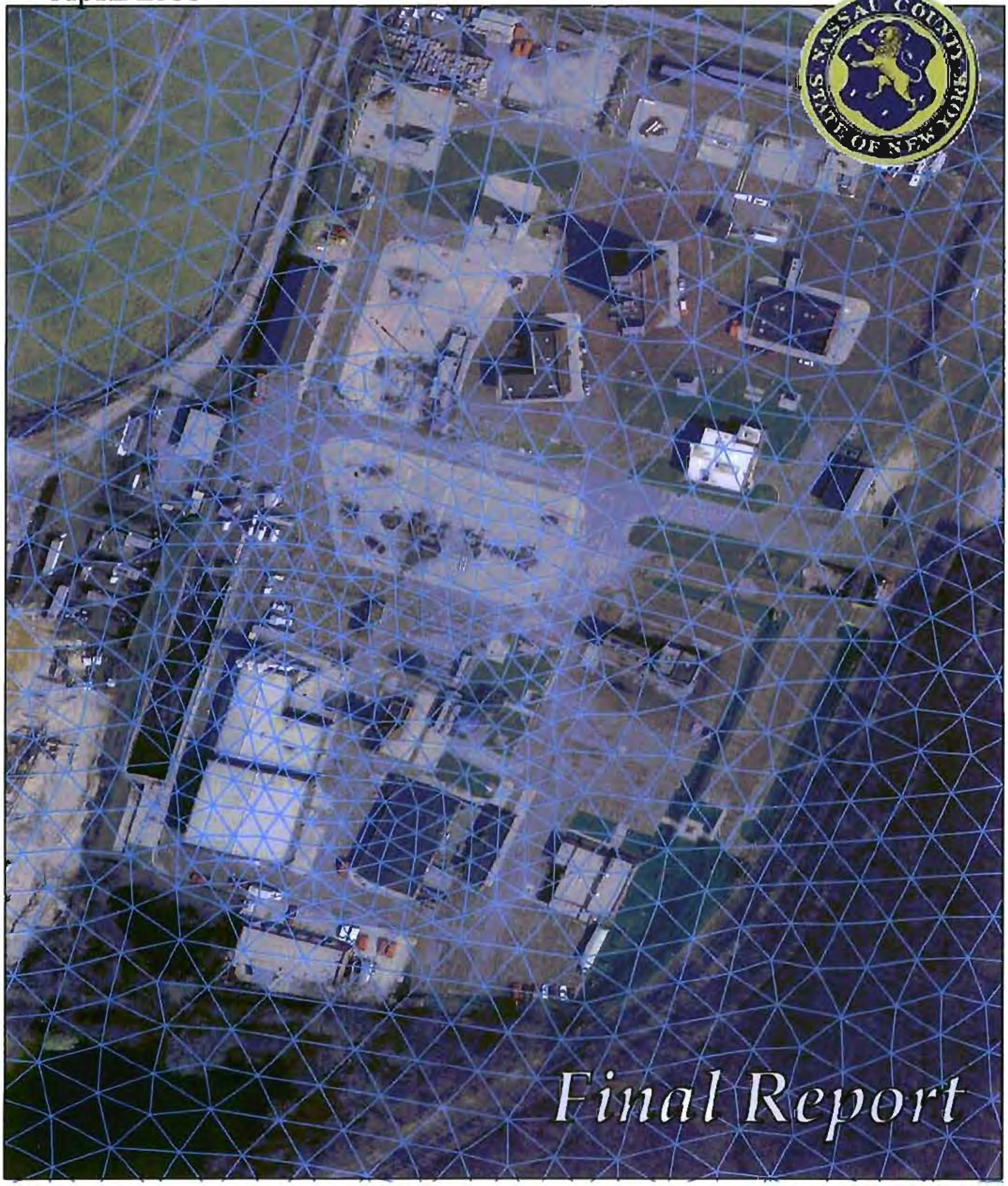
Nassau County Department of Public Works

Firemen's Training Center Groundwater Model

April 2008



Contents

Figures

Tables

Executive Summary

There are three Superfund sites within the study area that collect and treat groundwater from the upper portion of the Magothy aquifer in the vicinity of Bethpage State Park in Bethpage, New York. Along with the Nassau County Firemen's Training Center (NCFTC; Nassau County), the Town of Oyster Bay Landfill (TOBAY / NYSDEC) and the former Claremont Polychemical Corporation (USEPA) are responsible for contaminating the upper portion of the Magothy aquifer with volatile organic compounds.

During routine operation of the remedial treatment system for the NCFTC, a large "spike" in volatile organic compound concentrations was observed in groundwater samples collected from County owned and operated offsite recovery well ORW-4 in October 2002. Both the level of contamination observed in the "spike" and the presence of volatile organic compounds not related to training activities at the NCFTC resulted in the initiation of an investigation of potential sources. The investigation conducted by the Nassau County Department of Public Works - Water and Wastewater Engineering Unit resulted in the presentation of a *Review of Offsite Volatile Organic Plume Characteristics* to the New York State Department of Environmental Conservation (NYSDEC) in December, 2003 and to the United States Environmental Protection Agency (USEPA) in March, 2004.

Following this review of offsite conditions, it was determined that due to the complex nature of the local geology and the interaction of three groundwater remediation systems an updated version of the 1994 finite element groundwater model developed for the NCFTC, would aid in the identification of the source or sources of volatile organic compounds impacting the County's remedial efforts and evaluate the risk to downgradient public supply wells.

This updated groundwater model was developed and run under various scenarios to determine the extent of contamination originating from the NCFTC and the potential for that contamination to impact downgradient community public supply wells. The model was also used to evaluate several potential upgradient facilities in Nassau County as a possible source of these non-NCFTC related constituents and evaluate the risk of groundwater contamination from NCFTC and potential non-NCFTC sources on downgradient public supply wells.

Model simulations confirm the spatial extent of contamination originating from NCFTC as mapped by Nassau County Department of Public Works (NCDPW). Simulations suggest that the plume generated from the NCFTC facility is being captured by County operated offsite recovery wells. The plume is bounded to the east by County offsite recovery wells ORW-4, 6 and 7 and TOBAY recovery well 2. The simulated western boundary of the plume is approximately located at County offsite recovery well 5 and the former Bethpage State Park irrigation well N-617. The NCFTC plume is restricted vertically by the surface of a dense lignitic clay layer located at the base of the County offsite recovery system.

Model simulations suggest that hypothetical contamination originating from sources other than the NCFTC, Town of Oyster Bay Landfill and the former Claremont Polychemical Corporation appears to be only partially controlled by the three existing remedial operations and may have affected water quality in deeper portions of the Magothy aquifer, outside of the influence of all three remediation systems. This deeper contamination requires further study since it presents the greatest threat to local public supply wells.

Water quality in the upper Magothy has also been impacted by volatile organic compounds in areas that are both east of the offsite County recovery wells and downgradient of the TOBAY system. Model simulations indicate that this contamination is not from NCFTC and has likely originated from an unknown source located east of the NCFTC offsite recovery well network, potentially in western Suffolk County as well as a potential long-term water table source at Claremont Polychemical. Both of these potential sources also require additional investigation since they are not fully contained by the three operating groundwater recovery systems. Model simulations suggest that at least some of this contamination is being captured by County recovery wells ORW- 4, 6, and 7.

Contaminant transport simulations project that Village of Farmingdale public supply well N-7852 could be impacted by low levels (<5ppb) of volatile organic compounds originating from potential non-NCFTC sources. This public supply well is located in a deeper portion of the Magothy aquifer and is not subject to contamination originating at the NCFTC.

Section 1
Introduction

Since 1960, the Nassau County Fireman's Training Center (FTC), also known as the Nassau County Fire Service Academy (FSA) in Nassau County, New York has been used to conduct fire fighting training exercises. These exercises involve both outdoor and indoor training. Outdoor exercises are conducted in open burn areas where steel or concrete pits are filled with fuel oil, primed with gasoline and ignited. Indoor exercises are conducted inside brick mockup buildings in which straw and wooden pallets are placed over steel pans, which also contain fuel oil. The fuel oil is primed with gasoline and the pallets and straw are ignited and later extinguished by the firefighters. In addition to fuel oil and gasoline, waste solvents were alleged to have been used between 1970 and 1980 (NCDPW, 1992).

As a result of the fire fighting training exercises, a plume of groundwater contamination developed, originating from the FTC site. This plume was caused by unburned fuel that was poured onto the ground or that was washed out of mockup buildings. This washout was drained to a series of dry wells until 1984 when a new drainage system was installed which isolated burn area runoff and included an oil/water separator to treat the runoff.

Based on Nassau County Department of Public Works (NCDPW) investigations, the New York Department of Environmental Conservation (NYSDEC) classified the site as a Class 2 Inactive Hazardous Waste Disposal Site in March 1988. A Remedial Investigation/Feasibility Study (RI/FS) was completed in 1992. As part of the treatment facility design report, a three-dimensional finite element groundwater model was developed in 1994 by Camp, Dresser and McKee (CDM) to better estimate the extent of the FTC plume and to determine effective locations for offsite groundwater extraction wells. Following completion of the design report, a groundwater treatment plant was constructed onsite and began full scale operation in July, 1999.

During the course of routine offsite treatment operations, a large "spike" in volatile organic compound concentrations was observed in samples collected from County owned and operated offsite recovery well ORW-4 in October 2002. Volatile organic concentrations in this well rose from historical concentrations of approximately 200 ppb to 934 ppb in less than three weeks. Concentrations of several individual compounds also increased from historic concentrations of below 10 ppb to concentrations greater than 100 ppb. Dichlorodifluoromethane, a compound never detected in groundwater beneath the NCFTC, increased in this well from concentrations less than 5 ppb to a high of 38 ppb during this event (NCDPW, 2002).

Both the level of contamination and presence of volatile organic compounds not related to training activities at the Nassau County Firemen's Training (NCFTC) resulted in the initiation of an investigation of potential sources. The investigation conducted by the Nassau County Department of Public Works Water and Wastewater

Engineering Unit resulted in the presentation, *Review of Offsite Volatile Organic Plume Characteristics*, to the New York State Department of Environmental Conservation (NYSDEC) in December, 2003 and to the United States Environmental Protection Agency (USEPA) in March, 2004. Subsequent investigations have identified groundwater contamination east and downgradeint of the FTC site. Contamination downgradient has distinct eastern and western chemical signatures (Table 1-1; Figure 1-1), in which select compounds of the eastern plume were never detected onsite at the Firemen's Training Center. The primary constituents associated with contamination at the FTC site have historically been benzene, tetrachloroethylene (PCE) and two of its break-down products, trichloroethylene (TCE) and cis-1,2 dichloroethylene (DCE). However, other organic compounds have recently been detected in offsite recovery wells ("eastern plume" in Table 1-1).

To the north of the FTC site are two hazardous waste sites, Old Bethpage Landfill, and the former Claremont Polychemical Corporation (Figure 1-2). Both of these sites have offsite groundwater recovery wells and treatment onsite. Treated water is either re-injected to the aquifer or is discharged to recharge basins. On-going investigations conducted by the USEPA at the Claremont Polychemical site have revealed contamination at depth upgradient of the former Claremont facility.

Following review of these conditions, it was determined that due to the complex nature of the local geology and the interaction of three groundwater remediation systems (former Claremont Polychemical Corp. (USEPA), Town of Oyster Bay Landfill (TOBAY/NYSDEC) and the Firemen's Training Center (Nassau County)), an updated version of the 1994 finite element groundwater model would aid in the identification of the source or sources of volatile organic compounds impacting the County's remedial efforts and evaluate the risk to downgradient public supply wells. Specifically, the intent of the revised model is to: 1) define the horizontal and vertical extent of the FTC plume; 2) simulate the downgradient migration of the plume; 3) investigate the potential for the FTC plume to impact downgradient public supply wells, and 4) assess the potential impacts of groundwater plumes originating from the Claremont site and possible sources further upgradient on public supply wells and FTC recovery wells.

Section 2 of this report describes the development and calibration of the revised FTC model. Section 3 of this report documents several contaminant transport simulations that were conducted using the revised model. Section 4 presents conclusions and recommendations. References are listed in Section 5.

Table 1-1
Principal Chemical Constituents of Plumes Downgradient of FTC

Western Plume	Eastern Plume
Benzene *Cis*-1,2 Dichloroethylene Tetrachloroethylene Trichloroethylene	Benzene
	Cis-1,2 Dichloroethylene
	Tetrachloroethylene
	Trichloroethylene
	Dichlorodifloromethane
	1,1 Dichloroethylene
	1,2 Dichloroethane
	Isopropylbenzene
	1,1,1 Trichloroethane
	1,2,4 Trimethylbenzene
	Vinyl Chloride
	O-xylene

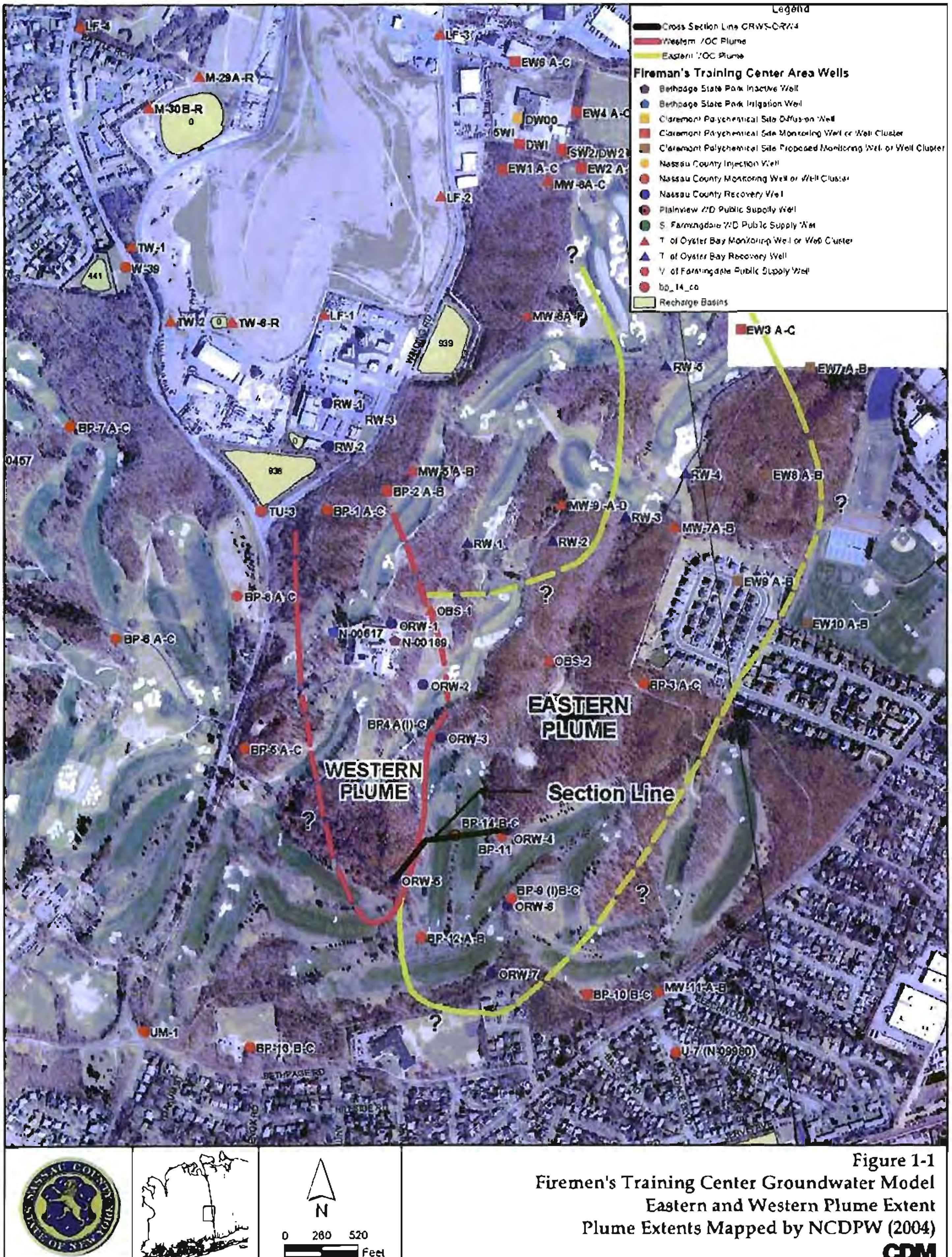


Figure 1-1
Firemen's Training Center Groundwater Model
Eastern and Western Plume Extent
Plume Extents Mapped by NCDPW (2004)
CDM

