 and 4 are potentially scope items and may not be completed.

Modeling Strategies

Similarity with USGS & Arcadis

- Use the same technical approach (accepted by NYSDEC)
  - Same numerical codes
- Model domain & boundary conditions
- Lithology & aquifer hydraulic properties
- Vertical discretization
- Hydrogeologic data (averaged)
  - Regional supply wells
  - On-site & off-site monitoring wells data
  - Precipitation data
  - Recharge basins data
- Calibration targets
  - Heads from on-site & off-site monitoring wells
  - Flow patterns (horizontal & vertical)

Modeling Strategies

Difference from USGS & Arcadis

- Calibration methods
  - trial-and-error; and
  - PEST code (parameter estimation)
- Variable layer thickness
- Refined grid spacing for site-specific area
- Sloping Raritan clay surface
- Long-term averaged hydrogeologic data
- Supply wells with actual screen intervals (elevations)
- Particle tracking may be performed with transient flow field
- Transport processes
  - Advective, dispersive, reactive, etc.
  - Sequential degradation of chlorinated hydrocarbons

Numerical Model Domain (Study Area)

Figure 1

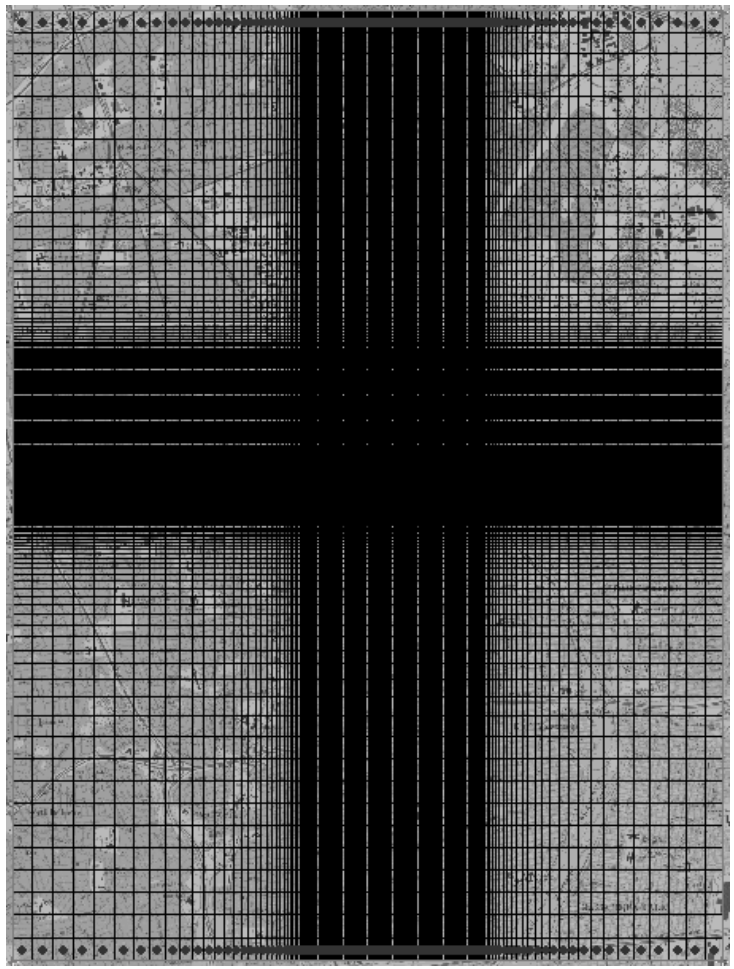


Figure 2

Numerical Domain Details

- Adopted the similar model domain used by USGS and Arcadis
  - With dimensions of
  - North to South = 40,000 ft; and East to West = 30,000 ft.

- NWIRP industrial area is located approximately in the northern center of Figures 1 and 2.

- The plume was 12,000 ft long in early 1990s, currently it is about 18,000 ft long.

- TtEC will use 182 rows by 172 columns ~ 31,304 (nodes each layer) ~ 219,128 total model nodes (~ 1/6th of Arcadis)