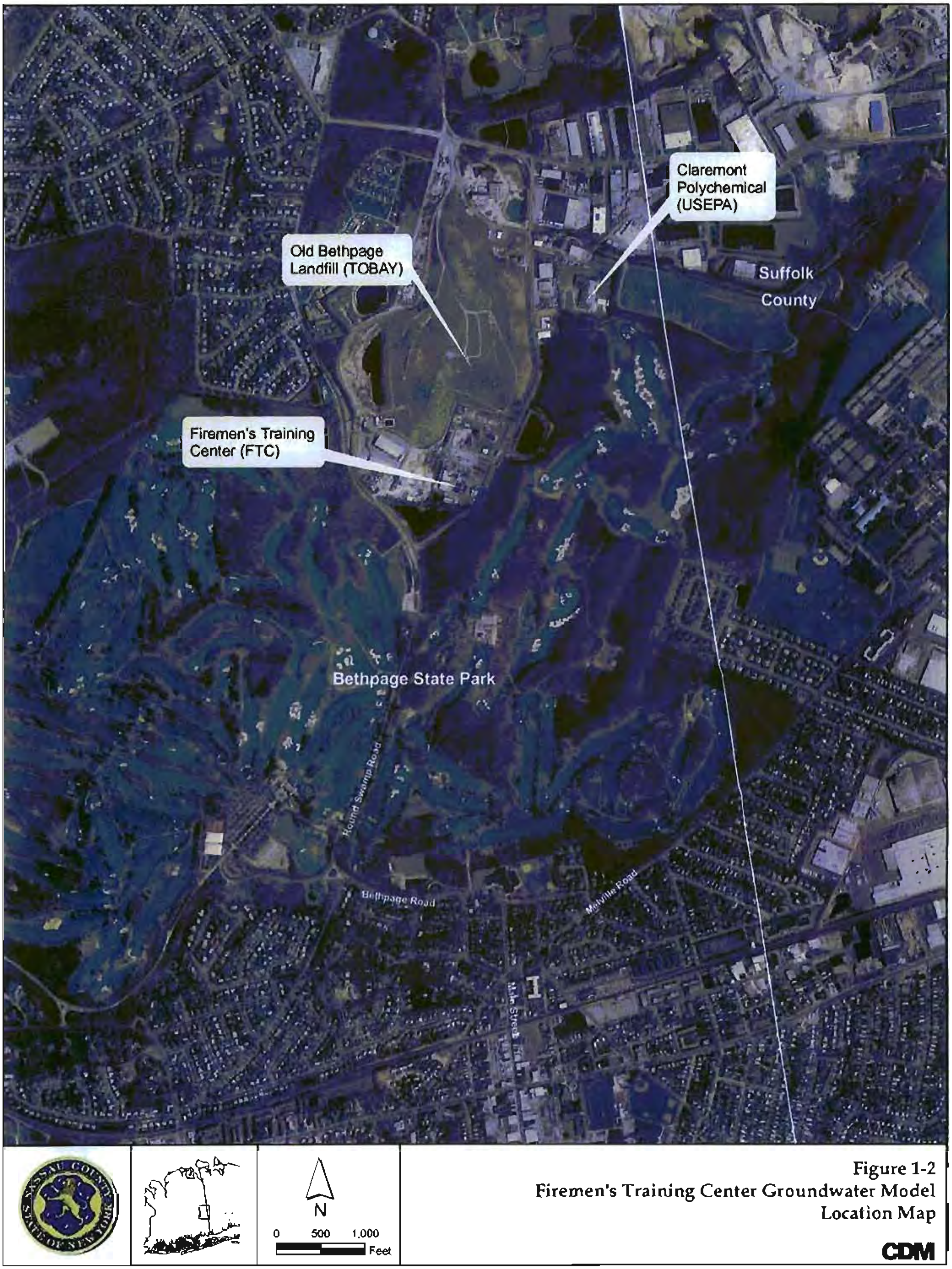


Figure 1-2
Firemen's Training Center Groundwater Model
Location Map

CDM

Section 2
Model Development

2.1 Modeling Objectives

The previous groundwater model developed in 1994 for the Firemen's Training Center focused around the site itself and areas immediately downgradient. Since one of the principal objectives of the new model was to examine the potential for existing contamination to impact public supply wells further downgradient of the site, it became necessary to expand the model grid.

The Nassau County regional groundwater model was recently updated as part of the Source Water Assessment Program (SWAP) for New York State (NYSDOH, 2003). For the FTC site, a new model was developed that utilized the updated Nassau County model to provide stratigraphy and flow boundaries. The new groundwater model was developed to meet the following objectives:

- Create a new grid designed specifically for simulating the FTC western plume and the eastern plume of unknown origin (Figure 1-1), including potential upgradient sources;
- Update the geology and hydrogeologic properties, based on the updated Nassau County regional model and confirm that these are consistent with the site conceptual model. Make use of more recent information provided by NCDPW from their FTC studies to further refine the stratigraphy of the model;
- Recalibrate the updated FTC model;
- Simulate the FTC plume, and compare model simulation results with recent plume mapping by NCDPW identified as the western plume;
- Perform a series of contaminant transport simulations from several potential upgradient sources;
- Perform contaminant transport simulations from various monitoring wells to determine the potential for contamination observed in the monitoring wells to impact to downgradient public supply wells owned and operated by the Village of Farmingdale.

2.2 Modeling Codes

DYNSYSTEM groundwater modeling software was utilized in this study, including DYNFLOW (single-phase groundwater flow) and DYNTRACK (solute transport).

2.2.1 DYNFLOW

DYNFLOW is a fully three-dimensional, finite element groundwater flow model. This model has been developed over the past 25 years by CDM engineering staff, and is in general use for large scale basin modeling projects and site specific remedial design investigations around the world. It has been applied to over 200 groundwater modeling studies in the United States, including a number of Long Island studies. The DYNFLOW code has been reviewed and tested by the International Groundwater Modeling Center (IGWMC) (van der Heijde 1985, 1999). The code has been extensively tested and documented by CDM.

The governing equation for three-dimensional groundwater flow that is solved by DYNFLOW is:

$$S_s \frac{\partial \phi}{\partial t} = \frac{\partial}{\partial x_i} K_{ij} \frac{\partial \phi}{\partial x_j} ; i, j = 1, 2, 3$$

where the state variable φ represents the potentiometric head [L]; K_{ij} represents the hydraulic conductivity [LT^{-1}] tensor; S_s is the specific storativity (volume/volume/length), [L^{-1}]; x_i is a Cartesian coordinate and t is time.

DYNFLOW uses a grid built with a large number of tetrahedral elements. These elements are triangular in plan view, and give a wide flexibility in grid variation over the area of study. This allows important features to be represented with a fine degree of detail. An identical grid is used for each level of the model, but the thickness of each model layer (the vertical distance between levels in the model) can vary at each point in the grid. In addition, 2-dimensional elements can be inserted into the basic 3-dimensional grid to simulate thin features such as faults. One-dimensional elements can be used to simulate the performance of wells which are perforated in several model layers.

DYNFLOW accepts various types of boundary conditions on the groundwater flow system including:

- Specified head boundaries (where the piezometric head is known, such as at rivers, lakes, ocean, or other points of known head);
- Specified flux boundaries (such as rainfall infiltration, well pumpage, and no-flow "streamline" boundaries);
- Rising water boundaries; these are hybrid boundaries (specified head or specified flux boundary) depending on the system status at any given time. Generally used at the ground surface to simulate streams, wetlands, and other areas of groundwater discharge;
- Head-dependent flux (3rd type) boundaries including "river" and "general head" boundary conditions.

2.2.2 DYNTRACK

DYNTRACK is the companion solute transport code to DYNFLOW. DYNTRACK uses the random-walk technique to solve the advection-dispersion equation. DYNTRACK has been developed over the past 20 years by CDM engineering staff. The partial differential equation describing transport of conservative solutes in a groundwater flow field is:

$$n_e \frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i} n_e D_{ij} \frac{dC}{dx_j} - q_i \frac{dC}{dx_i} \; ; i, j = 1, 2, 3$$

where C is the concentration at any x_i location, n_e is the effective porosity, q_i is the specific discharge vector, and D_{ij} is the dispersion tensor. The first term on the right hand side of the equation represents the dispersive flux as embodied by Fick's Law; the second term represents the advective flux of solute mass.

DYNTRACK uses a Langrangian approach to approximate the solution of the partial differential equation of transport. This process uses a random walk method to track a statistically significant number of particles, wherein each particle is advected with the mean velocity within a grid element and then randomly dispersed according to specified dispersion parameters.

In DYNTRACK, a solute source can be represented as an instantaneous input of solute mass (represented by a fixed number of particles), as a continuous source on which particles are input at a constant rate, or as a specified concentration at a node. The concentration within a particular zone of interest is represented by the total number of particles that are present within the zone multiplied by their associated solute mass, divided by the volume of water within the zone. DYNTRACK has also been reviewed and tested by the IGWMC (van der Heijde 1985).

2.3 Model Framework and Grid

A much more extensive and highly discretized finite element grid was developed for the updated FTC model, as computer capabilities have increased significantly over the past decade. The new finite element grid, shown in plan view by Figure 2-1, covers 76.7 square miles, extending from the position of the regional groundwater divide (northern boundary) to the coast (southern boundary). The model stretches approximately 7 miles in an east-west direction from South Oyster Bay Road in Nassau County to just east of Route 110 in Suffolk County. There are a total of 27,982 nodes defining 55,855 elements. Grid spacing is smallest at the FTC site (around the source area) and coarsens toward the model boundaries. Grid spacing around the FTC site and within the downgradient plume area ranges from 25-50 feet (Figure 2-2)

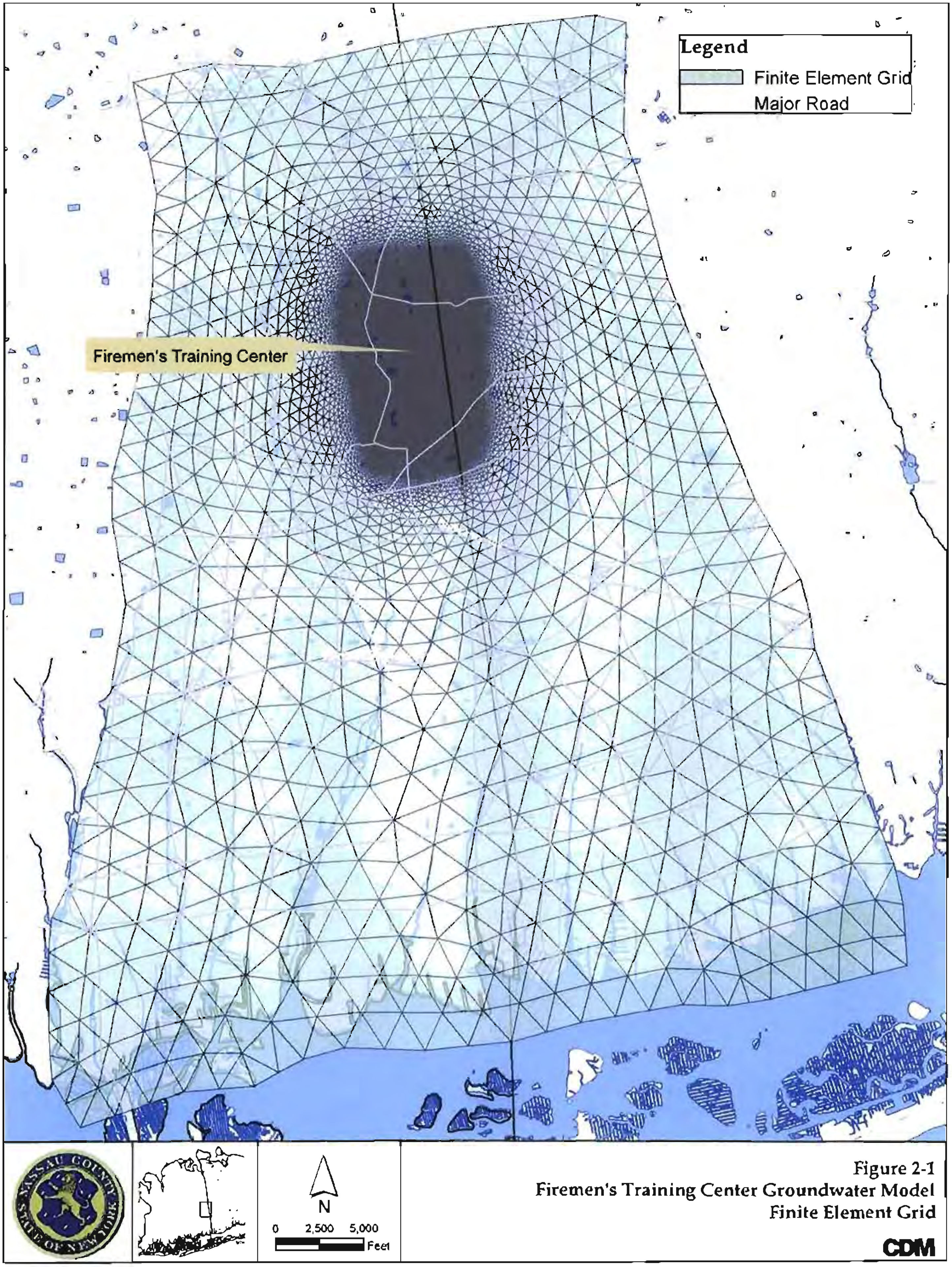


Figure 2-1
Firemen's Training Center Groundwater Model
Finite Element Grid

CDM

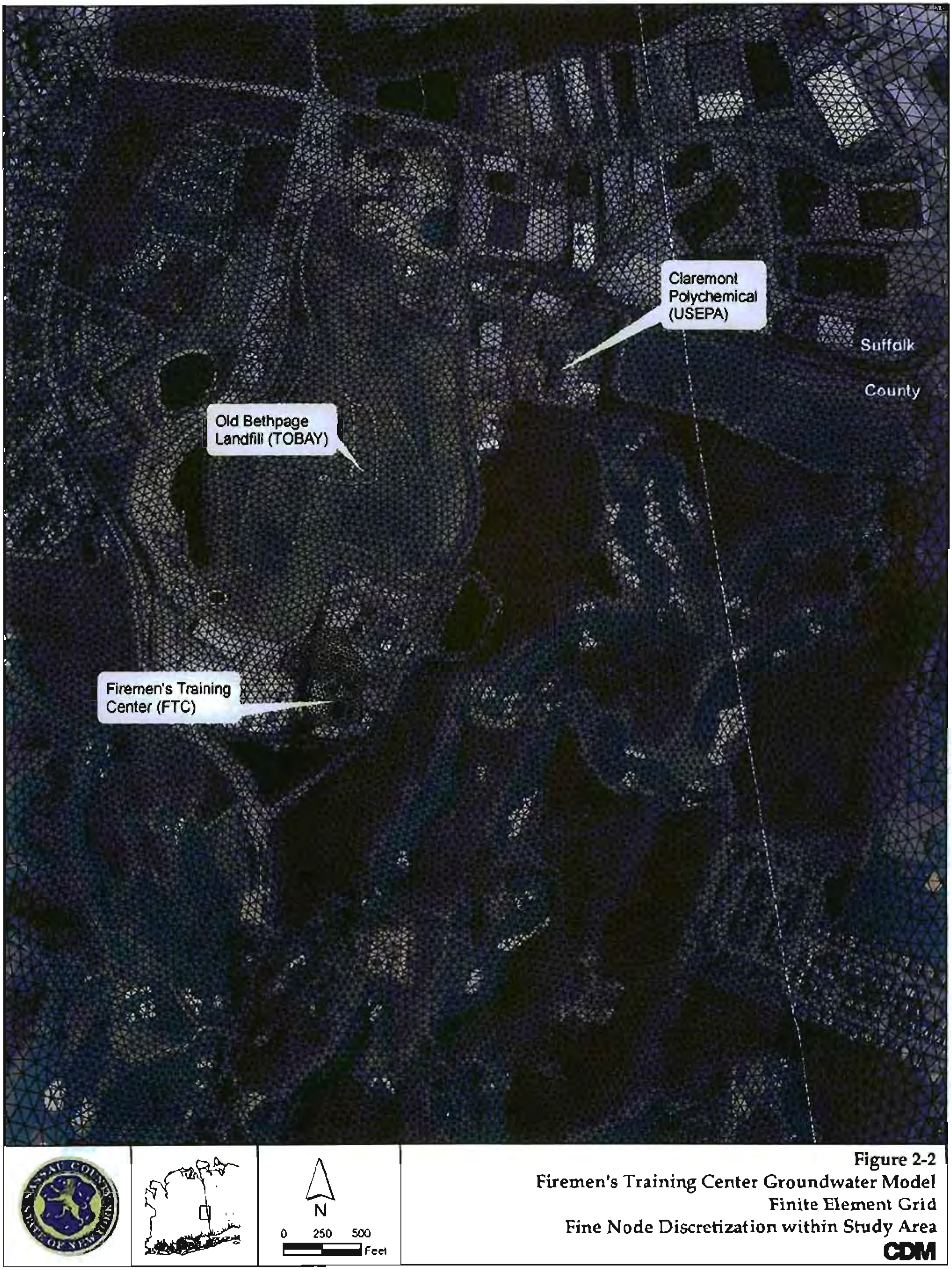


Figure 2-2
Firemen's Training Center Groundwater Model
Finite Element Grid
Fine Node Discretization within Study Area
CDM

and expands to approximately 1,000-2,000 feet at the model boundaries, outside the area of interest. The eastern and western boundaries of the grid are parallel to regional groundwater flow and represent no-flow boundaries.

Both steady-state and transient simulations were conducted for the FTC model. The model was initially calibrated under steady-state conditions using March 1992 as the calibration target (prior to any remediation activities). However, to effectively simulate contaminant transport from FTC and other potential sources, a transient model is required. Therefore, a transient model was developed simulating real-time conditions of pumping and recharge between 1950-2005. At the time the model was developed, 2006 pumpage for Nassau and Suffolk Counties was not available. The calibration was checked using Nassau County and FTC monitoring wells during the transient simulation.

2.4 Hydrogeologic Properties and Stratigraphy

The vertical extent of the model extends from ground surface through the base of the Magothy aquifer to the top of the Raritan clay. The model contains 14 levels comprising 13 layers. Layer separation was based on geologic logs and cross sections provided by Nassau County Department of Public Works from various wells throughout the model extent (Figure 2-3).

Using the new grid, the basic hydrogeologic framework was interpolated from the recently updated Nassau County regional groundwater model (CDM, 2003). The geology was further refined based on geologic logs and cross sections provided by NCDPW. The primary refinement was the addition of a grey-black lignitic clay. A north-south cross-section is shown on Figure 2-4. A brief description of the layers within the model is provided below and average hydraulic and contaminant transport properties are summarized in Table 2-1. Values listed in Table 2-1 fall within the range of Long Island aquifer properties as reported by the United States Geological Survey (USGS; Buxton and Smolensky, 1999).

2.4.1 Model Layers and Hydrogeologic Framework

Layer 13: Upper glacial outwash deposits, moderately to highly permeable, consisting of gray, brown, and yellow fine to very coarse sand and gravel. The upper level of layer 13 is level 14 and represents the topographic surface. To accurately define the topographic surface, elevations in the model were taken from elevations in the Long Island Digital Elevation Models (DEM). Long Island DEMs are available for download at: http://pbisotopes.ess.sunysb.edu/reports/dem_2/dems/.