Regional Lithology from USGS Model

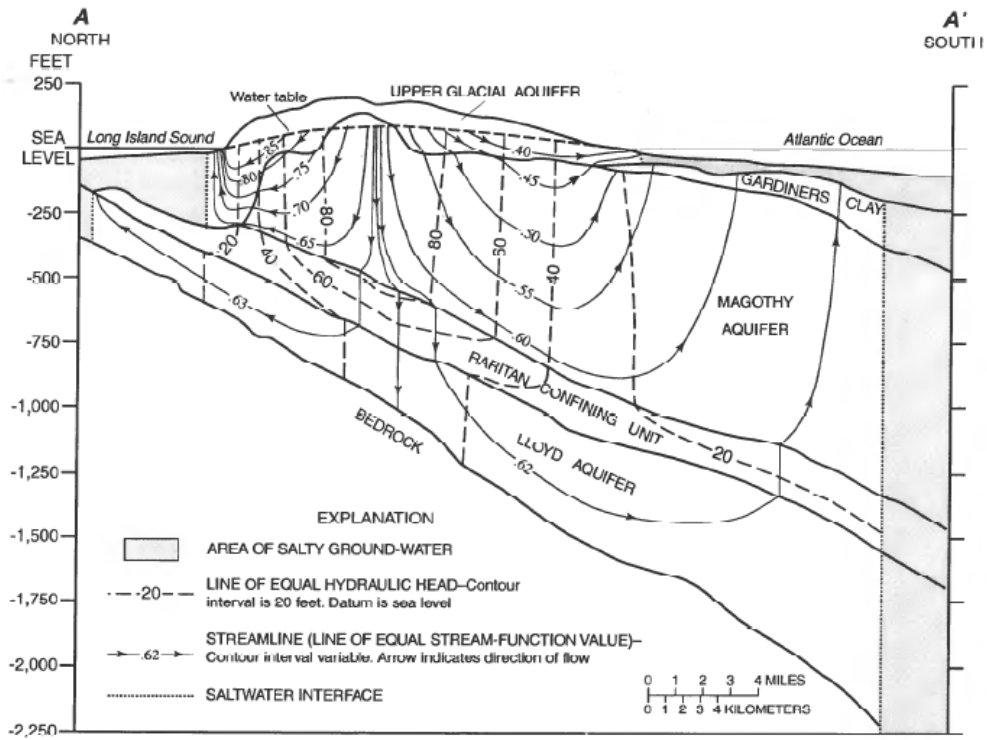


Figure 3

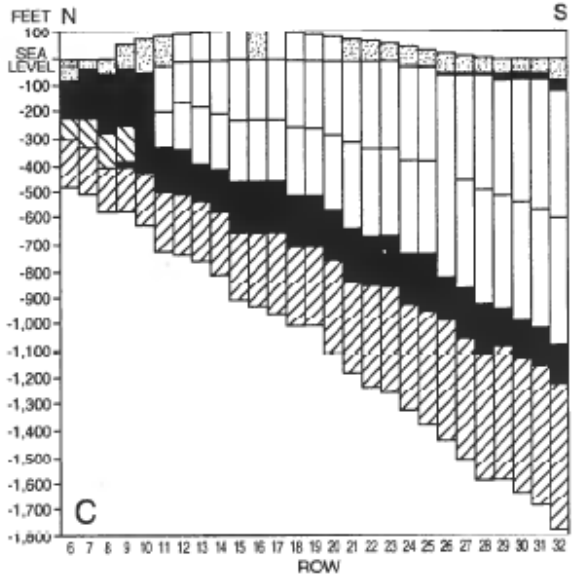
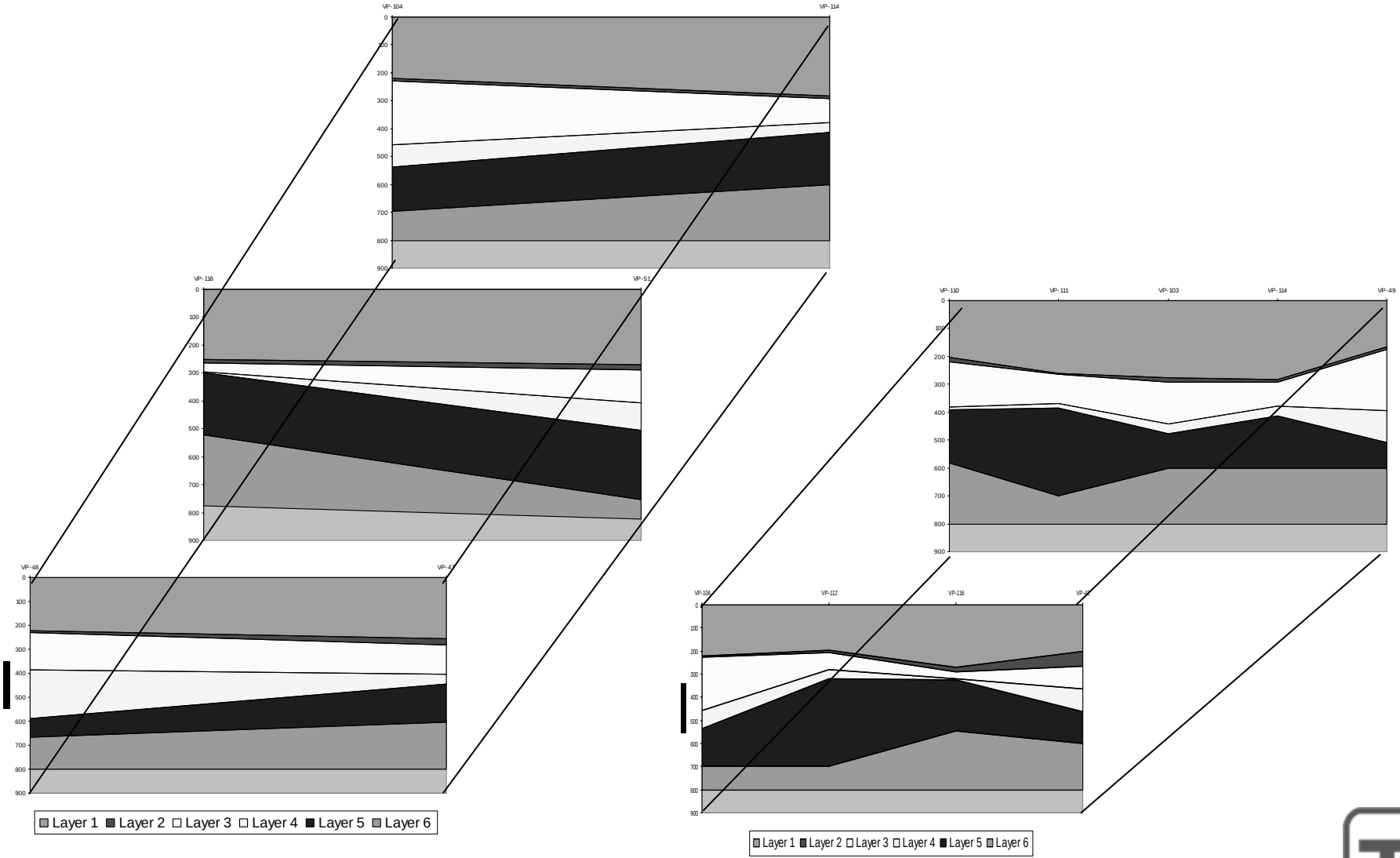