The thickness of layer 13 ranges between 1 – 144 feet thick. The average thickness of Layer 13 is 37 feet. Horizontal hydraulic conductivity ranges between 65-250 ft/day, vertical conductivity ranges between 1-25 ft/day, and specific yield ranges from 0.15 to 0.30. Much of this layer is unsaturated within the study area.

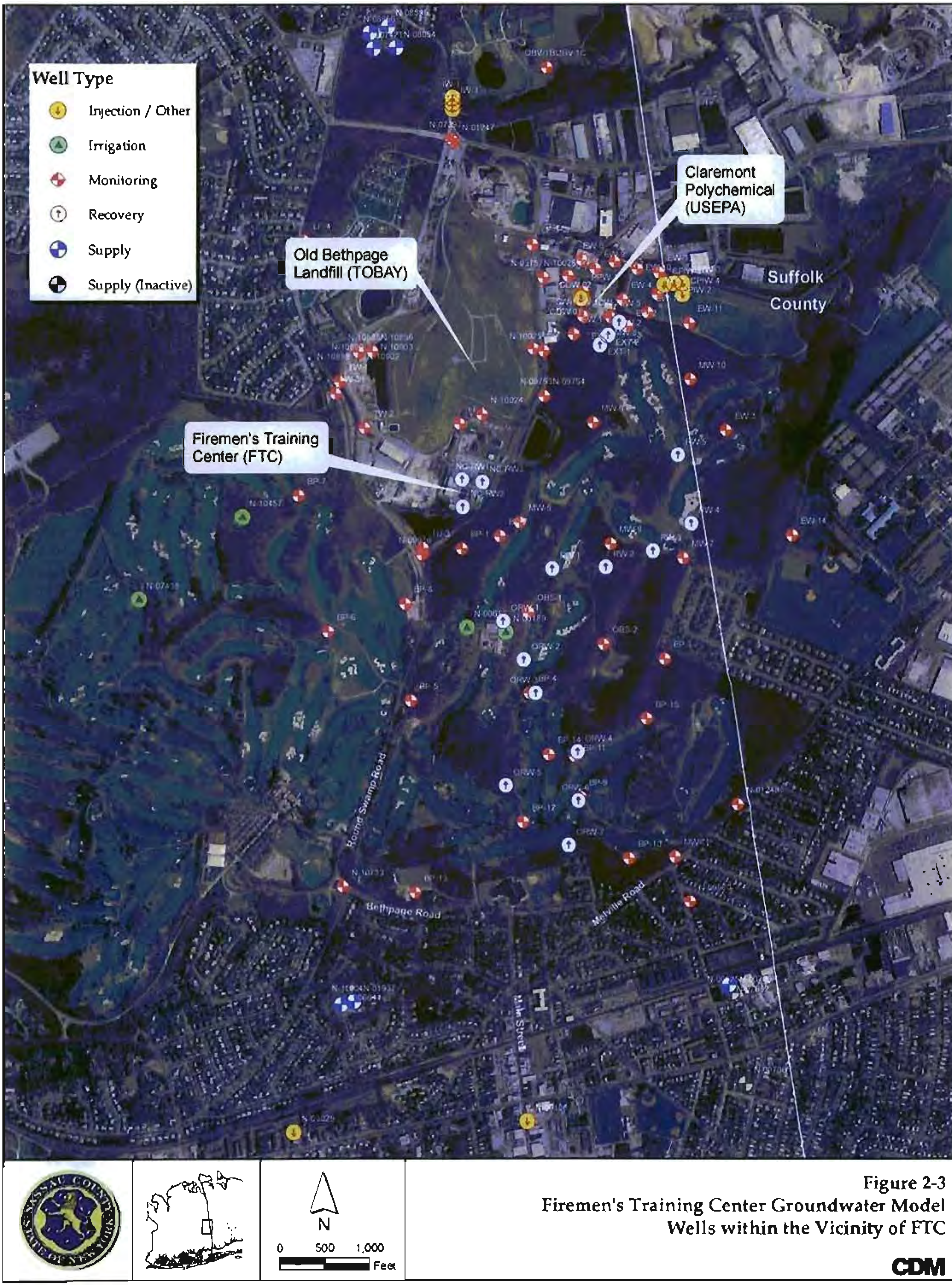


Figure 2-3
Firemen's Training Center Groundwater Model
Wells within the Vicinity of FTC

CDM

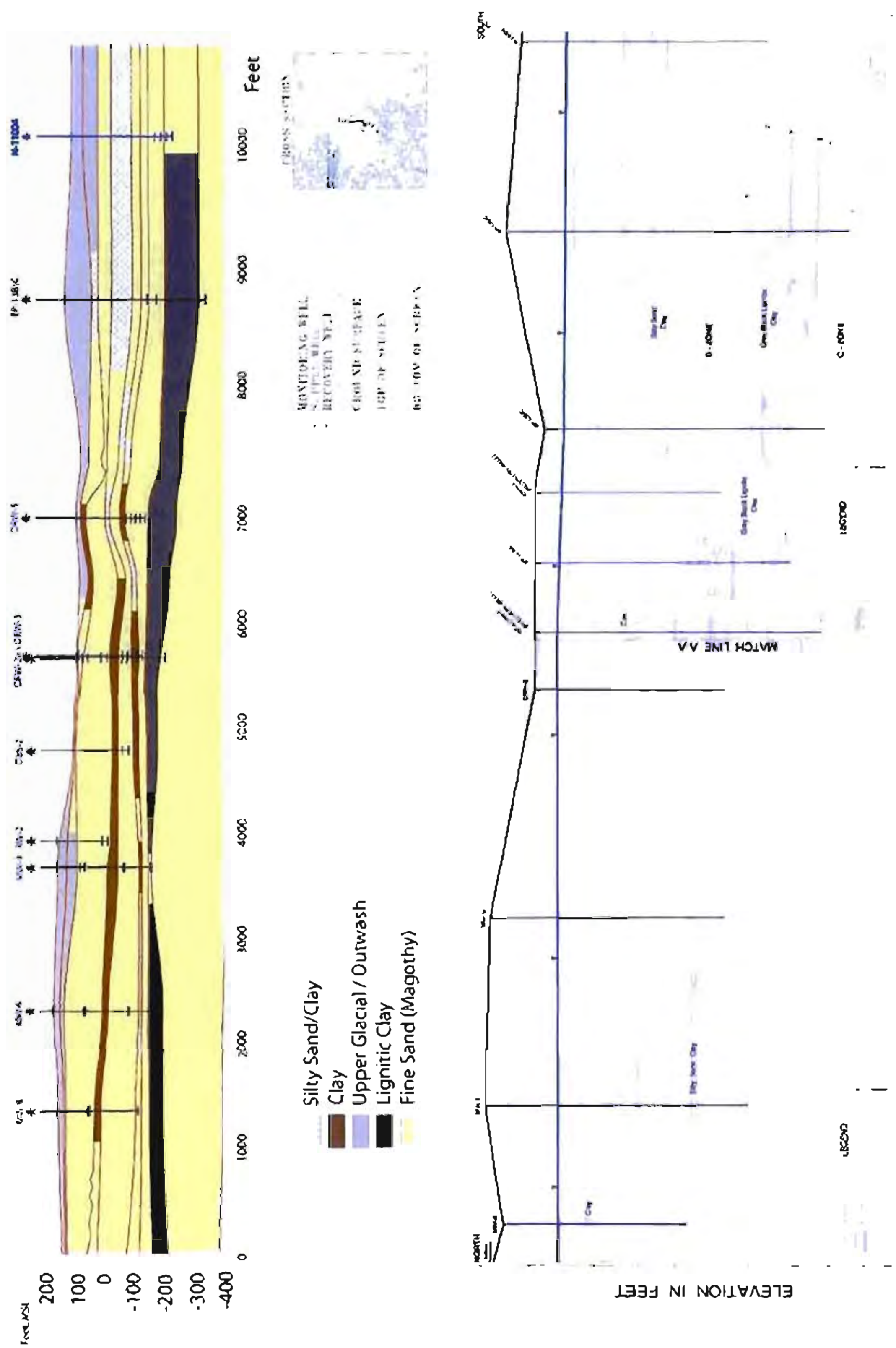


Figure 2-4 North-south cross-section. Model representation of NCDPW cross section (below).

Table 2-1
Average Hydraulic and Contaminant Transport Properties

Layer	Hydraulic Conductivity (ft/d)		Specific Yield	Storativity (1/ft)	Dispersion		Dispersion Anisotropy	Effective Porosity
	Horizontal	Vertical			Long. (ft)	Lat. (ft)		
13	228.16	22.81	0.30	0.0000013	30	3	0.10	0.24
12	225.48	22.52	0.30	0.0000013	30	3	0.10	0.24
11	192.75	18.30	0.27	0.0000013	30	3	0.10	0.22
10	37.72	0.54	0.13	0.0000013	30	3	0.10	0.14
9	41.00	0.58	0.14	0.0000013	30	3	0.10	0.14
8	52.45	0.74	0.15	0.0000013	30	3	0.10	0.15
7	54.22	0.78	0.15	0.0000013	30	3	0.10	0.15
6	54.01	0.78	0.15	0.0000013	30	3	0.10	0.15
5	46.46	0.61	0.149	0.0000013	30	3	0.10	0.15
4	48.64	0.65	0.15	0.0000013	30	3	0.10	0.15
3	48.64	0.65	0.15	0.0000013	30	3	0.10	0.15
2	113.17	1.13	0.19	0.0000013	30	3	0.10	0.24
1	112.98	1.13	0.19	0.0000013	30	3	0.10	0.24

Layer 12: Layer 12 is lithologically similar to layer 13 consisting of moderate to highly permeable upper glacial outwash deposits. The thickness of layer 12 rages between 4-75 feet thick, having an average thickness of 22 feet. Horizontal conductivity ranges between 1 - 250 ft/day, and vertical conductivity ranges between 0.5-25 ft/day. Specific yield ranges between 0.09 and 0.30. As with layer 13, much of layer 12 is unsaturated in the study area.

Layer 11: Layer 11 is composed of both upper glacial and Magothy deposits. The thickness of layer 11 ranges between 1 to 123 feet, with an average thickness of 51 feet. Horizontal conductivity ranges between 30 - 250 ft/day, and vertical conductivity ranges between 0.35-25 ft/day. Specific yield ranges between 0.15 and 0.30.

Layer 10: Primarily composed of the Magothy aquifer. The Magothy aquifer is an upward fining sequence of the Cretaceous Age Matawan Group consisting of fine to medium grained quartz sand, silt, clay, and gravel. Southern portions of layer 10 contain the northern extent of the Gardiners and 20-foot clay. The Gardiners clay is a grayish green and brown clay of Pleistocene age that extends eastward in a band along the south shore. The clay was most likely deposited during an interglacial period (Stumm, 2001).

The "20-foot" clay is a marine deposit that lies within the Pleistocene upper glacial deposits in an east-west band along southern Nassau County. The thickness of layer 10 ranges between 5 - 99 feet, having an average thickness of 33 feet. Horizontal conductivity ranges between 1 - 185 ft/day, vertical conductivity ranges between 0.01 -1.85 ft/day and specific yield ranges between 0.07 - 0.25.

Layer 9: Similar properties as layer 10. Layer 9 represents the shallow portions of the NCDPW defined "B"-hydrogeologic zone, or "B-Zone" within the FTC study area.. The "B-Zone" is the most contaminated segment of the Magothy Aquifer beneath Bethpage State Park, at an approximate elevation of 80 to 100 feet below mean sea level (msl). The thickness of layer 9 ranges between 3 - 115 feet, having an average thickness of 53 feet. Horizontal conductivity ranges between 1 - 185 ft/day, vertical conductivity ranges between 0.01 -1.85 ft/day and specific yield ranges between 0.07 - 0.25.

Layer 8: Primarily composed of the Magothy aquifer. Layer 8 is within the "B-Zone" and is generally thin within the FTC study area. The thickness of layer 8 ranges between 10 and 113 feet, with an average thickness of 46 feet. Horizontal hydraulic conductivity ranges between 1 - 65 ft/day, vertical hydraulic conductivity ranges between 0.1 - 1 ft/day, and specific yield ranges between 0.09 - 0.25.

Layer 7: Magothy aquifer with portions of clay and sandy clay. Layer 7 is also within "B-Zone" downgradient of the Firemen's Training Center, as defined by Nassau County Department of Public Works. The thickness of layer 7 ranges between 8-57 feet, having an average thickness of 32 feet. Horizontal conductivity ranges between 1 - 65 ft/day, vertical hydraulic conductivity ranges between 0.1 - 1 ft/day, and specific yield ranges between 0.09 - 0.25.

Layer 6: Similar to layer 7; Lignitic clay is present in northern portions of study area, representing shallow, thin portions of the clay that have been observed at the vicinity and immediately upgradient of the former Claremont Polychemical facility. The thickness of layer 6 ranges between 8 - 78 feet, having an average thickness of 32 feet. Hydraulic conductivity of layer 6 ranges between 0.3-65 ft/day and 0.01-1 ft/day in the horizontal and vertical directions, respectively. Specific yield ranges between 0.07-0.25.

Layer 5: Magothy aquifer with the lignitic clay layer in the vicinity of the Firemen's Training Center. The lignitic clay layer represents a major change and addition to the lithology of the Nassau County regional model. The surface of this clay (level 5) generally represents the base of the "B-Zone" in the study area. The thickness of layer 5 throughout the model domain ranges between 12-208 feet, having an average thickness of 46 feet. Horizontal conductivity ranges between 0.3 - 80 ft/day, vertical hydraulic conductivity ranges between 0.01 - 2 ft/day, and specific yield ranges between 0.07 - 0.21. The thickness of the lignitic clay unit ranges between 10 - 126 feet, averaging 93 feet.

Layer 4: Magothy aquifer - upper portion of the NCDPW defined "C"-hydrogeological zone, or "C-Zone". The "C-Zone" occurs in sediments approximately 180 to 200 feet below mean sea level. The thickness of layer 4 ranges between 5-176 feet, having an average thickness of 54 feet. Horizontal hydraulic conductivity ranges between 35 - 80 ft/day, vertical conductivity ranges between 0.35 - 2 ft/day, and specific yield of layer 4 is 0.15.

Layer 3: Identical properties to layer 4. Layers 3 and 4 were derived from a single layer in the Nassau County regional groundwater model, but were split into two layers to increase vertical discretization in the model.

Layer 2: Magothy aquifer, basal portion. The base of the Magothy is very coarse, having been deposited in a high-energy environment involving stream and deltaic deposition. The thickness of layer 2 ranges between 81-213 feet, having an average thickness of 190 feet. Horizontal hydraulic conductivity ranges between 50 - 125 ft/day, vertical conductivity ranges between 0.5 - 1.25 ft/day, and specific yield ranges between 0.17 - 0.20.

Layer 1: Similar to layer 2, composed of the basal portion of the Magothy aquifer. The thickness of layer 1 ranges between 96-312 feet, having an average thickness of 190 feet. Below layer 1 is the top of the Raritan clay, which for the purposes of this model is considered impermeable. Horizontal hydraulic conductivity of layer 1 ranges between 50 - 125 ft/day, vertical conductivity ranges between 0.5 - 1.25 ft/day, and specific yield ranges between 0.17 - 0.20.

2.4.2 Contaminant Zones

Based upon numerous water quality analyses evaluated during hydrogeologic investigations conducted by NCDPW, the underlying lithology has been categorized into three zones each increasing with depth: 1) the "A-Zone"; 2) "B-Zone"; and 3) "C-Zone". The A-hydrogeological zone or "A-Zone" begins at the water table and extends to approximately 85 feet below sea level (approx. 185 feet below grade) where the B-Zone begins. The B-Zone extends to approximately 150 feet below mean sea level (approx. 250-260 feet below grade). In many areas, the top of the lignitic clay defines the base of the B-Zone. The C-Zone extends from the base of the B-Zone to areas below the lignitic clay.

The well construction and hydrogeologic zone designations for all County-owned off-site monitoring wells can be found in the following table (Table 2-2).