Figure 4

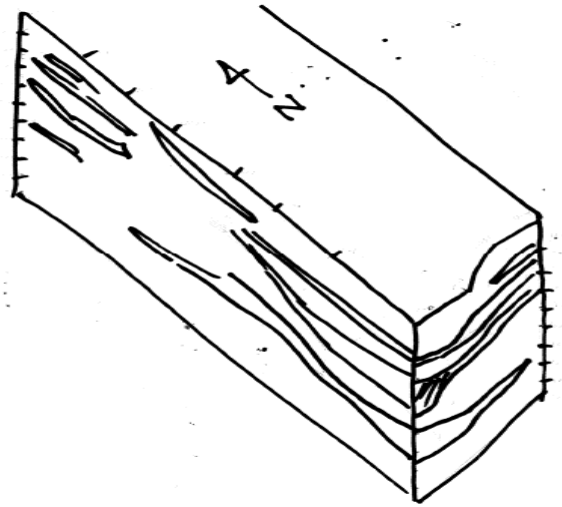
Lithology used in USGS model (Figure 3) and USGS report (Buxton & Smolensky, 1999) (Figure 4)

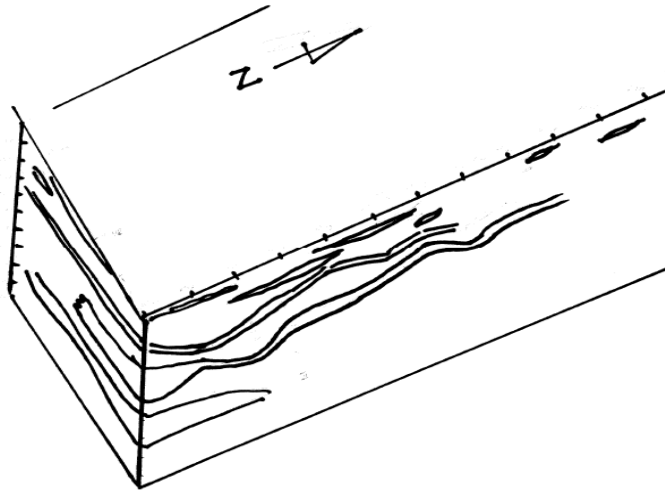
Site-Specific Lithology

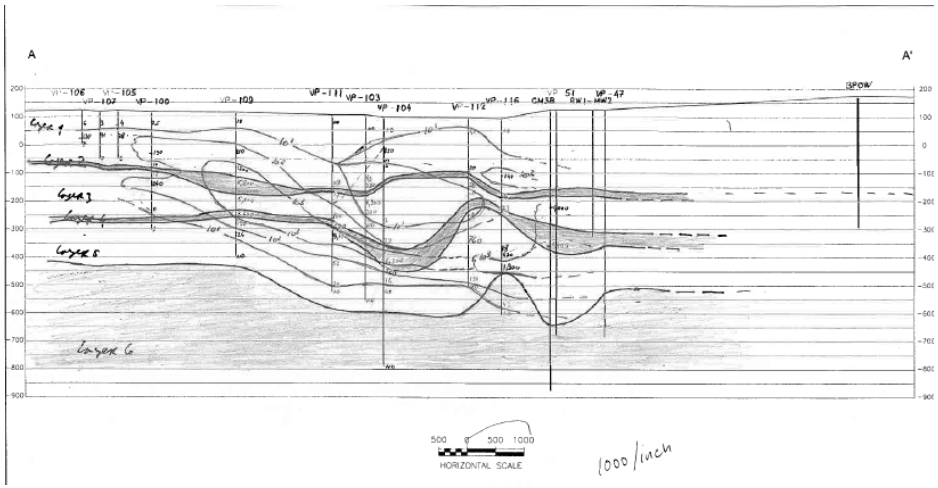
Site Specific based on Vertical Profile Borings



Site-Specific Lithology Details







Not to scale

- Lithology based on site-specific data, and will be refined during modeling process.
- Lower Figure-Shaded (predominately fines) and white layers (predominately sands) approximate lithologic layers.
- Red contour lines approximate TCE concentrations and plume thickness.