NCDPW and the NYSDEC have determined that the volatile organic contamination from the FTC site is within the B-Zone and therefore offsite extraction wells were screened within this zone. Routine groundwater sampling conducted by the County also supports much higher contaminant concentrations in the B-Zone than either the A or C-Zones. Water quality in the C-Zone has historically been very good in which contamination was only detected in one County-owned monitoring well, BP-4C. This well has shown some contamination during the initial offsite investigation in 1992. Recent sampling of County-owned wells has revealed contamination within the C-Zone at monitoring wells BP-3C and BP-10C. Contamination at these locations is not from an FTC source as BP-10C is very deep and beneath the low permeability lignitic

Table 2-2
NCDPW Off-Site Monitoring Well Construction Details

Monitoring Well	MP Elevation (Feet Above Mean Sea Level)	Date Installed	Method Of Drilling	Screen Interval (Feet Below Ground Surface) Top Of Screen	Bottom Of Screen	Casing	Screen
W-39	114.50	05/08/90	Auger	41	60	Black Steel	Stainless Steel
BP-3A	124.54	08/15/90	Auger	54	74	Black Steel	Stainless Steel
BP-3B	123.57	07/19/90	Modified Mud/Water Rotary	215	235	Stainless Steel	Stainless Steel
BP-3C	123.68	07/26/90	Modified Mud/Water Rotary	280	300	Stainless Steel	Stainless Steel
BP-4A	92.69	08/20/90	Auger	19	39	Black Steel	Stainless Steel
BP-4B	91.72	08/29/90	Modified Mud/Water Rotary	170	190	Stainless Steel	Stainless Steel
BP-4C	91.67	08/30/90	Modified Mud/Water Rotary	280	300	Stainless Steel	Stainless Steel
BP-4I	92.10	04/12/94	Modified Mud/Water Rotary	82	102	PVC	Stainless Steel
BP-5A	96.34	09/26/90	Auger	29	49	Black Steel	Stainless Steel
BP-5B	96.58	09/24/90	Modified Mud/Water Rotary	180	200	Stainless Steel	Stainless Steel
BP-5C	96.28	09/25/90	Modified Mud/Water Rotary	250	270	Stainless Steel	Stainless Steel
BP-6A	102.55	09/28/90	Auger	24	44	Black Steel	Stainless Steel
BP-6B	102.58	08/16/90	Modified Mud/Water Rotary	180	200	Stainless Steel	Stainless Steel
BP-6C	102.35	08/20/90	Modified Mud/Water Rotary	256	276	Stainless Steel	Stainless Steel
BP-7A	148.35	10/03/90	Auger	75	95	Black Steel	Stainless Steel
BP-7B	147.90	09/12/90	Modified Mud/Water Rotary	228	248	Stainless Steel	Stainless Steel
BP-7C	148.40	09/13/90	Modified Mud/Water Rotary	310	330	Stainless Steel	Stainless Steel
BP-8A	92.29	08/16/90	Auger	20	40	Black Steel	Stainless Steel
BP-8B	91.43	08/06/90	Modified Mud/Water Rotary	130	150	Stainless Steel	Stainless Steel
BP-8C	91.48	08/08/90	Modified Mud/Water Rotary	260	280	Stainless Steel	Stainless Steel
BP-9I	85.18	04/15/94	Auger	84	104	PVC	Stainless Steel
BP-9B	85.09	12/19/91	Modified Mud/Water Rotary	184	204	Black Steel	Stainless Steel
BP-9C	84.88	12/22/91	Modified Mud/Water Rotary	322	342	Black Steel	Stainless Steel
BP-10B	81.21	02/16/92	Modified Mud/Water Rotary	210	230	PVC	Stainless Steel
BP-10C	80.94	02/10/92	Modified Mud/Water Rotary	360	380	PVC	Stainless Steel
BP-11	81.76	04/22/94	Auger	78	98	Black Steel	Stainless Steel
BP-12A	78.33	04/19/94	Auger	69	89	PVC	Stainless Steel
BP-12B	78.24	08/10/96	Mud/Water Rotary	181	201	Black Steel	Stainless Steel
BP-12C	78.56	12/16/99	Mud/Water Rotary	370	390	PVC	Stainless Steel
BP-13B	133.37	11/13/00	Mud/Water Rotary	280	310	PVC	Stainless Steel
BP-13C	133.67	01/07/00	Mud/Water Rotary	455	475	PVC	Stainless Steel
BP-14B	81.50	12/18/01	Mud/Water Rotary	200	240	PVC	Stainless Steel
BP-14C	81.48	12/13/01	Mud/Water Rotary	310	350	PVC	Stainless Steel
BP-15B	98.38	10/12/05	Mud Rotary	210	230	PVC	Stainless Steel
BP-15C	98.45	10/06/05	Mud Rotary	255	295	PVC	Stainless Steel
OBV-1B	157.26	09/01/05	Mud Rotary	168	188	PVC	Stainless Steel
OBV-1C	156.69	08/23/05	Mud Rotary	255	275	PVC	Stainless Steel

clay unit and BP-3C is well east of the defined limits of contamination originating from FTC. This is addressed in more detail in Section 3 of this report.

2.5 Boundary Conditions

Two general types of boundary conditions are represented by the model: specified head boundary conditions and specified flow boundary conditions. Fixed, or specified head boundary conditions are applied to locations where water levels or heads remain constant. Specified flow boundary conditions are used to describe groundwater pumping, recharge and impermeable boundaries (e.g., no flow boundaries).

2.5.1 Top and Bottom of the Model

The boundary at the top of the model is the phreatic surface, representing a rising water boundary condition, whereby the water table can freely move up and down in response to pumping and/or recharge. Intersection of the water table with the surface results in discharge from the groundwater system to stream baseflow. Massapequa

Creek and Amityville Creek are represented as a series of invoked rising nodes, or nodes in which the water table intersects the surface. The model is a saturated model and does not account for unsaturated flow.

The bottom of the model is the Raritan clay. For the purposes of this model, it is assumed that the Raritan clay acts as a no-flow boundary. Although some leakage through the Raritan clay occurs, leakage has a minimal effect on the flow field of the Magothy aquifer in this area of Nassau County and does not affect the results of contaminant transport simulations.

2.5.2 Fixed Head and No-Flow Boundary Assignments

The northern and southern boundaries of the model were set as no-flow and fixed head boundaries, respectively. Fixed heads in the southern portion of the model were set at 0.5 feet, representing mean sea level. These nodes were fixed at 0.5 feet as opposed to 0.0 feet to represent the rise in sea level since 1929 (the year upon which vertical datum is based). The northern boundary extends to the groundwater divide and a no-flow boundary was assigned.

The model grid was designed so that eastern and western boundaries of the model were perpendicular to long-term average head contours, and therefore parallel with regional groundwater flow. Therefore, the eastern and western boundaries of the model are set as no flow boundaries. No-flow boundaries were set from long-term average head contours that were simulated from running the regional Nassau County groundwater model under conditions of long-term average recharge and pumping.

2.5.3 Pumping

2.5.3.1 Water Supply

There are 10 community public water suppliers within the model grid (Table 2-3). For the purposes of the March 1992 steady-state calibration, winter pumping rates (1993-1994) were used. Winter pumping rates were used successfully when calibrating to March calibration targets in both the Nassau County and Suffolk County regional models. Total groundwater withdrawal from the Nassau County public supply wells within the model using winter pumping rates (October 1993 through March 1994, in this instance) averaged approximately 20.7 million gallons per day (mgd).

Winter-time water supply pumping from Suffolk County Water Authority, East Farmingdale, and South Huntington Water Districts in Suffolk County was also incorporated into the model. Water supply pumping in the modeled portion of Suffolk County averaged nearly 11.3 mgd. The locations of public supply wells within the model are shown on Figure 2-5. There are 157 supply wells within the model grid.

The transient model simulation utilizes monthly pumpage data from the water suppliers within the model grid. Water supply pumping rates were obtained from Nassau County Department of Public Works, Suffolk County Water Authority, East

Table 2-3
Community Public Water Suppliers in Groundwater Model

Nassau County
Bethpage Water District
Farmingdale Village
Levittown
Massapequa Water District
New York Water Service Corp.
Plainview Water District
South Farmingdale Water District
Suffolk County
East Farmingdale Water District
South Huntington Water District
Suffolk County Water Authority

Farmingdale, and South Huntington Water Districts between 1950-2005. As the transient model ran using monthly time steps, average daily pumping rates (CFD) were incorporated using the monthly data that were provided. Supply wells that were active between 1950 and 2005 are simulated. Additional well location data for wells placed online post-2005 and pumping data post-2005 were unavailable at the time of model development.

2.5.3.2 *Irrigation*
Since the 1930s, Bethpage State Park has irrigated the five golf courses on the grounds regularly throughout the spring and summer months. Two irrigation wells are directly downgradient of the FTC site and were in operation between the 1930s through 1981 when they were shut down due to volatile organic contamination. In the late-1970s, a third irrigation well was added, N-07438, and a fourth well was later added and placed online in 1988 (N-10457). These two irrigation wells remain in operation today. Well locations are shown on Figure 2-3.

Irrigation pumpage data were collected from NCDPW and the New York State Department of Environmental Conservation (NYSDEC). Only sparse data were available, however, particularly for the older wells, N-00189 and N-00617. Therefore, the data collected were assumed to be representative of long-term averages and assigned throughout the years of operation.

2.5.3.3 *Pumpage from Recovery Wells*
The steady-state calibration was run prior to any pumpage from recovery wells operating for FTC, Old Bethpage Landfill, and Claremont Polychemical, Inc. Pumpage data and operational history were obtained through NCDPW as well as any available literature (USEPA, 2002) and incorporated into the transient simulation. Water that was removed from recovery wells was either re-injected through diffusion wells (Claremont, FTC), or returned to recharge basins (TOBAY, FTC; Figure 2-6). For

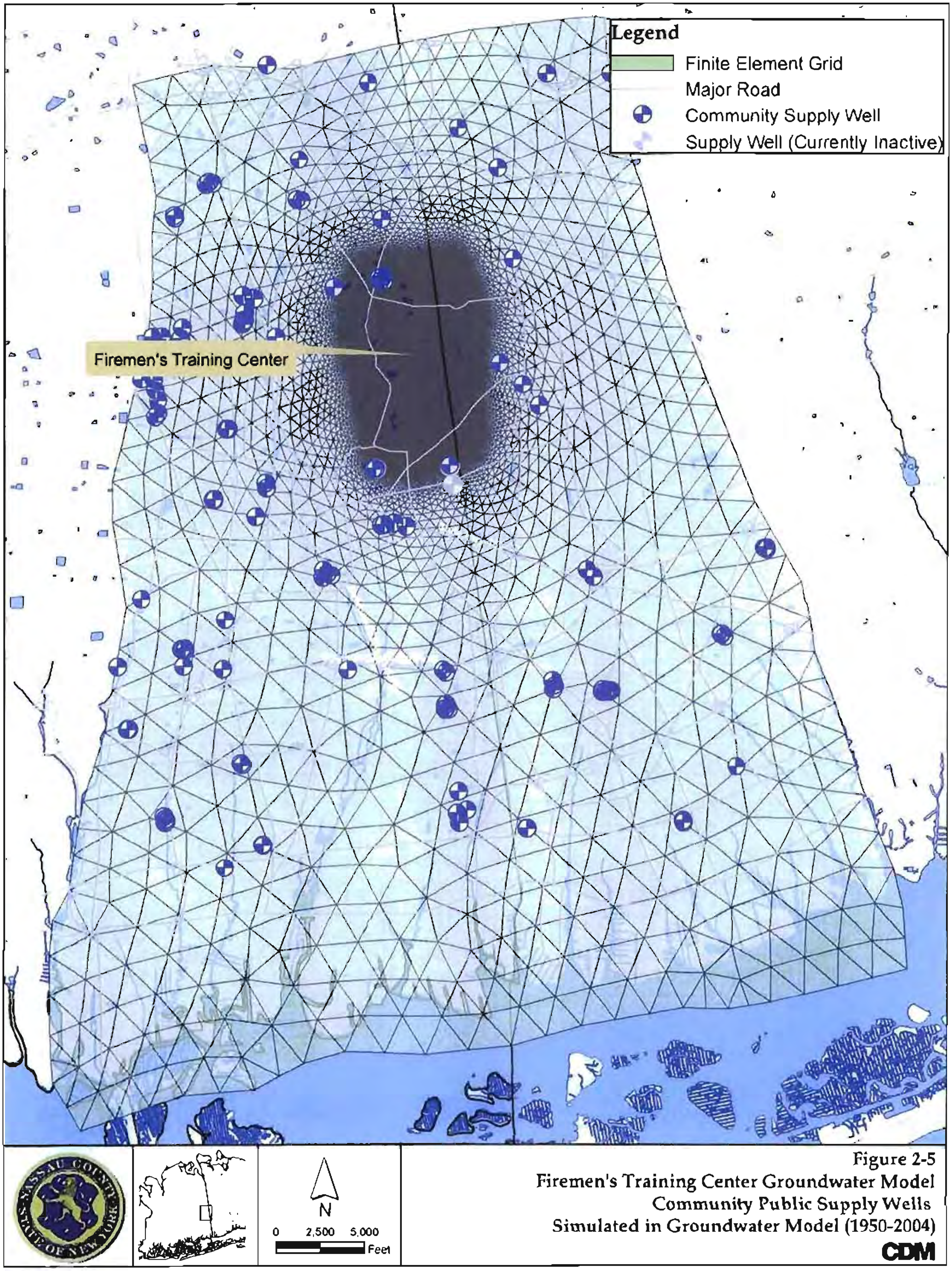


Figure 2-5
Firemen's Training Center Groundwater Model
Community Public Supply Wells
Simulated in Groundwater Model (1950-2004)

CDM

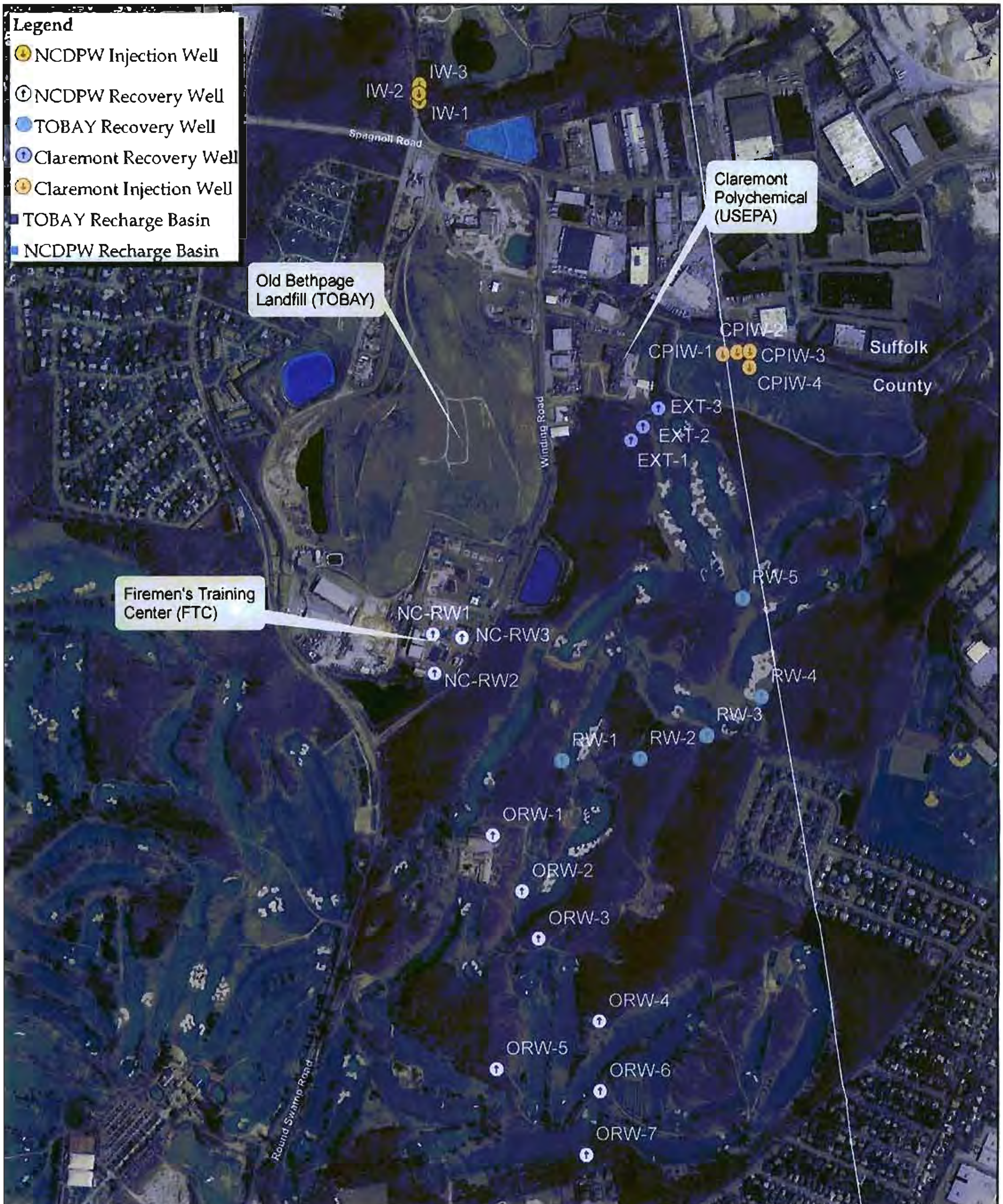


Figure 2-6
Firemen's Training Center Groundwater Model
Groundwater Remediation Systems
FTC, Old Bethpage Landfill, and Claremont Polychemical
CDM

FTC, 200 gpm was allowed to be returned to the recharge basin and the remainder was injected uniformly into the three injection wells. TOBAY pumping (and recharge) began in April 1992; FTC and Claremont Polychemical pumping began in July 1999.

2.5.4 Recharge Assignments

Recharge was applied in the model to represent the inflow of water from three different sources: precipitation, septic tanks (in unsewered areas), and leakage from water supply lines and sewers.

2.5.4.1 Recharge from Precipitation

Recharge from precipitation was calculated based on precipitation records from the Mineola station. The Mineola station is centrally located in Nassau County, has a long period of record, and has shown to be highly correlated to other Nassau County stations. The reported precipitation values from the Mineola station were increased by 12.5 percent to account for wind undercatch (CDM, 1990). Missing data were filled in with data collected from JFK International Airport (http://www.weatherunderground.com).

Recharge from precipitation was applied to the modeled area differently based on season and the distribution of recharge basins (recharge areas) and locations where stormwater is diverted to streams (runoff areas). In areas served by recharge basins (in Nassau County), 80 - 90 percent of the precipitation falling during the seven month non-growing season (October through April) was applied as recharge to the groundwater system. Areas in Nassau County having a high density of recharge basins returned up to 90 percent of precipitation as recharge (during the non-growing season), as it is assumed that a higher volume of stormwater will be captured by recharge basins.

During the growing season, in areas served by recharge basins, a much lower percentage (generally 15-25%) was applied as recharge, since the majority of precipitation is lost to evapotranspiration. However, a higher percentage of precipitation was returned if a particular month had a relatively high amount of precipitation and the majority of that precipitation fell during one or two storm events.

In areas of Suffolk County served by recharge basins, 80 percent of precipitation during the non-growing season and 15 percent of precipitation during the growing season was returned as recharge. These percentages were the same as those used for recharge basin areas in Nassau County.