VOC Plumes – Plan View (not to scale)

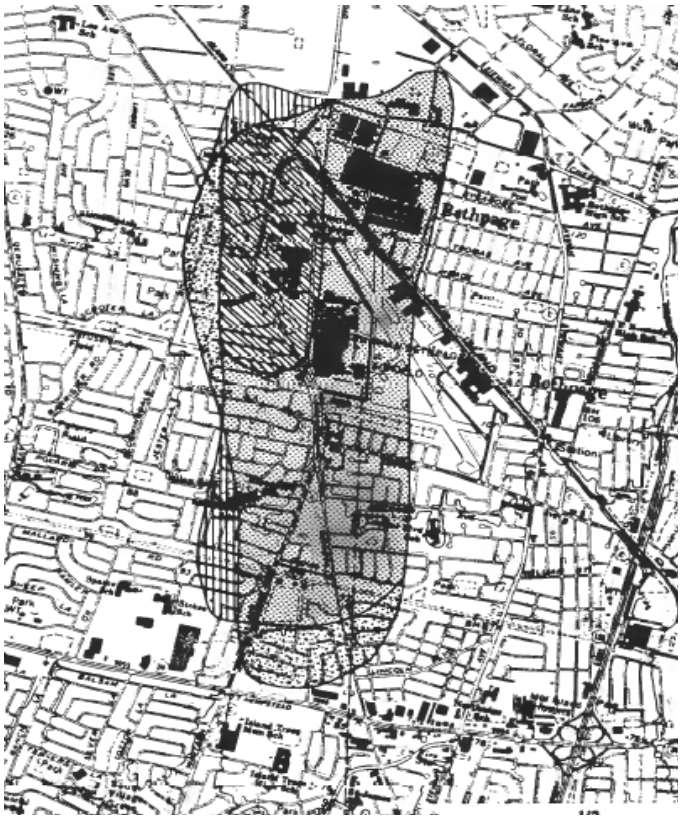


Figure 6 TCE, DCE and VC plumes in 1987 (USGS model)

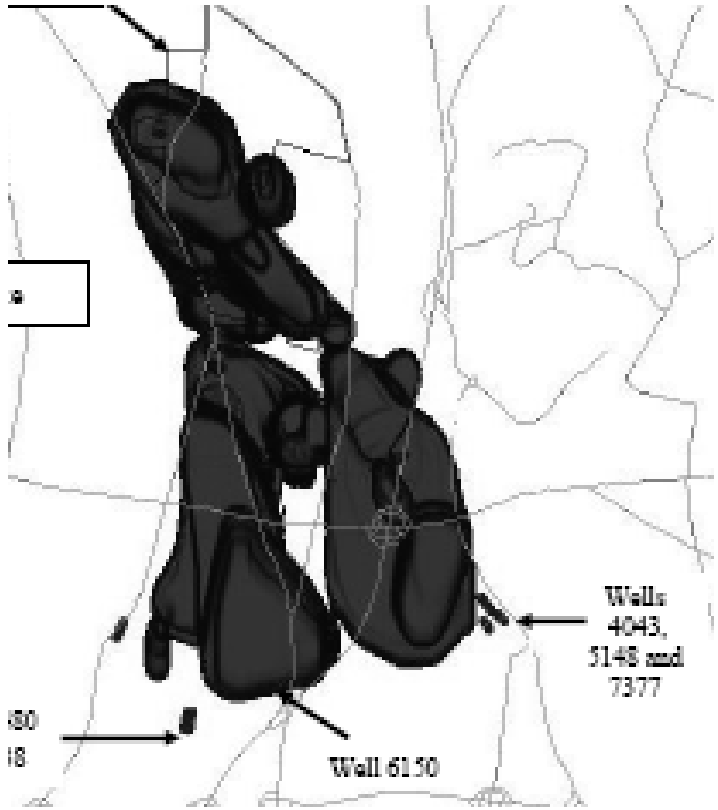
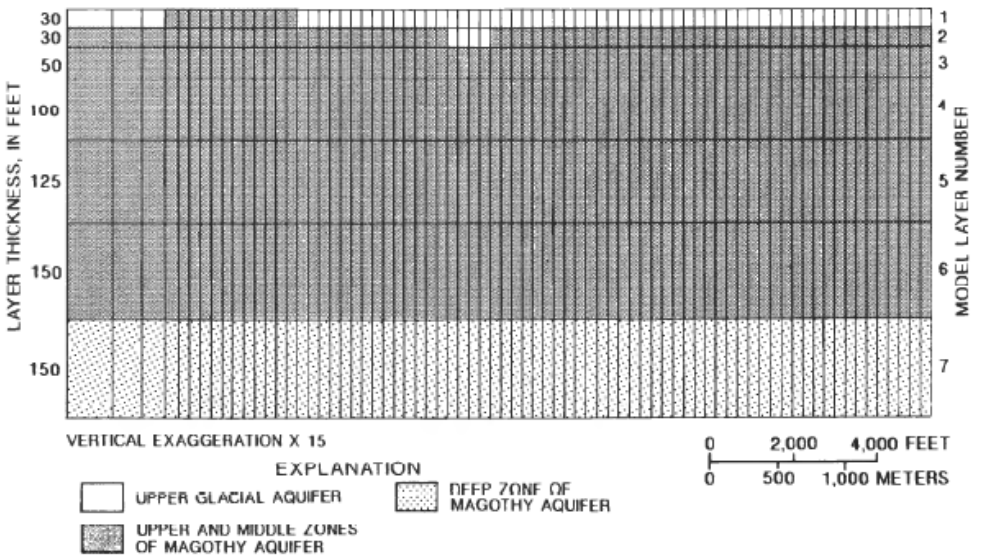


Figure 7 Total VOC plume (above 5 ug/L) in 2006 (Arcadis)

Site-specific model will be focused on the plume in the GM-38 area local capture for the pump and treat system.

Numerical Model (vertical discretization)

Figure 8



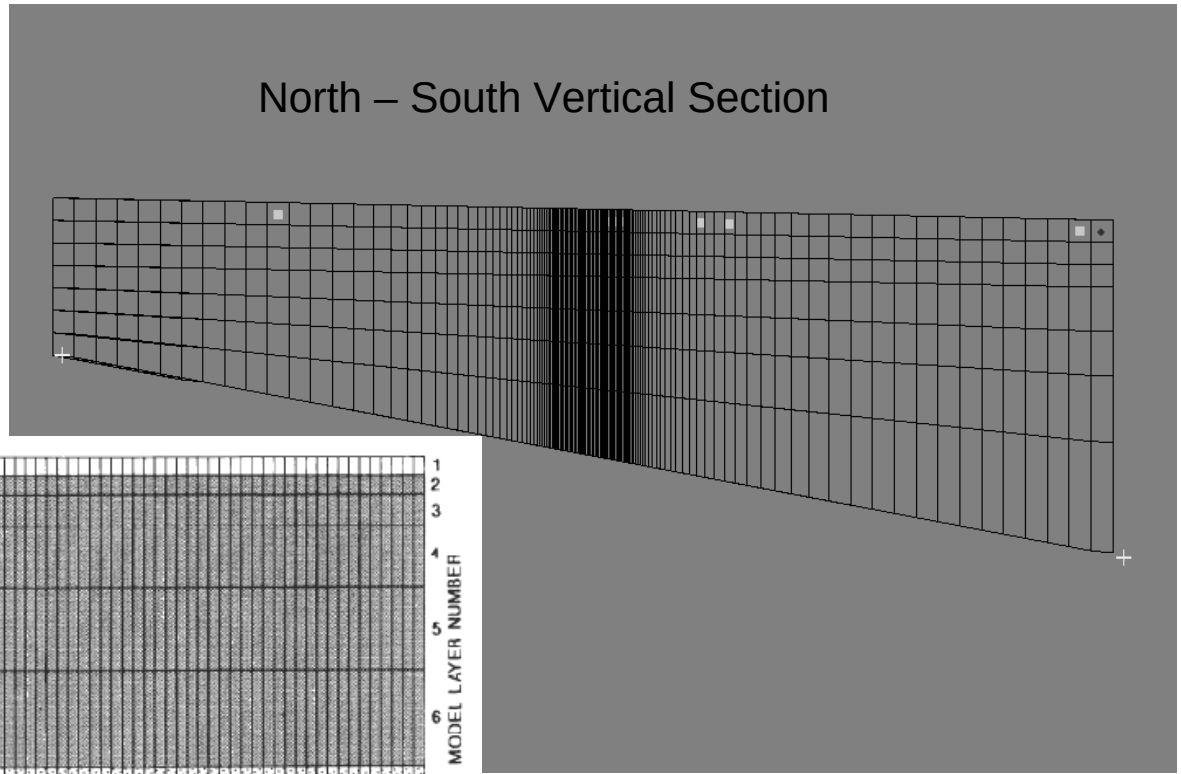


Figure 9
not to scale

Numerical Model (vertical discretization) Details

- USGS (Smolensky, 1995) performed an advective transport study for chlorinated hydrocarbons (PCE, TCE, DCE, and VC) beneath an industrial/residential area of Nassau County.

- Figure 8 is a north-south vertical section of the USGS advective transport model developed for this area. USGS used a total of 7 layers: Layer 1-upper glacial aquifer; Layer 2-mix of lower glacial and Magothy aquifers; Layers 3 to 7 represented the upper and lower Magothy aquifer.

- TtEC model will adopt USGS lithology; site-specific data incorporates variable spacing ranges from 50 ft to 1000 ft, and variable layer thicknesses.

- Figure 9 approximates the TtEC refined grid spacing along the plume in the area of GM-38 and the RW-1, 2, and 3 area. Vertical thickness ranges from 250 ft in the north to approximately 800 ft in the south. The TtEC grid spacing may be further refined as data is evaluated.

Model Domain & Surface Elevation (USGS Topo)