In areas where stormwater discharges directly to surface water, a significantly lower amount of precipitation was returned as recharge. During the five month growing season, all precipitation was assumed to be lost to evapotranspiration, or collected by storm sewers and discharged to the bays and Long Island Sound. In the non-growing season, 80 percent of precipitation was assumed to be available for recharge, however, some of the precipitation was assumed to be collected as stormwater runoff and discharged directly to the surrounding area. As used and documented in the Nassau County regional groundwater model (CDM, 1990, 2003), a runoff coefficient of 18.2% for the Massapequa Creek drainage area was applied. This coefficient has also been applied by the USGS for the Massapequa Creek recharge area (Ku et al, 1992).

Considering the model as a whole, the average of recharge from precipitation for the entire transient simulation (1950-2004) was 24.5 inches, or 49.3% of the long term average annual precipitation measured at the Mineola precipitation station (corrected for undercatch). This compares favorably to previous studies that estimated recharge from precipitation to be approximately 50 percent, on an average annual basis.

2.5.4.2 Recharge from Septic Tanks and Leaky Water and Sewer Lines

In areas served by septic tanks (unsewered areas), 85 percent of water supply pumping was returned as recharge to the groundwater system. Although areas of Nassau County within the model grid are now completely sewered, sewering did not begin in these areas until approximately 1970. In addition, most areas outside the Southwest Sewer District (SWSD) in Suffolk County remain unsewered. The onset of sewering was captured for each area in Nassau and Suffolk Counties using dates of sewer completion obtained by NCDPW. In general, sewering within the model grid occurred between 1970-1985. In sewered areas of Nassau and Suffolk Counties, 10 percent of water supply pumping was returned to the groundwater system to reflect leakage of sanitary sewers.

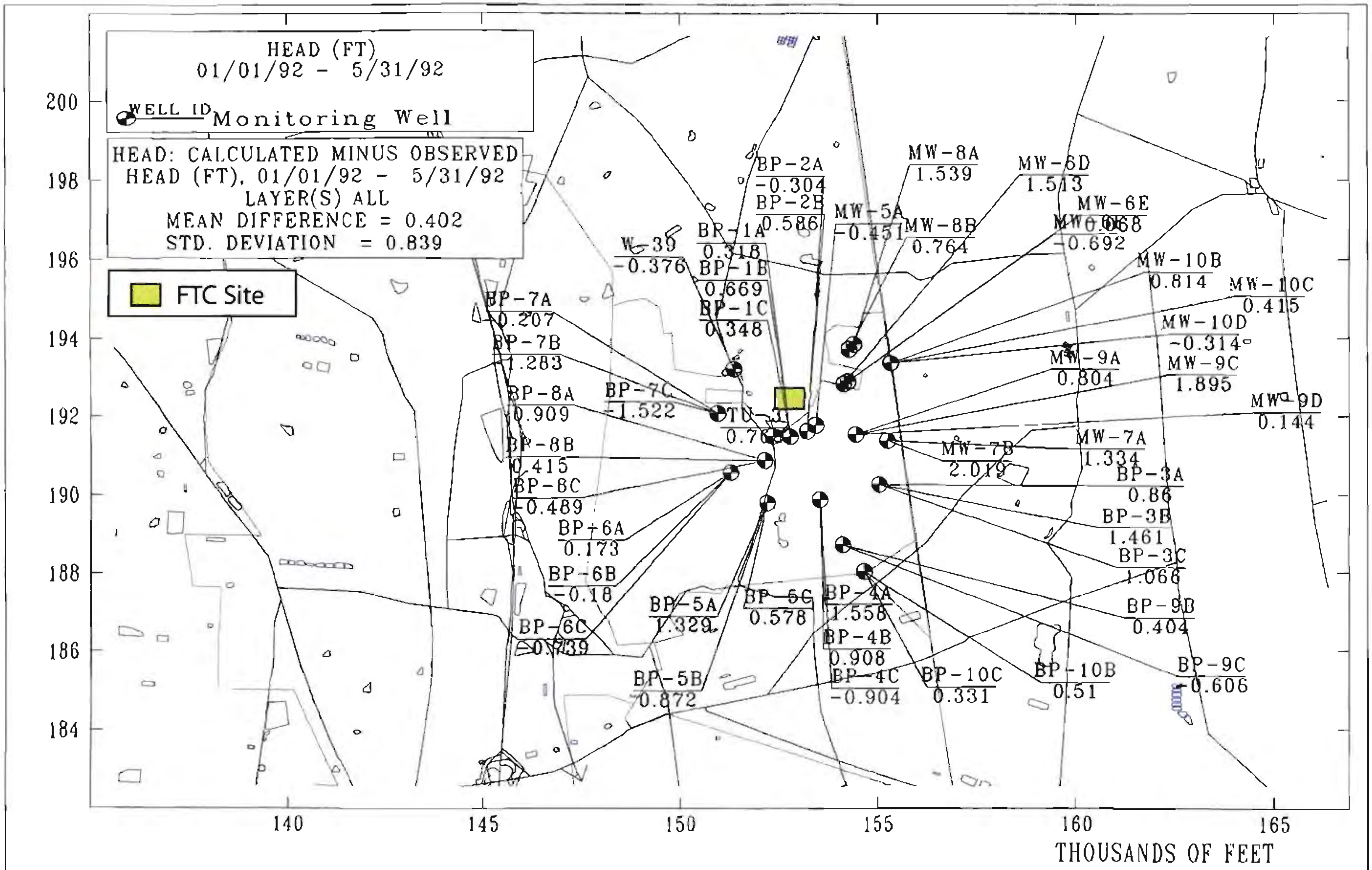
Recharge from septic tanks and leaky water and sewer lines were returned on a nodal basis, as an evenly distributed source of water. Within the boundaries of each water supplier, the number of nodes was totaled, and the percentage of pumpage to return was calculated. The returned pumpage was then divided by the number of nodes, and evenly distributed to each node within the water supplier's boundary. If a water supplier's boundary covered both sewered and non-sewered areas, it was sub-divided accordingly.

2.6 Model Calibration

The FTC groundwater model was calibrated under steady-state conditions to potentiometric heads measured in February 1992, representing baseline conditions prior to start-up of the nearby remediation system for the Town of Oyster Bay Landfill. The model calibration was further tested by comparing observed vs. simulated heads running a transient simulation from 1950-2005.

2.6.1 Steady-State 1992 Conditions

The steady-state calibration to 1992 conditions can be seen in Figure 2-7. Water level observations from 40 monitoring wells within the vicinity of FTC were used for model calibration. The simulated water table and potentiometric surface in the B-Zone is shown on Figures 2-8 and 2-9, respectively.



CDM

Firemen's Training Center Groundwater Model
Model Calibration Statistics - February 1992
Off-Site Monitoring Wells

Figure 2-7

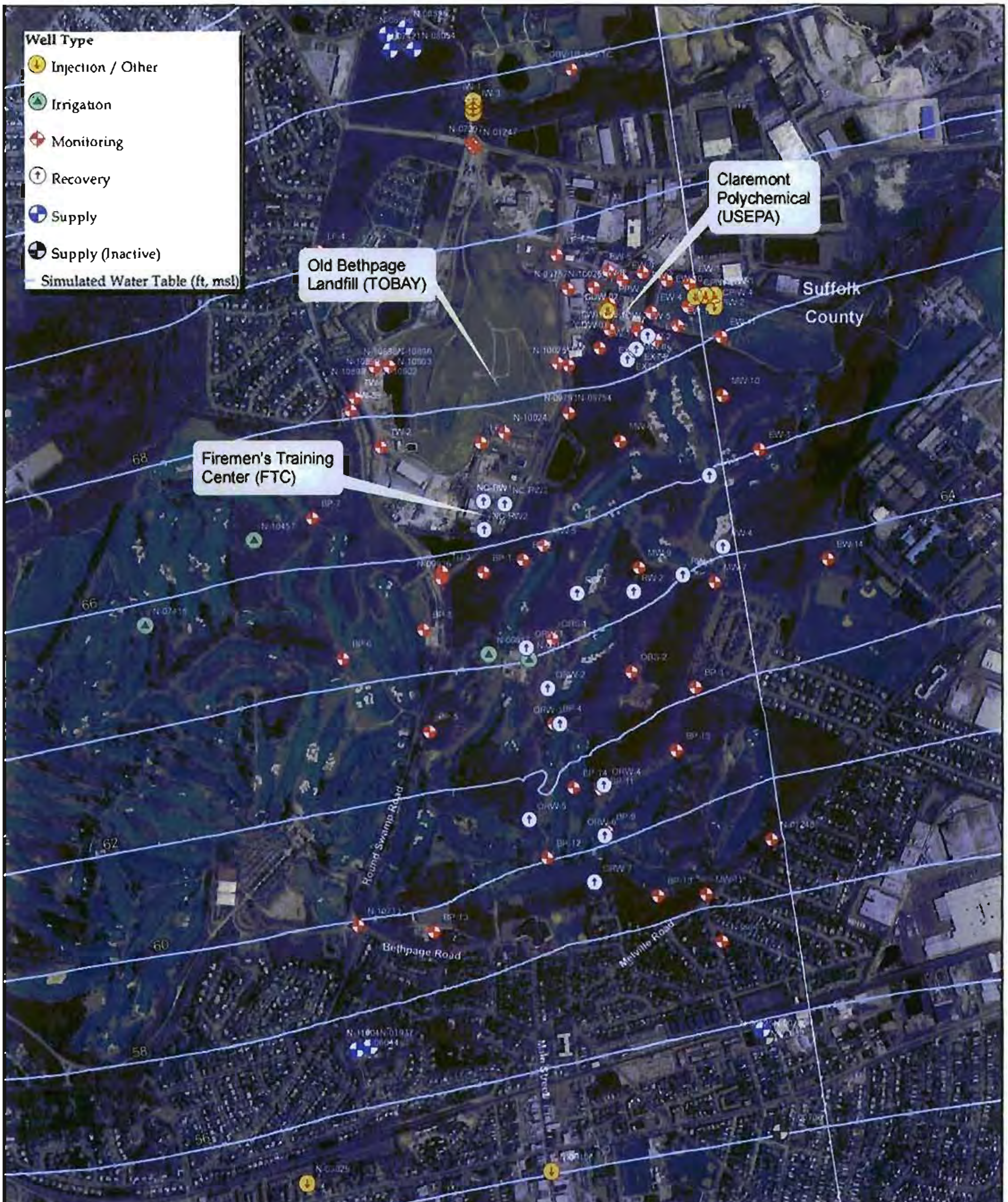


Figure 2-8
Firemen's Training Center Groundwater Model
Simulated Water Table
March 1992 Steady-State Simulation

CDM

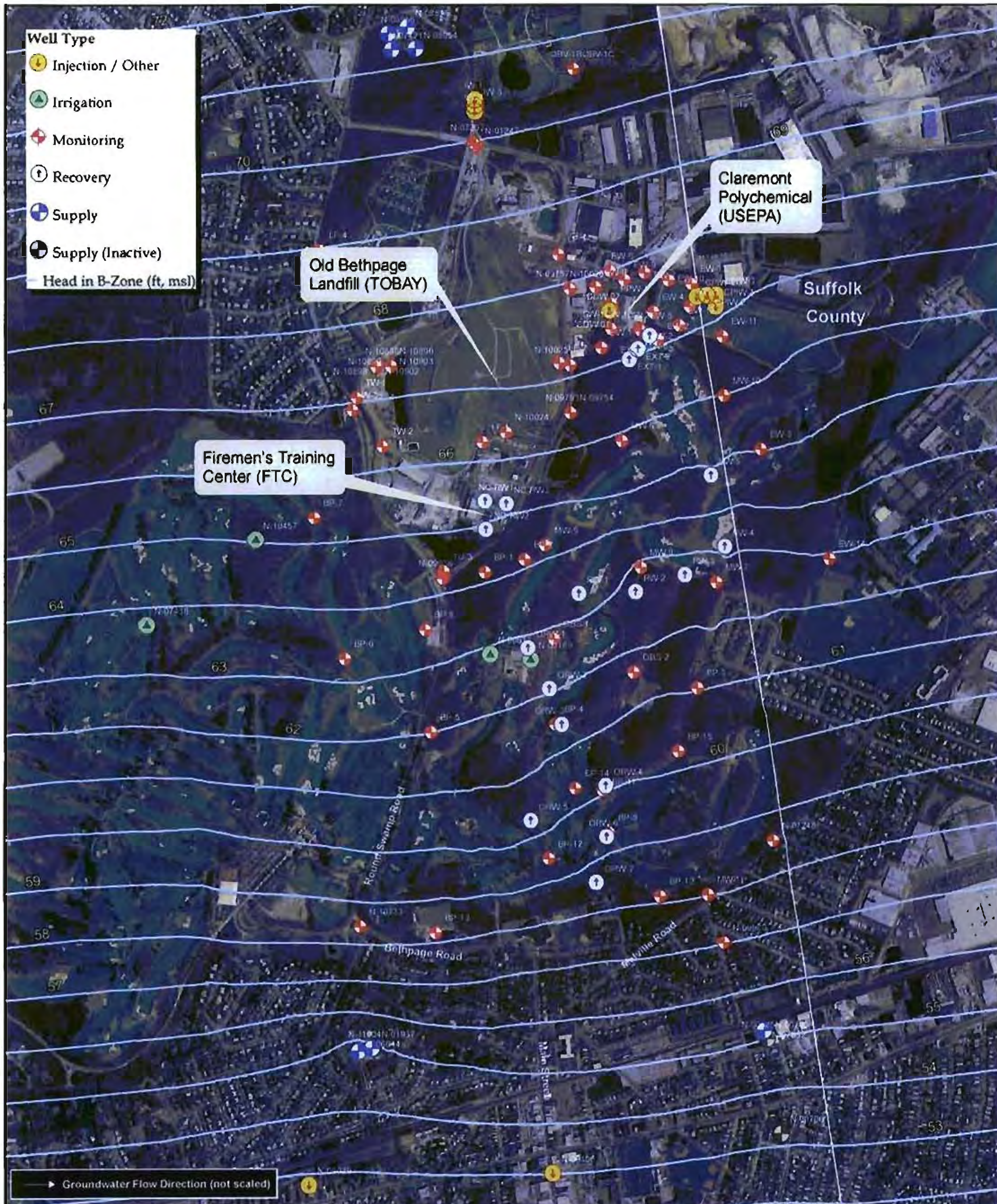


Figure 2-9
Firemen's Training Center Groundwater Model
Simulated Head in B-Zone
March 1992 Steady-State Simulation

CDM

The difference between observed and simulated groundwater heads is shown on Figure 2-7. The mean difference between observed and simulated head was 0.402 feet, with a standard deviation of 0.839 feet. Within the area of calibration, the normalized root mean square (NRMS) error is 3.81%, well below what is considered an acceptable calibration (<10%). The model calibration was also checked on a more regional scale, using Nassau and Suffolk County monitoring wells that are routinely monitored an a quarterly basis. Using March 1992 water level data for County wells within the model, the mean difference between simulated and observed heads was 0.78 feet, with a standard deviation of 2.21 feet. This corresponds to a NRMS of 2.7% throughout the model.

2.6.2 Transient Conditions - Calibration Check

To see how well the model reproduces groundwater heads through time, various simulations were saved during the transient run and compared to observed heads. Statistics are summarized in Table 2-4. From the transient simulation, the model was able to reproduce the baseline calibration (Feb/March 1992), both on a local and regional scale, as well as groundwater heads at various time periods within acceptable error (NRMS all well below 10%). Simulated water table elevation and groundwater head contours in the B-Zone are shown on Figures 2-10 and 2-11, respectively for April 2003, illustrating the impact of the recovery systems (compare to Figures 2-8 and 2-9). Note the groundwater mounding at the TOBAY recharge basins as a result of pumpage return. Simulated and observed heads throughout the calibration period for Nassau County monitoring wells within the vicinity of the study area are shown on Figure 2-12.