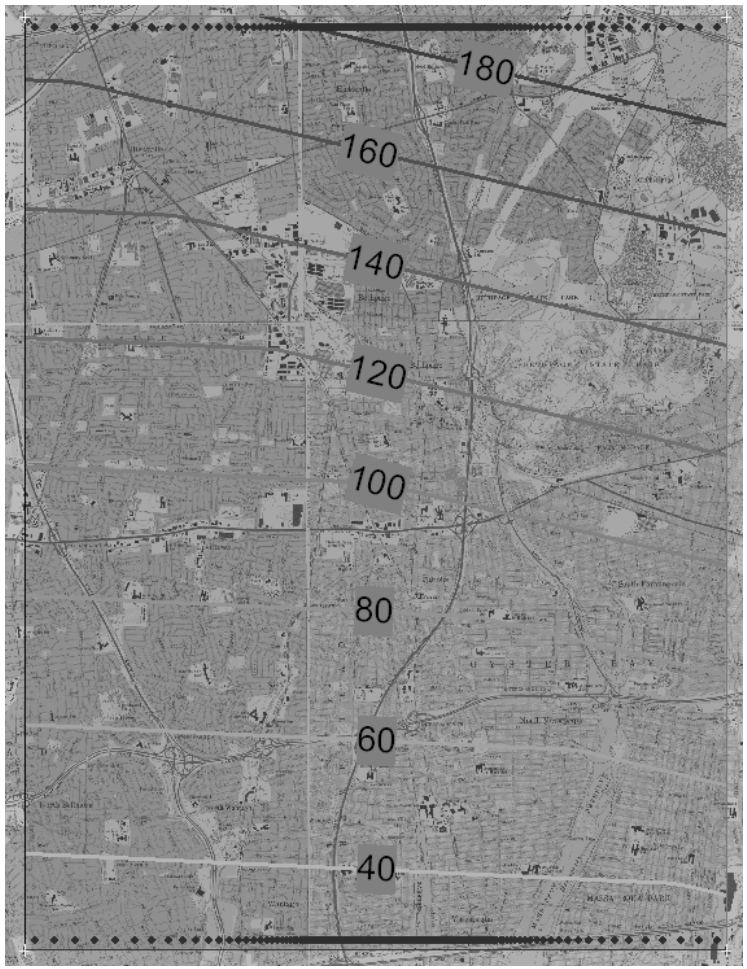
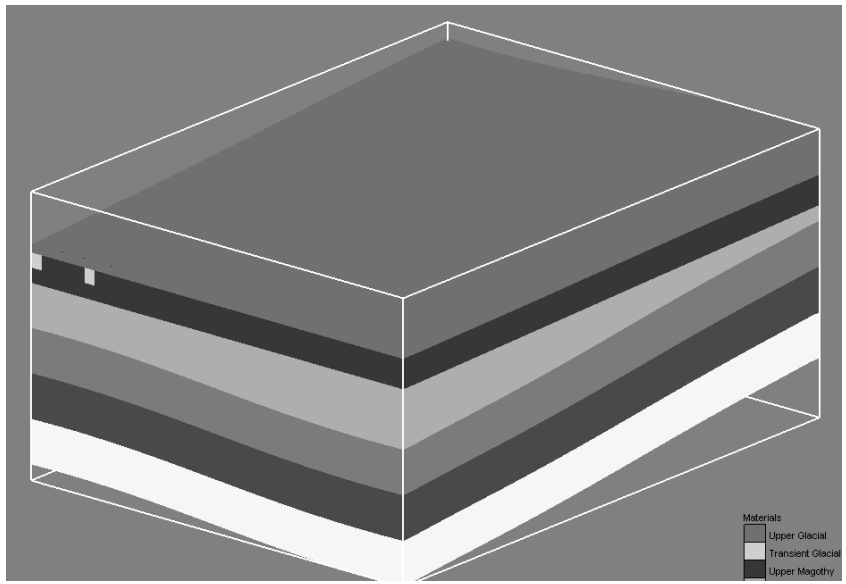


Figure 10



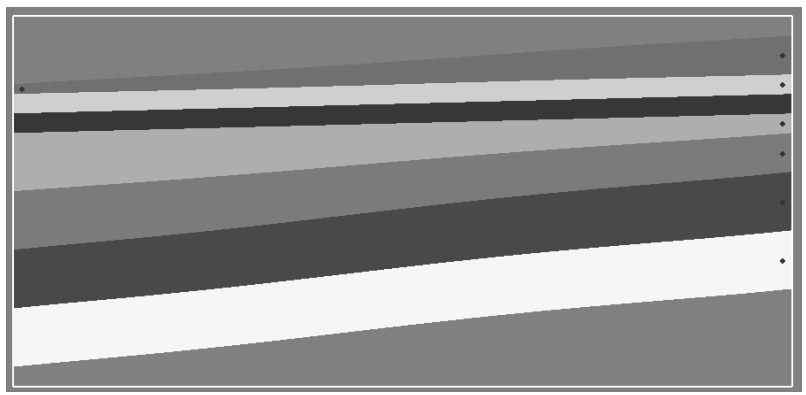


Figure 11 (top) Figure 12

Model Domain and Surface Elevation (USGS Topo) Details

- Model domain 30,000 (east-west) x 40,000 (north –south) ft; covers approximately 43 sq. miles (similar to Arcadis & USGS)
- USGS topo map (Figure 10) was used to interpolate surface elevation for the upper glacial aquifer.
- USGS structure contour maps (Site-Specific Figures 11 and 12) will be used to interpolate upper, middle, and lower Magothy aquifer elevations and Raritan clay surface.
- Ground levels are between 120 to 140 ft msl at the the NWIRP.
- Ground levels are about 80 to 100 ft at the GM-38 area.

Model Boundary Conditions

Mathematical Boundary Conditions

Based on USGS model:

- Dirichlet (specific head): northern and/or southern (approximate regional groundwater divide in north, or known head in the south);
- Neumann (specific flow) ~ water table (areal recharge); along flow lines; at the top of Raritan clay (assuming zero vertical flux); and at saltwater interface (zero lateral flux);
- Mixed ~ both (southern)

Recharge

- MacArthur Airport precipitation records (1984 - 2001)
- Recharge ~ 49% of precipitation (USGS study, 1995)
- Avg. areal recharge ~ 0.00588 ft/day (25.75 inches/yr)
- Variable areal recharge may be assigned across study area
- Various recharge (infiltration) basins

Boundary Conditions - USGS Study (1997, 2002, 2006, etc.)

Upper Glacial Aquifer

- USGS water table contour map

Magothy Aquifer

- USGS saturated thickness map
- USGS potentiometric map

Top of Raritan Confining Unit

- USGS Raritan structure contour maps
- USGS potentiometric maps

GIS Data Mapping

Transfer field data to numerical models

Layer elevations

- Upper glacial top & bottom
- Upper Magothy
- Middle Magothy
- Lower Magothy
- Top of Raritan confining unit

Aquifer properties

- Hydraulic conductivity data
- Storage data
- Porosity data
- Based on USGS study and TtEC data.

GIS Data Mapping

Regional/local pumping wells
- BWD Plants 4 & 5 wells, and others
- Pumping rates (steady-state or variable schedule)

Remedial wells
- RW-1, RW-2, RW-3
- Screen intervals & pumping rates (constant and/or variable)

Monitoring wells
- On-site
- Off-site

Infiltration (recharge) basins
- On-site
- Off-site

Observed Regional Groundwater Levels (USGS, 2006)

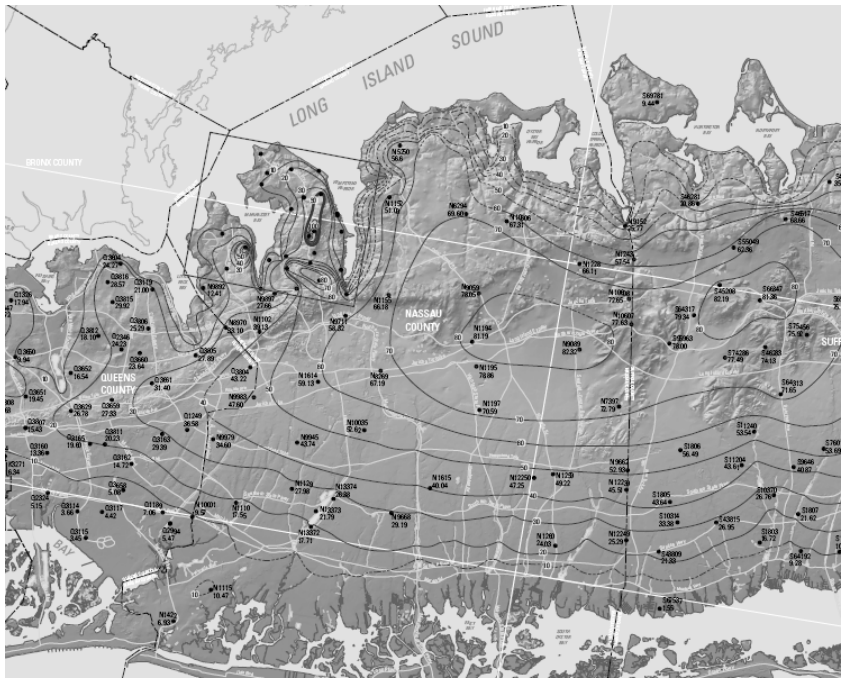


Figure 13 Upper glacial aquifer

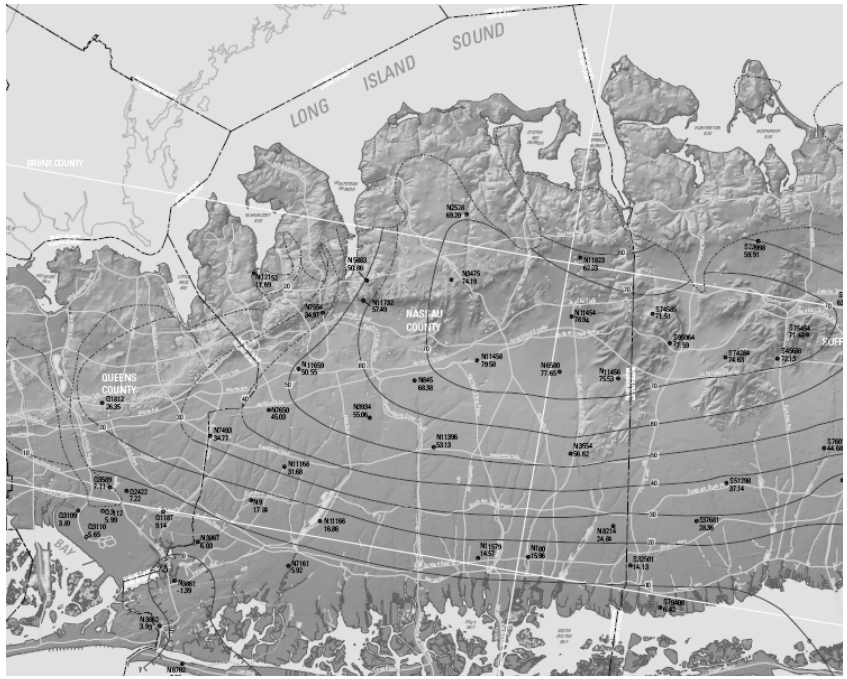


Figure 14 Magothy aquifer

Regional and site-specific groundwater elevation data will be used in calibration of model.