Table 2-4
Statistics for Calibration Check

Time Period	Calculated Head - Observed Head (ft)		NRMS Error
	Average	Std. Deviation	
Feb/March 1992	-0.436	0.834	3.79%
March 1992[1]	0.548	2.285	2.82%
April 2003	-0.650	1.005	4.57%

[1]FTC Regional model target (Nassau and Suffolk County monitoring wells)

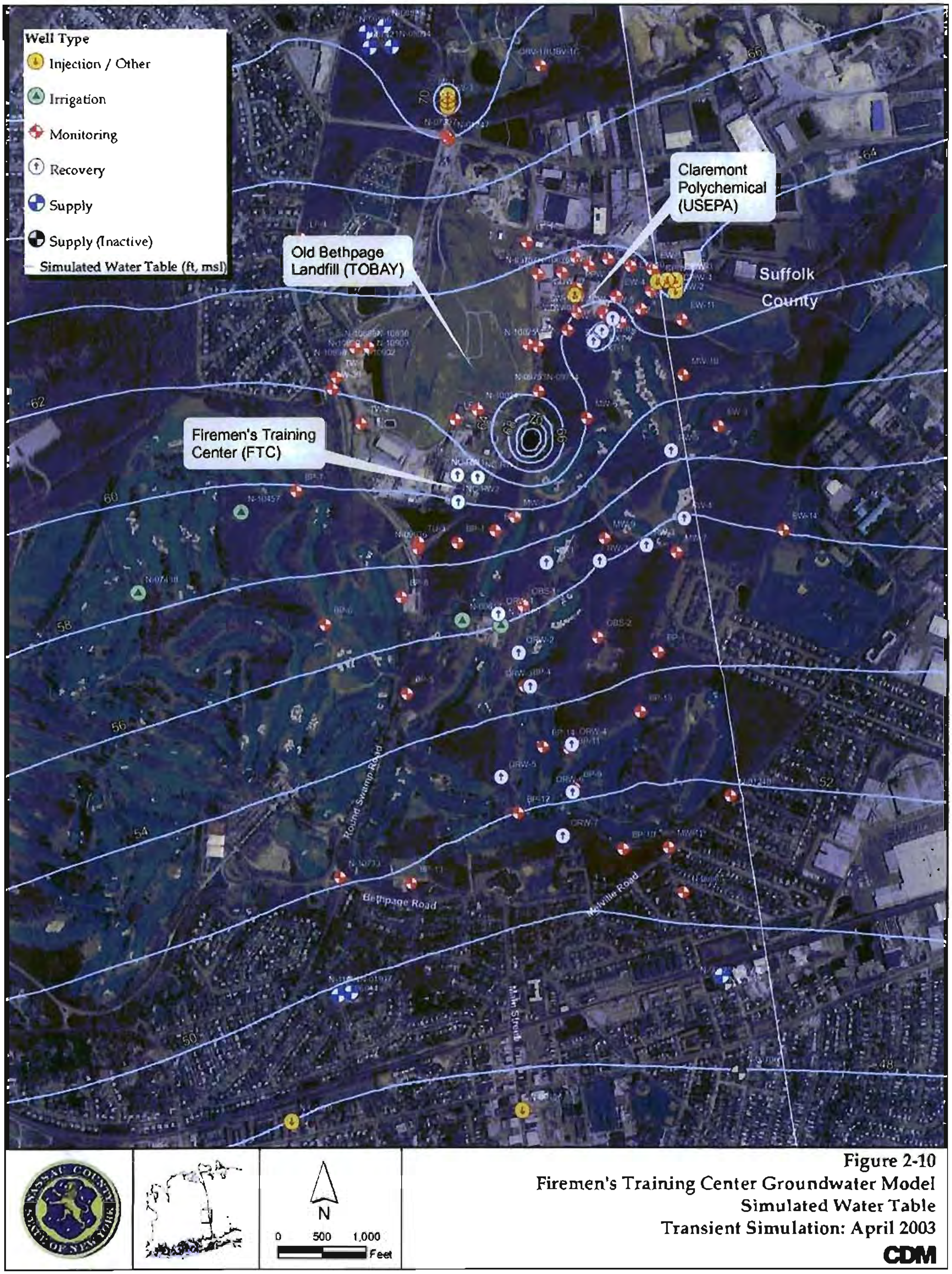


Figure 2-10
Firemen's Training Center Groundwater Model
Simulated Water Table
Transient Simulation: April 2003
CDM

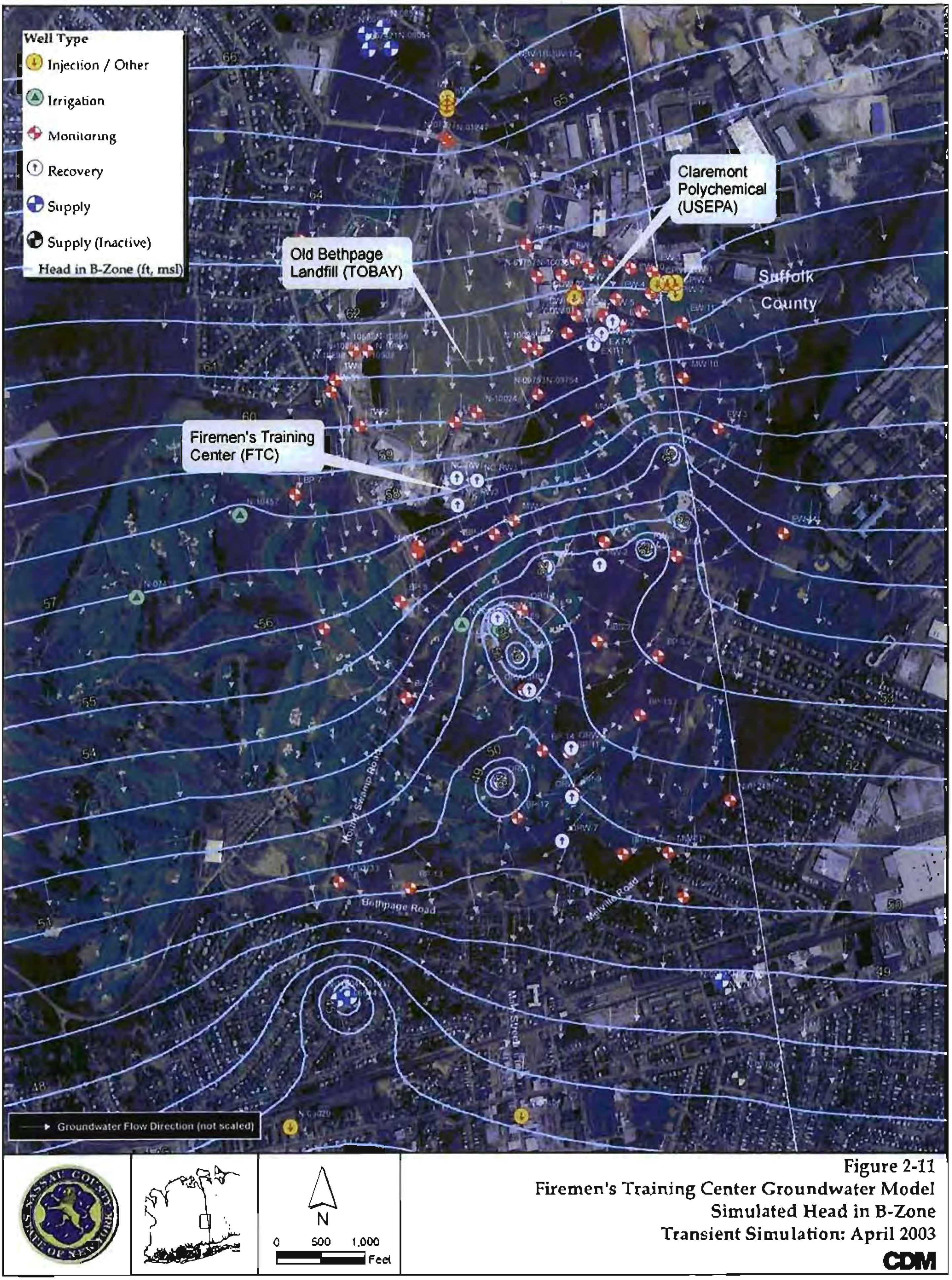


Figure 2-11
Firemen's Training Center Groundwater Model
Simulated Head in B-Zone
Transient Simulation: April 2003
CDM

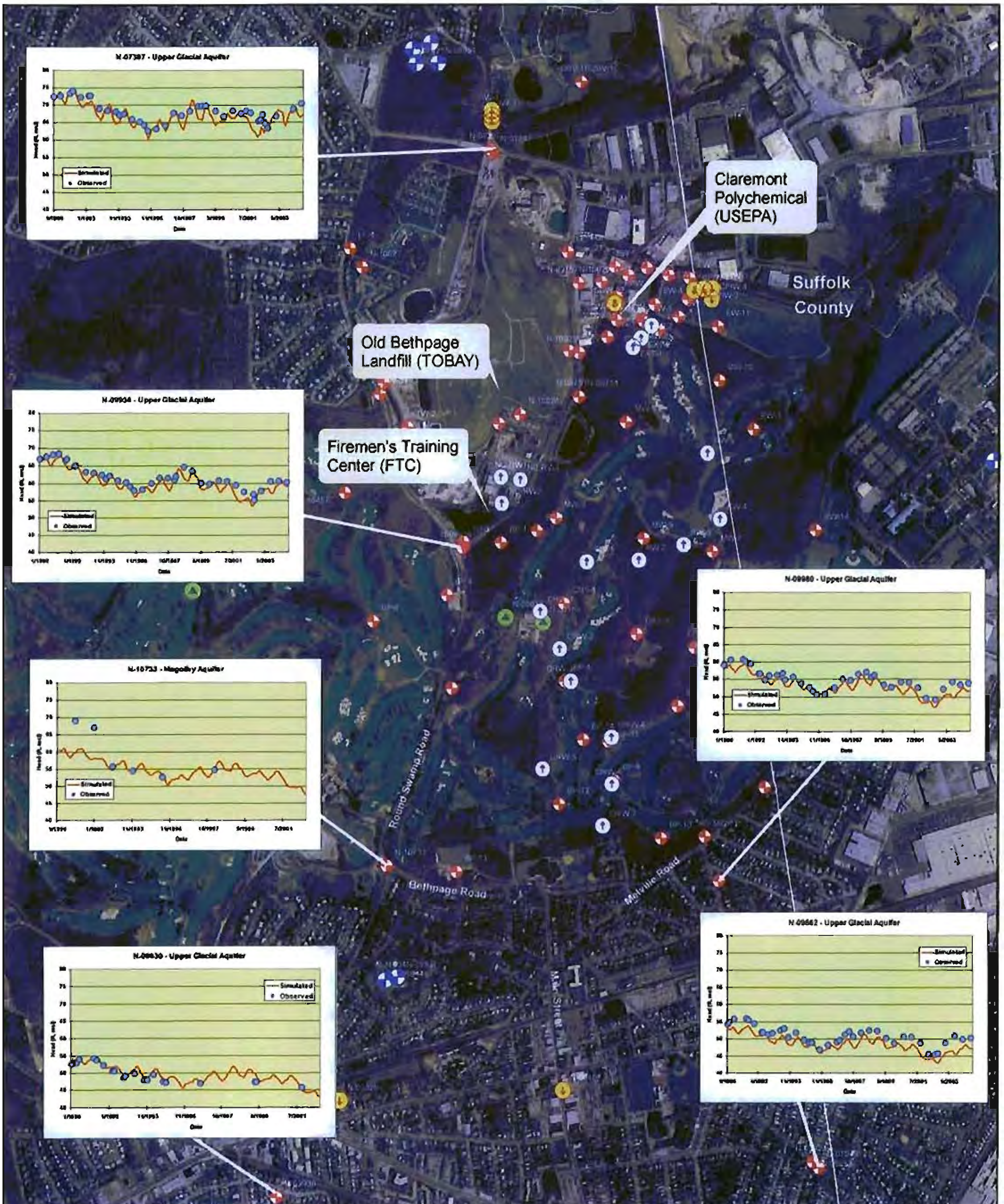


Figure 2-12
Firemen's Training Center Groundwater Model
Transient Model Results through Calibration Period; 1990-2004
Nassau County Wells within Vicinity of FTC Study Area
CDM

Section 3
Contaminant Transport Simulations

3.1 Introduction

Groundwater flow and contaminant transport within the vicinity of Bethpage State Park are affected by remedial operations being conducted simultaneously by Nassau County, the Town of Oyster Bay (TOBAY) and the United States Environmental Protection Agency (USEPA; Figure 3-1). The Fireman's Training Center remediation operates three onsite recovery wells (RW-1, 2 and 3) and seven offsite recovery wells (ORW-1 through 7) that are located southeast of the FTC in Bethpage State Park. Treated water is returned to the local aquifer system via a single recharge basin located on the north side of Bethpage-Sweethollow Road and through the use of three injection wells: IW-1, IW-2 and IW-3 (Figure 3-1).

Two other remediation systems have been installed within the vicinity of the Firemen's Training Center (FTC). Upgradient of FTC, a groundwater treatment system consisting of five (5) recovery wells (designated RW-1 through 5) is owned and operated by the Town of Oyster Bay as part of the remediation of contamination originating from the Old Bethpage Landfill. Treated water pumped from these wells is discharged into two recharge basins (see Figure 3-1). The eastern basin was constructed in the late 1990s and began recharging flow in 1998 (NCDPW, personal communication). A second remedial system is operated by the USEPA at the former Claremont Polychemical site. Three recovery wells that have been designated EXT-1, 2 and 3 operate on the southeast corner of the property. Treated water is then returned to the aquifer via four groundwater injection wells designated CPIW-1 through 4.

Following the development and calibration of the groundwater flow model, a series of simulations were conducted to establish contaminant transport properties and define the extent of the groundwater contamination plume originating from the Firemen's Training Center (FTC). In addition, several particle tracking simulations were also performed to examine possible upgradient sources to the FTC recovery wells and contamination found at depth in County-owned monitoring wells BP-3C and BP-10C. The following contaminant transport simulations were conducted:

- <u>Development of the contaminant plume originating from the Firemen's Training Center</u>: This simulation releases a continuous source of contamination at the FTC site for both benzene as well as halogenated organics.

- <u>Contributing areas to ORW-4, ORW-5, ORW-6 and ORW-7 within the B-Zone</u>: To evaluate the performance of the FTC offsite extraction wells, simulations were conducted that calculated the capture zones of these offsite extraction wells within the B-Zone.

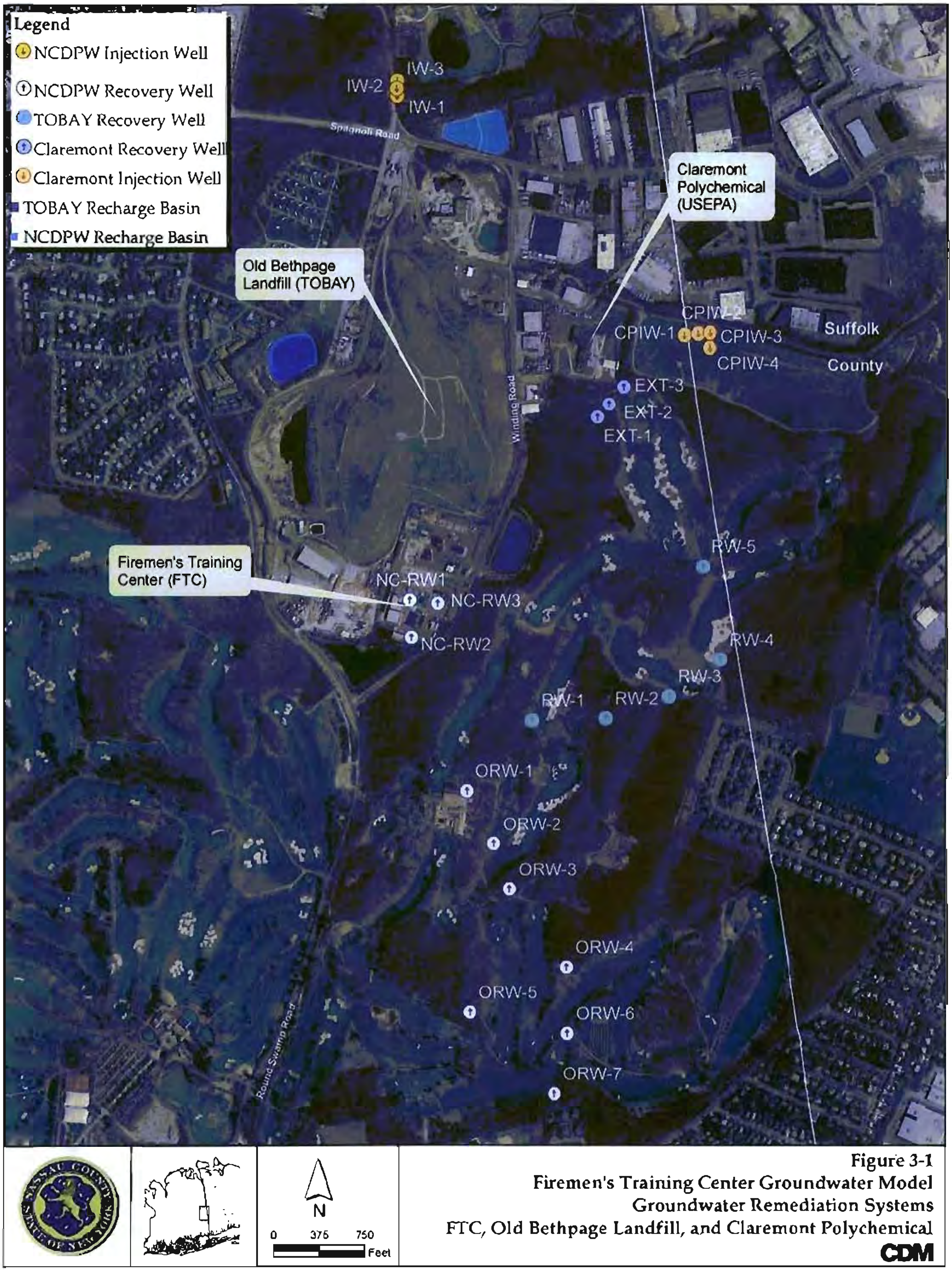


Figure 3-1
Firemen's Training Center Groundwater Model
Groundwater Remediation Systems
FTC, Old Bethpage Landfill, and Claremont Polychemical

CDM

Upgradient particle track simulations released from Claremont Polychemical, the former Captree Chemical facility (currently Mr. Bar-B-Que), the former American Louvre facility, Trulite Louvre (formerly Filtron Corp.), Hitemco, the former Dyna Force Inc. (currently Molloy Brothers Moving & Storage), and the former Life Industries facility: These potential upgradient sources have been identified by NCDPW following a review of available NCDH records. Contaminant transport simulations were conducted to evaluate the migration of potential releases of contamination which may have occurred since the facilities have been in operation.

- Particle track simulations from Claremont Polychemical monitoring wells EW-2D, EW-7D, and EW-10D: These simulations were conducted to evaluate the future migration of contamination at these wells under average conditions of pumping and recharge.

- Contributing areas within the B-Zone to Village of Farmingdale public supply wells N-07852 (1-3), N-06644 (2-2), and N-11004 (2-3): Since most of the contamination lies within the B-Zone, the "B-Zone contributing area" to the supply wells was simulated.

- Forward particle tracks and contaminant plume simulations from BP-3C and BP-10C: The purpose of this simulation was to determine whether downgradient public supply wells would be impacted by contaminants found in these wells.

- Simulate the long term effects of three remedial pumping scenarios on the capture of the FTC volatile organic plume and determine any potential impacts to Village of Farmingdale public supply wells.

Contaminant transport simulations were conducted using DYNTRACK, the companion solute transport code to DYNFLOW (see Section 2).

3.2 Firemen's Training Center

Two sets of simulations were conducted for contamination originating from the Firemen's Training Center. The first simulation considered chlorinated hydrocarbons, while the second simulated a source of benzene. The source area developed for both of these plumes covers an area of approximately 0.80 acres and includes both the Burn Area (BAF) and the Corrugated Metal Building (CMB) drywell fields, which are known onsite sources of VOC and hydrocarbon contamination (Figure 3-2).