Model Calibration (TBD)

- Calibration Parameters
  - Hydraulic conductivity
  - Boundary Conditions
- Calibration Statistics
  - Mean error
  - Root Mean Square
    - water level range
    - Residuals
- Scatter plot
  - Computed vs. observed
  - Residuals

Evaluation of Hydraulic Scenarios

Hydraulic Capture Scenarios-Values (TBD)

- RW-1-exisiting
- RW-2 (not likely used for extraction because of potential influence on Bethpage Water District Plant #4 Wells, to be re-evaluated)
- RW-3-to be installed

Evaluation Criteria

- Water level drawdown (cone of depression)
  - Steady-state & transient
- Capture zone analyses
  - Particle tracking method
  - RW-3 screen interval
  - RW-3 related monitoring well locations

Reference List-Documents Used in Development of Model

- **Arcadis. Comprehensive Groundwater Model Report, U.S. Naval Weapons Industrial Reserve Plant (NWIRP)/Northrop Grumman, Bethpage, New York. 2003. Prepared for Tetra Tech NUS, Inc.**
- **Feldman, S.M., D.A. Smolensky, J.P. Materson. 1992. Groundwater Quality in the Bethpage-Hicksville-Levittown Area, Long Island, New York, With Emphasis on Volatile organic Compounds.**
- **Tetra Tech NUS, Inc. GM-38 Area Vertical Profile Boring Installation Summary Report, Naval Weapons Industrial Reserve Plant (NWIRP), Bethpage, New York. 2002. Prepare for U.S. Navy Engineering Field Activity Northeast.**
- **U.S.G.S. Water Resources Investigations, Report 92-4148. 1999. Simulation of the Effects of Development of the Ground-Water Flow System of Long Island, New York.**
- **U.S.G.S. Water Resources Investigations, Report 92-4148. 1995. Three-Dimensional Advective Transport of Volatile Organic Compounds in Ground Water beneath an Industrial-Residential Area of Nassau County, New York.**

Reference List - Supplemental Data Supplied by Arcadis to TtEC

- **Arcadis. Off-site Vertical Profile Borings (VPB) Data including geophysical logs, sample core logs, chemical data tables, location coordinates, and vertical elevations. 2008.**
- **Arcadis. Data Table-Coordinates and Screen Intervals of Occidental Chemical Corporation Monitoring Wells Associated with the Model, Northrop Grumman Systems Corporation, Bethpage, New York. 2009**
- **Arcadis. Data Table-Coordinates and Screen Midpoint Elevations of Monitoring Wells Associated with the Groundwater Model, Northrop Grumman Systems Corporation, Bethpage, New York. 2009**
- **Arcadis. Data Table-Coordinates and Screen Interval Elevations of Supply Wells Associated with the Groundwater Model, Northrop Grumman Systems Corporation, Bethpage, New York. 2009**
- **Arcadis. Data Table-Pumping Rates of Supply Wells Associated with the Groundwater Model, Northrop Grumman Systems Corporation, Bethpage, New York. 2009**

Reference List - Reports/Documents Supplied by Arcadis, Prepared on Behalf of Northrop Grumman

- **Arcadis. 2000 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2001. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2001 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2002. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2002 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2003. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2003 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2004. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2004 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2005. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2005 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2006. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2006 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2007. Prepared for Northrop Grumman Corporation.**
- **Arcadis. 2007 Annual Groundwater Monitoring Report, Groundwater Interim Remedial Measure, Northrop Grumman Corporation, Bethpage, New York. 2008. Prepared for Northrop Grumman Corporation.**

Reference List - Model Reports/Documents Prepared by Arcadis on Behalf of U.S. Navy

- **GM38 Area Remedial Design Modeling Results, Northrop Grumman Regional Groundwater Model, Northrop Grumman Corporation. Memo to Mike Wolfert and Carlo San Giovanni from Robert Porsche and Doug Smolensky. December 4, 2002.**
- **GM38 Design Simulation No. 1, TT/NUS Modeling. Memo to Dave Brayack, Tetra Tech NUS, Inc. from Robert Porsche and Doug Smolensky. December 2, 2002.**
- **GM38 Design Simulation No. 2, TT/NUS Modeling. Memo to Dave Brayack, Tetra Tech NUS, Inc. from Robert Porsche and Doug Smolensky. April 11, 2003. Comprehensive Groundwater Model Report, U.S. Naval Weapons Industrial Reserve Plant, Northrop Grumman, Bethpage, NY, prepared by ARCADIS G&M, Inc. April 28, 2003.**
- **GM-38 Area Model Simulation Results Comparison. Letter to Dave Brayack, Tetra Tech NUS, Inc. from Robert Porsche, Doug Smolensky and Mike Wolfert. May 5, 2003.**
- **Capture Zone Assessment for GM-38 Remedial System and Bethpage Water District Plant 4. Memo from Robert Porsche to Carlo San Giovanni. July 25, 2005.**
- **GM-38 Area Remedial System Injection and Monitoring Well Placement Assessment, TTEC, Bethpage, New York. Memo from Robert Porsche and Doug Smolensky to Carlo San Giovanni. December 19, 2005.**
- **GM-38 RW-3 Effectiveness Modeling. Memo from Robert Porsche to Carlo San Giovanni. February 15, 2006.**
- **Evaluation of a Third Remedial Well for the GM-38 Area Remedial System, Bethpage, New York. Memo from Robert Porsche and Doug Smolensky to Carlo San Giovanni. July 25, 2006.**