The contaminant transport simulations used dispersivity and effective porosities listed previously in Table 2-1. The simulations were run using monthly time steps that were saved from the transient groundwater flow simulation performed for the period from 1950-2050. All pumping and recharge data are incorporated into the transport simulations. Long-term average monthly pumping from public supply wells were used to simulate supply pumpage between 2006-2050 and long-term average monthly precipitation was used for recharge. In addition to establishing the current extent of the plume under historical pumping and recharge conditions, three Nassau County

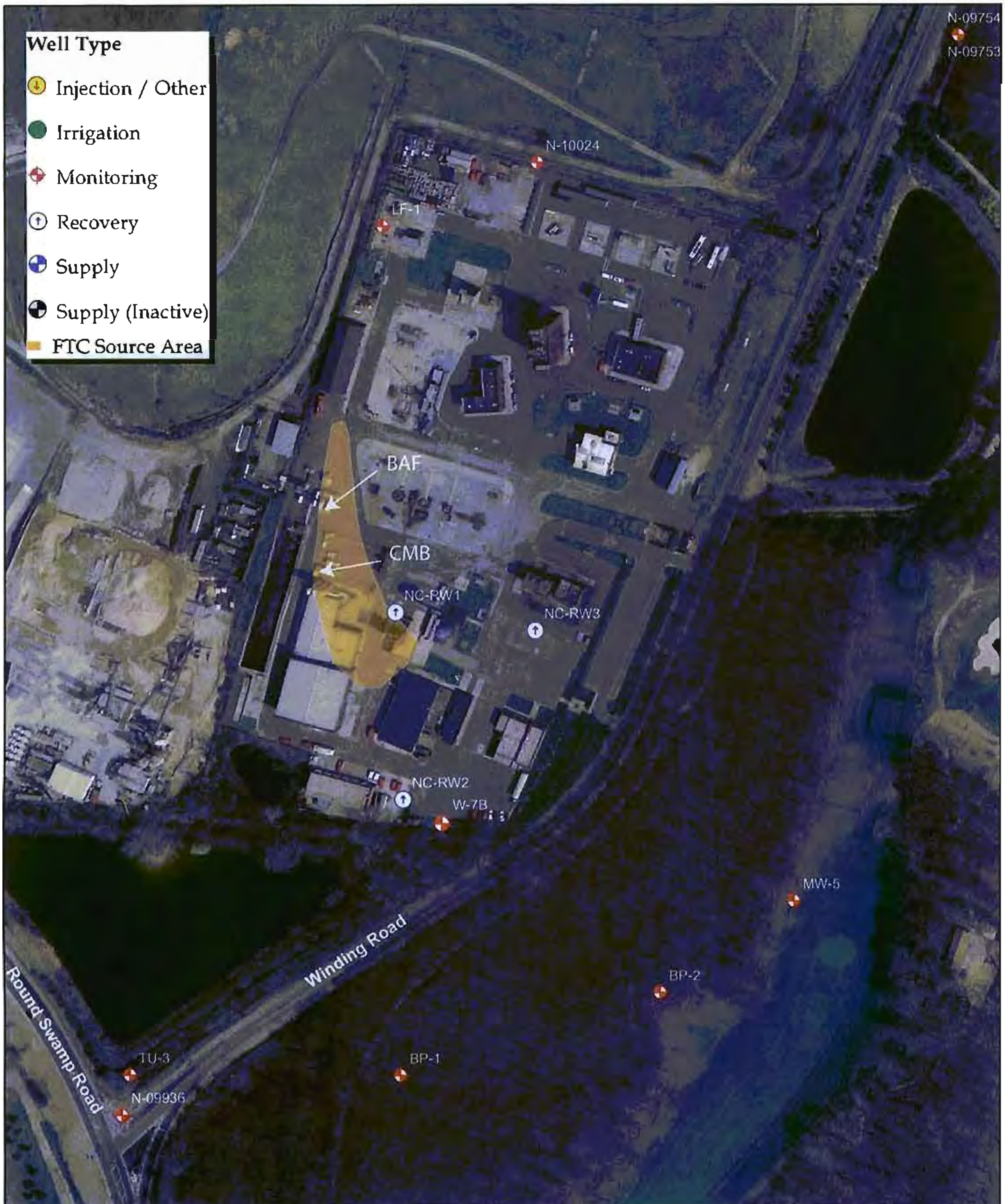


Figure 3-2
Firemen's Training Center Groundwater Model
Source Area for Contamination at FTC Facility

CDM

remediation scenarios were evaluated to determine the most effective approach to remediate the plumes.

3.2.1 FTC Plume - Chlorinated Hydrocarbons

Fuel oil and gasoline have been the primary ignition sources at the Firemen's Training Center since it has been operated. Although the use of solvents containing chlorinated hydrocarbons is not well documented, it is reported that these solvents had been used at the site between 1970 and 1980. Since various chlorinated hydrocarbons are found in several monitoring wells downgradient of the FTC facility, a contaminant transport simulation was conducted to estimate the extent of the chlorinated hydrocarbon contamination that could be attributed to the FTC facility, using conservative assumptions.

The chlorinated hydrocarbon plume simulation was run as a fixed continuous source of 3,000 ppb from 1970-1980. Historically, the highest observed concentration of chlorinated hydrocarbons at the FTC facility was 2,807 ppb in monitoring well W-7B. Although solvents were reportedly used onsite between 1970 and 1980, they were not used continuously. Since the solvents were not used continuously, and only fuel oil and gasoline were used as ignition sources since 1980, a continuous source of 3,000 ppb between 1970 and 1980 represents a conservative approach to simulate the chlorinated hydrocarbon plume from the site.

The retardation factor used for the chlorinated hydrocarbon plume was 2.0, which falls within the range reported for halogenated organic compounds on Long Island. This retardation factor was used based on the total distance traveled by the plume, with the leading edge of the plume simulated to fall in the southern portions of Bethpage State Park and north of Bethpage Road. This retardation factor also allows the plume to sink to the base of the "B-Zone" which is observed from water quality data collected by NCDPW (NCDPW, unpublished data, 2005). As a conservative assumption, no biological degradation was included in the simulation.

The horizontal distribution of the contaminant plume at the beginning of 2005 is shown in Figure 3-3 and in cross-section in Figure 3-4. The plume follows a general south-southeasterly direction and most of the leading edge of the plume is north of Bethpage Road. The simulated plume does not migrate east of the offsite Nassau County recovery wells (ORW-4, ORW-6 and ORW-7) except in northern most portions, where the plume appears to have migrated further to the east due to the combined pumping effects of the Town of Oyster Bay (TOBAY) recovery wells RW-1 and RW-2. The plume does not migrate west into BP-5. Historical water quality sampling of BP-5 indicates that the well has not been impacted by organic compounds. In 2005, most of the simulated chlorinated hydrocarbon plume is within the B-Zone.

The simulation results indicate that some volatile organic contamination has migrated south of Bethpage Road (generally at or slightly above 5 ppb). This likely represents a portion of the plume that has migrated downgradient of the offsite recovery system

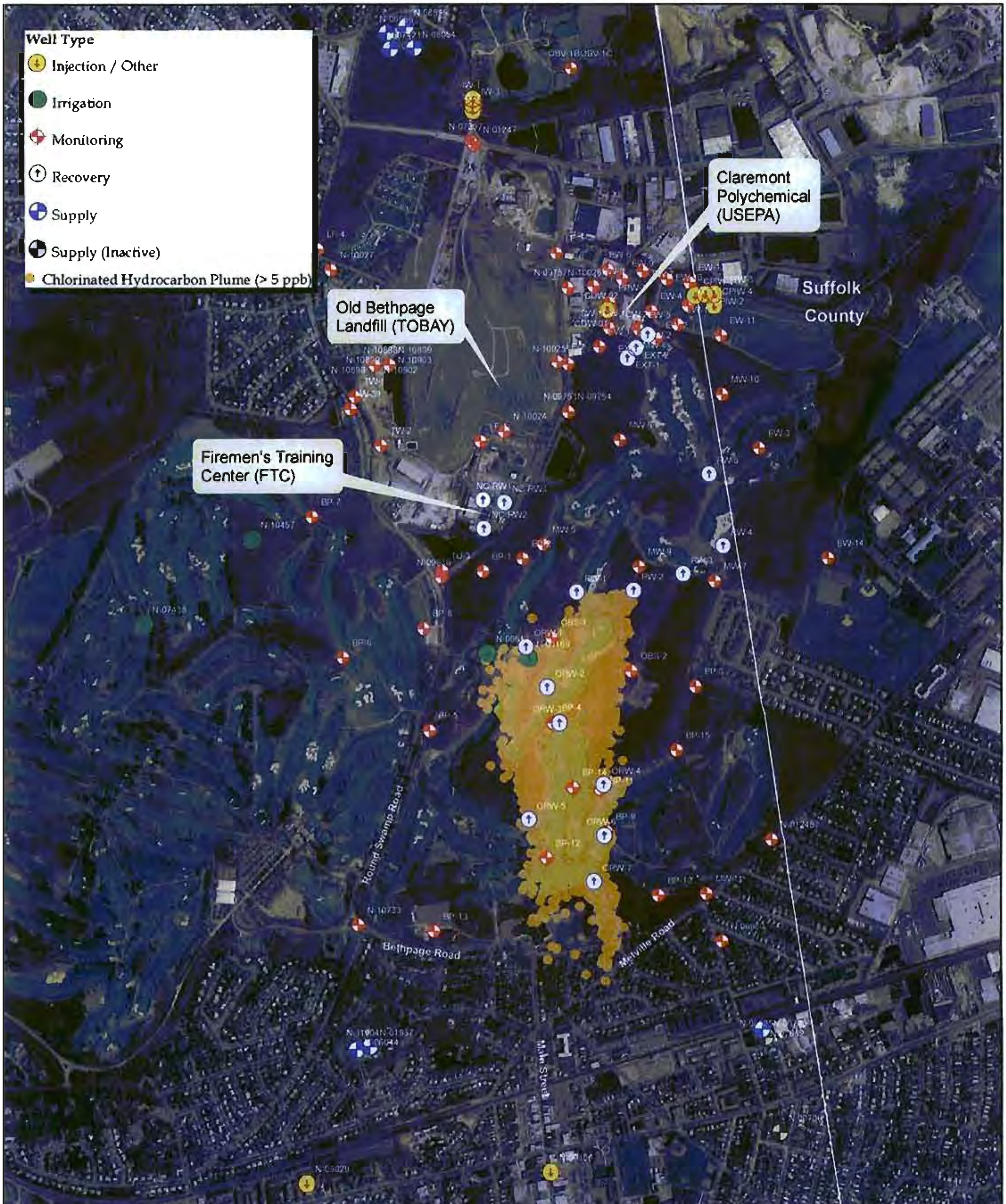


Figure 3-3
Firemen's Training Center Groundwater Model
Simulated Chlorinated Hydrocarbon Plume from FTC, 2005
Continuous Source of 3,000 ppb, 1966-1985

CDM

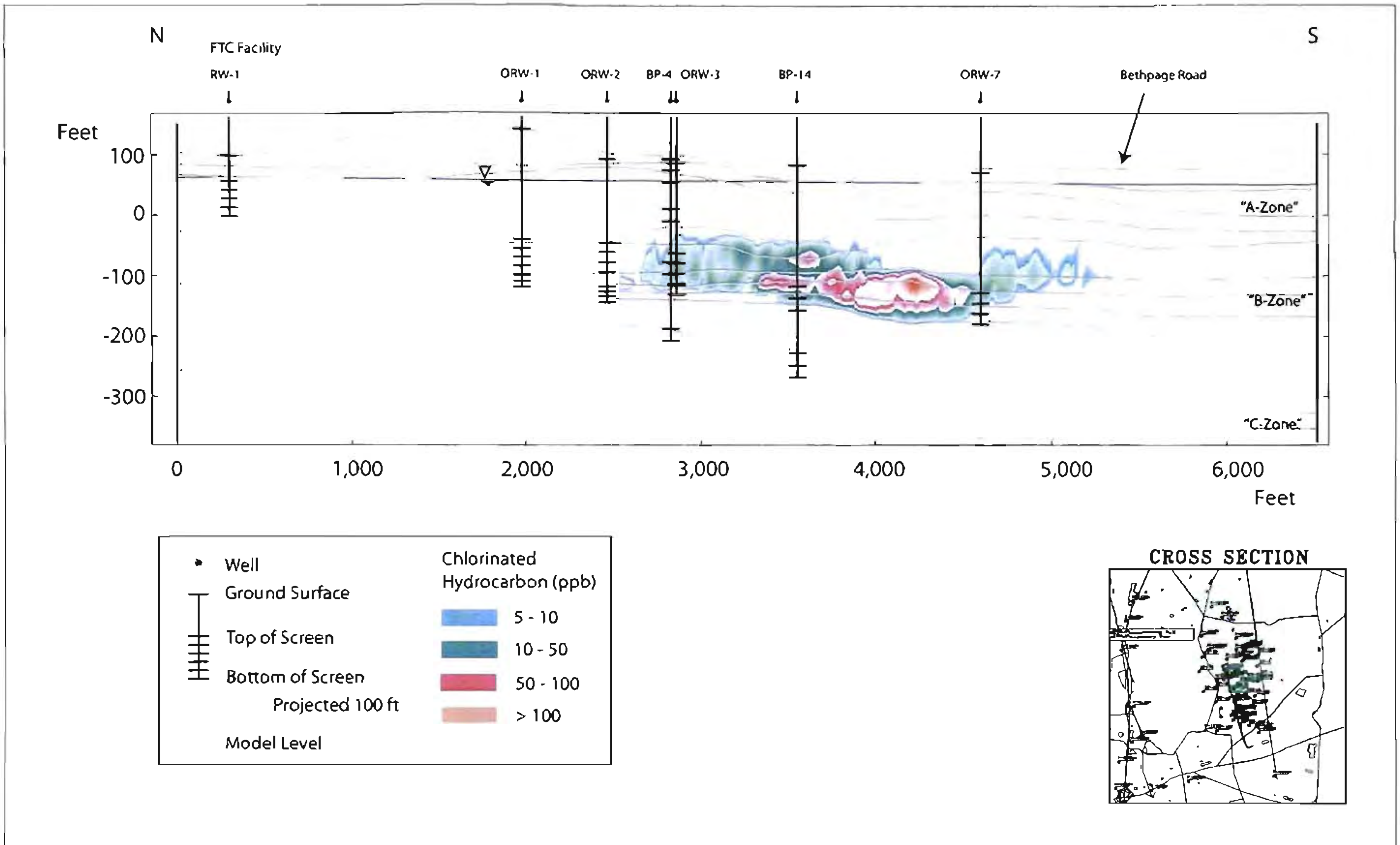


Figure 3-4
Firemen's Training Center Groundwater Model
NW-SE Cross Section of Simulated Chlorinated Hydrocarbon Plume from FTC, 2005
Continuous Source of 3,000 ppb from 1970 - 1980

CDM

prior to plant start up. It appears that this represents the uppermost portion of the plume which is not captured by ORW-7. Although no monitoring wells exist in this area, NCDPW water quality data indicate that ORW-7 contained low levels of organic compounds at start-up (July 1999). Therefore, it is possible that portions of the plume have migrated downgradient of the recovery system prior to recovery system start-up, as observed in the simulated results.

An additional conservative simulation was run in which a continuous source of chlorinated hydrocarbons at a concentration of 3,000 ppb was run for the period 1966 to 1985. Results are shown in plan view and in cross-section on Figures 3-5 and 3-6, respectively. As shown on the figures, the extent of the plume resembles that of the initial simulation (fixed source between 1970-1980), but the plume has migrated a bit further downgradient (approximately 600 feet) and extends further north as source ended five years later than the initial simulation.

It is important to note that since a detailed contamination history is not known, particularly for chlorinated hydrocarbons, the model was not calibrated to concentrations, but rather to general plume extent. The plume dimensions generally match field observations (primarily within the B-zone) obtained following a review of the available, "Annual Operations and Monitoring Summaries", prepared for the FTC site. For various observation wells, the simulated concentration is within an order of magnitude.

3.2.2 FTC Plume - Benzene

Following the early 1980s, only fuel oil and gasoline were used as ignition sources for fire training exercises, with gasoline being the primary source since FTC has been in operation. Benzene has been the primary contaminant found in observation wells on the FTC site and immediately downgradient of the site.

In 1992, an extraction well was installed as part of the FTC remediation system pilot test and design. Benzene concentrations in this extraction well were on the order of 3,000 ppb. As a conservative approach, a continuous source of 5,000 ppb of benzene was simulated at the site between 1966 and 1992, the longest potential term of point source impact. Since the extraction well was installed in 1992, the source strength of benzene was reduced and is simulated at 500 ppb until 2000 when the full remediation system was in operation and the source of benzene to groundwater was removed completely.

Benzene is a biodegradable compound and therefore a decay coefficient was incorporated into the model. From previous experience modeling benzene migration in Long Island aquifers, decay coefficients have ranged between 0.005/day (0.4 year half-life) to 0.00095/day (2 year half-life). As a conservative approach, 0.00063/day was used as a decay coefficient, representing a 3 year half-life. A retardation factor of 1.2 was used to model the benzene plume, again based on previous modeling experience of benzene migration on Long Island, as well as the relative high mobility of benzene as compared to many other organic compounds (Fetter, 1999).

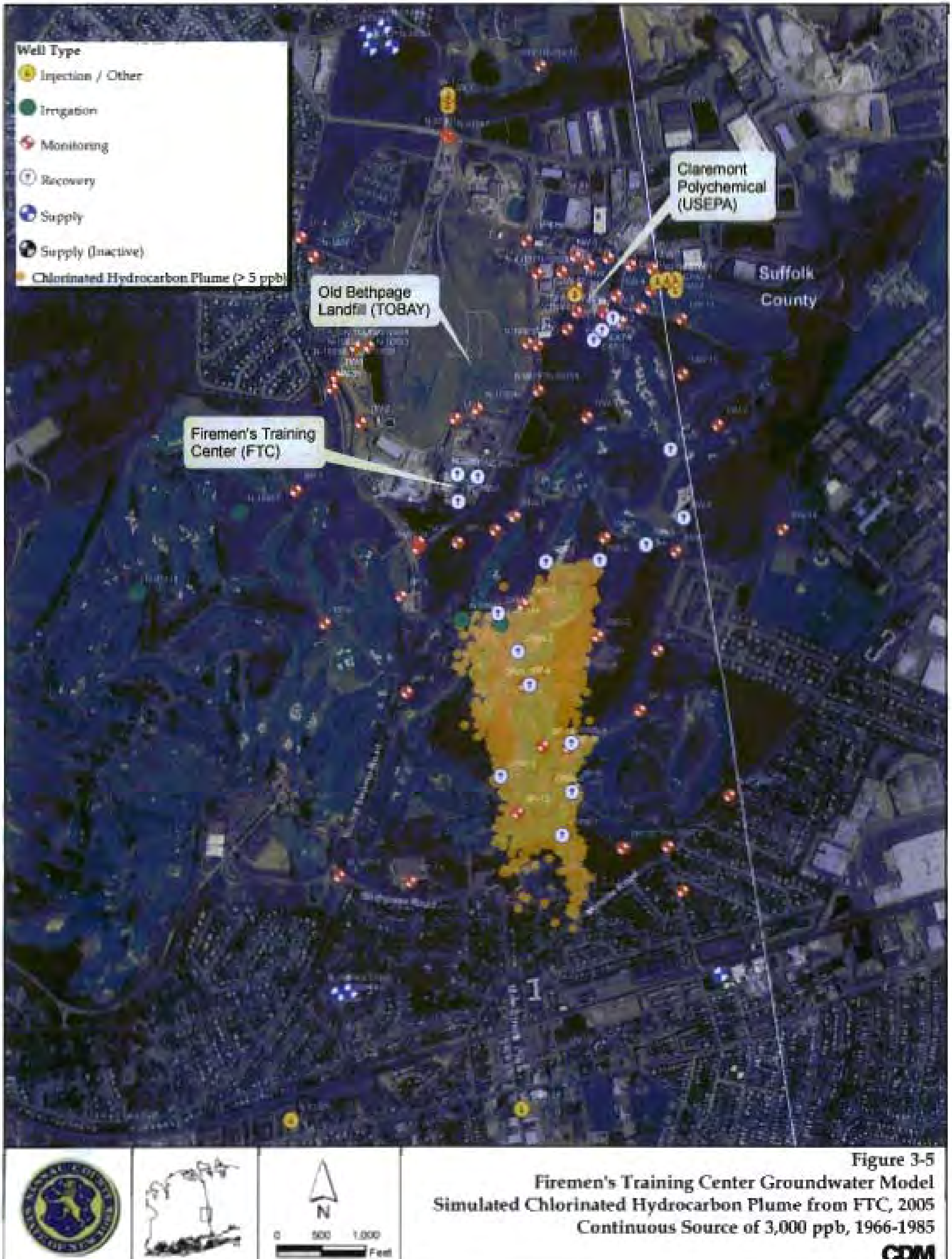
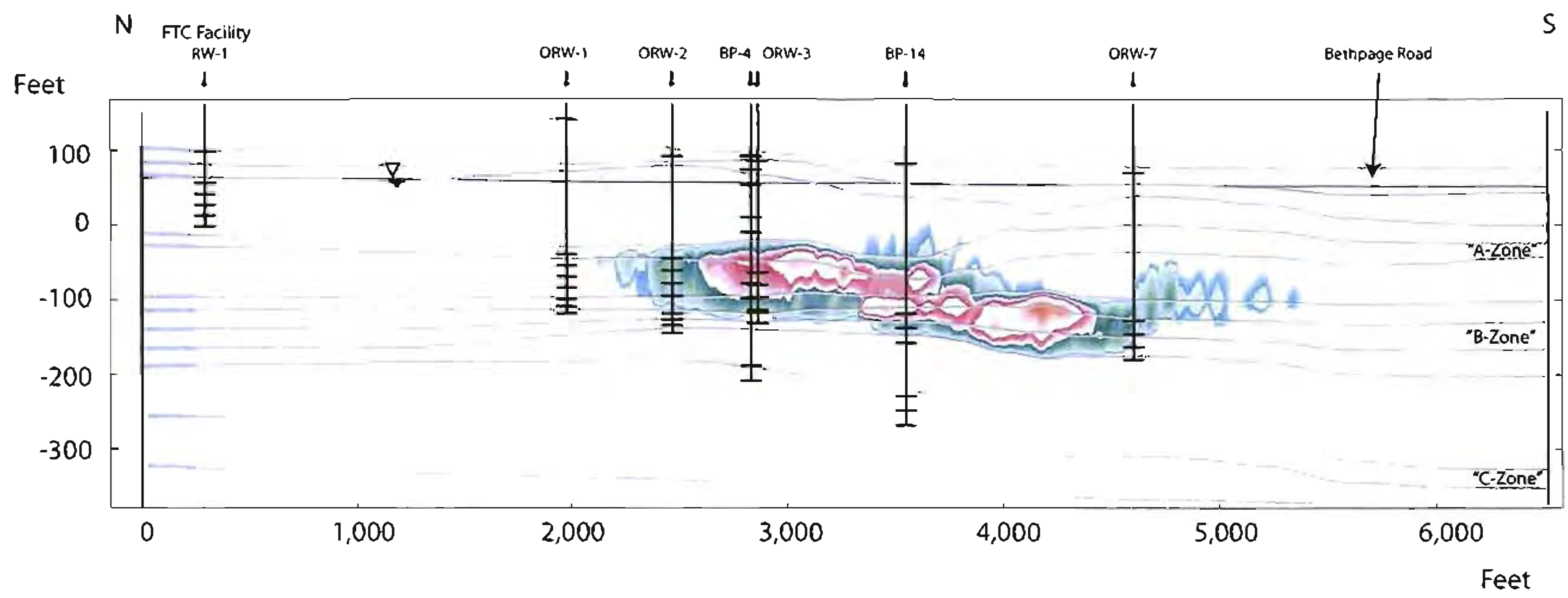


Figure 3-5
Firemen's Training Center Groundwater Model
Simulated Chlorinated Hydrocarbon Plume from FTC, 2005
Continuous Source of 3,000 ppb, 1966-1985

CDM



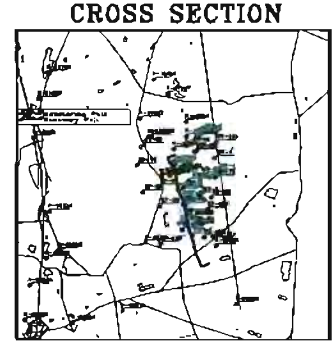


Figure 3-6
Firemen's Training Center Groundwater Model
NW-SE Cross Section of Simulated Chlorinated Hydrocarbon Plume from FTC, 2005
Continuous Source of 3,000 ppb from 1966 - 1985

CDM

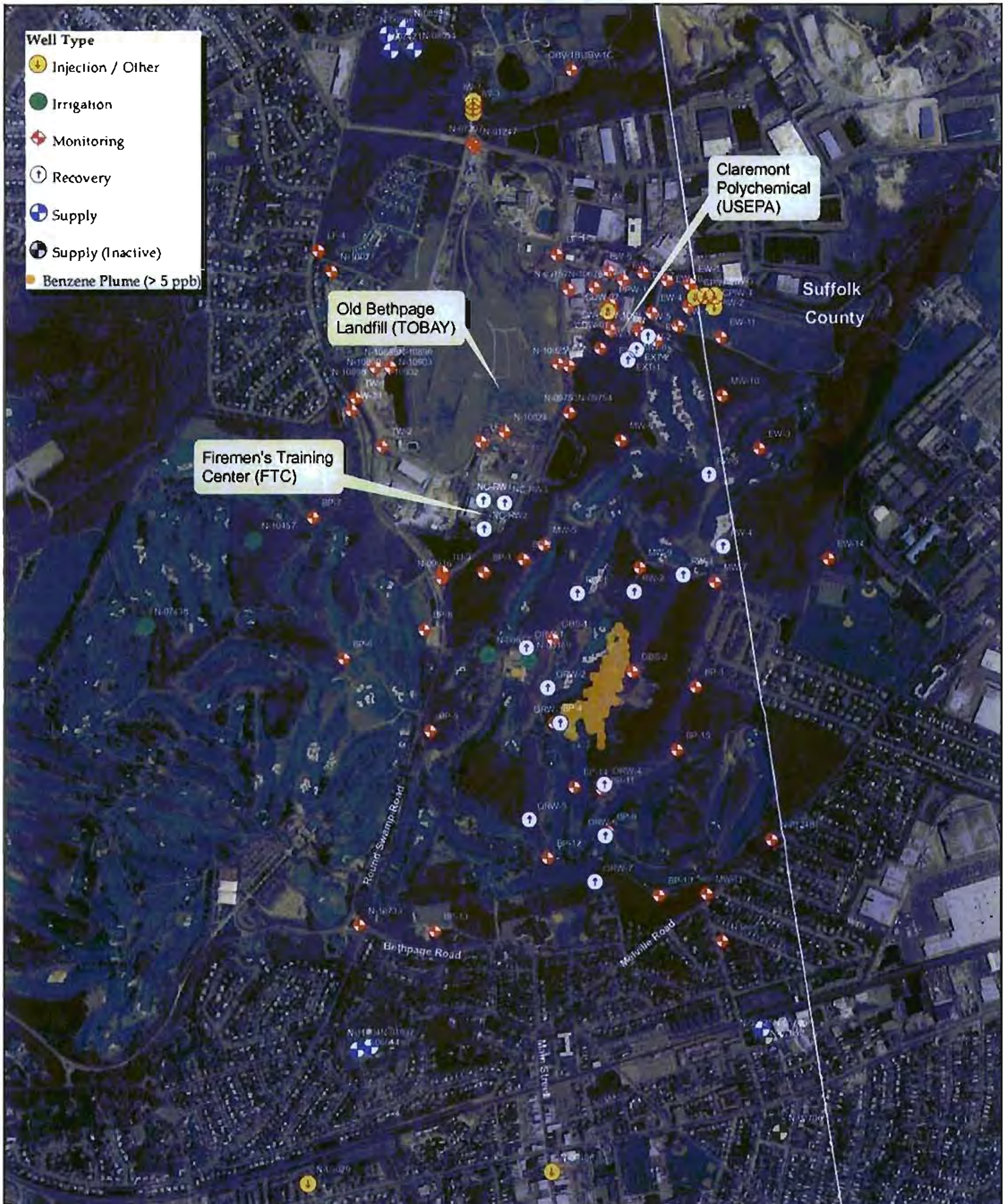
The simulated benzene plume in 2005 is shown in plan view and cross section on Figures 3-7 and 3-8, respectively. As shown in the figures, using FTC as a sole source of benzene, much of the plume has been removed or is dispersed and degraded by 2005. Higher concentrations of benzene are simulated around ORW-3 and BP-4 and some of the plume is captured by TOBAY system extraction wells RW-1 and RW-2. The plume does not generally migrate east of the FTC extraction wells except in areas under the influence of the TOBAY system.

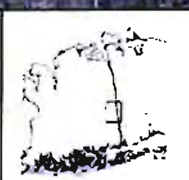
Water quality data collected by NCDPW have shown concentrations of benzene well above 5 ppb, particularly in BP-14B (>100 ppb). This condition could not be reproduced in the groundwater model simulations using benzene characteristics and the source concentrations described above, despite using a conservative approach. Benzene is less dense than water and is considered a light-non-aqueous phase liquid (NAPL). Since it is less dense than water, it will typically float on the water table and concentrations found at depth are typically low and due to vertical diffusion and dispersion. Under natural gradients, it is unlikely to find high benzene concentrations at depths of 100 feet below the water table. However, it is possible that due to the pumping from the various recovery wells, benzene has migrated well below the water table into the B-Zone.

As mentioned above, benzene is a biodegradable compound. However, the rate of biodegradation can be slowed in anaerobic zones or if some other phenomenon is occurring. It is possible that biodegradation is not occurring or is limited due to the mixing of the chlorinated hydrocarbon plume with benzene. Biodegradation rates on benzene may also be affected by the presence of landfill leachate. Historical dissolved oxygen data are not available, but it is possible that a slug of very high concentration of benzene was introduced that was mixed with other constituents which created an anaerobic core. This slug may have been toxic to bacteria and biodegradation of benzene limited in the core, while occurring along the fringe of the plume as more oxygenated native groundwater mixed. When the remediation system was put into operation, it is possible that this slug was drawn to deeper depths to which it is currently observed.

3.3 Eastern Contamination

Benzene, cis-1,2 dichloroethene, trichloroethylene, and tetrachloroethylene are found in all FTC recovery wells, but there are a suite of other chemicals, including dichlorodifluoromethane, a chemical never detected on the FTC site, that are frequently detected in downgradient recovery and observation wells. In addition, volatile organic contamination has been found in County monitoring wells BP-3, BP-10, BP-15, as well as in TOBAY monitoring well MW-7 and USEPA (Claremont) monitoring well EW-14, all of which are well east of the eastern most extent of the contamination originating from FTC (see Figures 3-3, 3-5, and 3-7). Figure 3-9 shows the extent of the FTC plume as well as an estimated extent of other contamination found in eastern portions of the study area in both Nassau and Suffolk Counties. As is the case with the FTC plume, the "eastern plume" is primarily located within the B-Zone. Contamination is also found within the C-Zone and is discussed later in this section. In the following discussion, only the





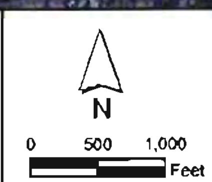


Figure 3-7
Firemen's Training Center Groundwater Model
Simulated Benzene Plume from FTC, 2005
Continuous Source of 5,000 ppb, 1966-1992; 500 ppb 1992-2000

CDM

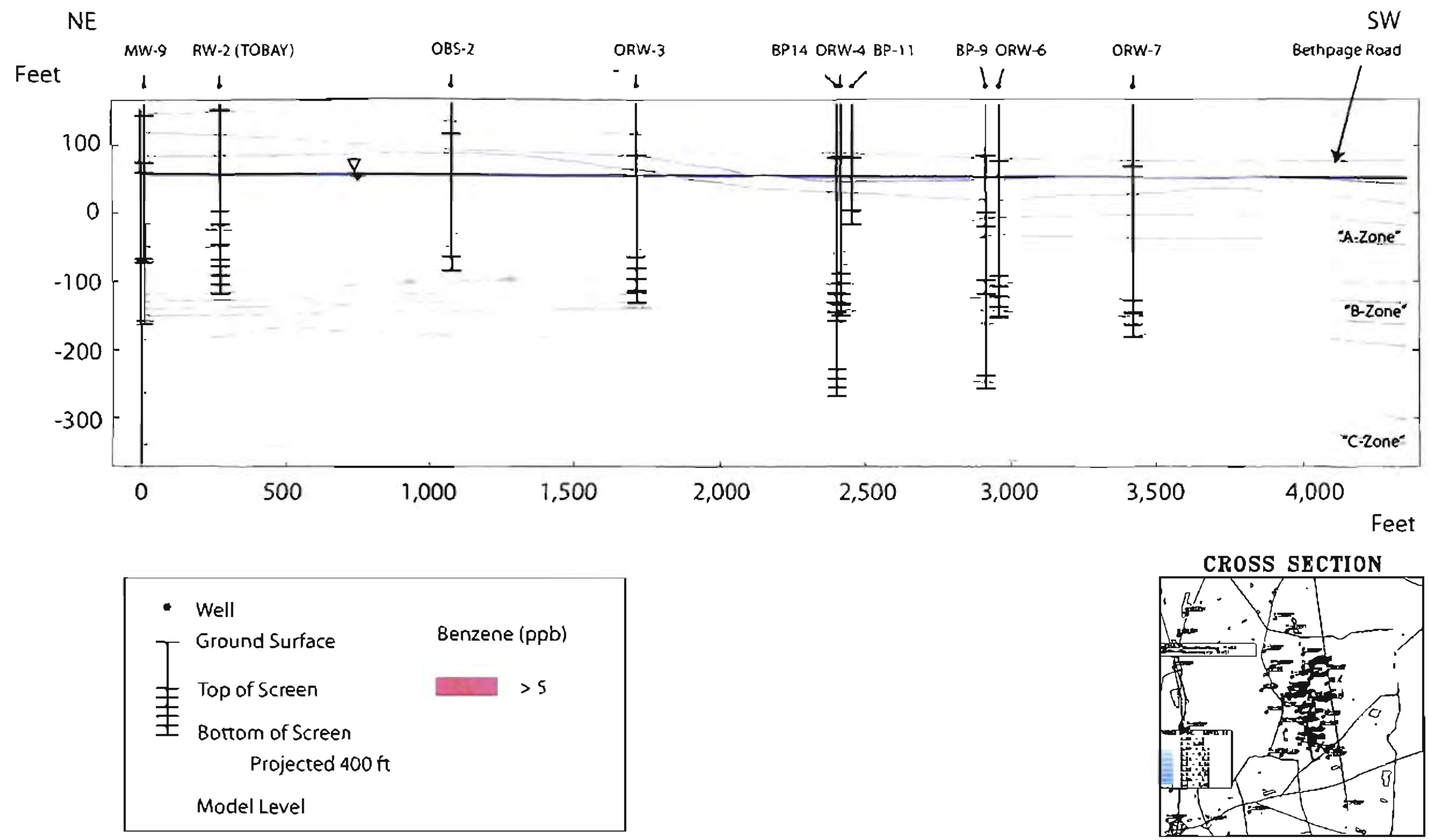


Figure 3-8
Firemen's Training Center Groundwater Model
NW-SE Cross Section of Simulated Benzene Plume from FTC, 2005
Continuous Source of 5,000 ppb from 1966 - 1992; 500 ppb 1992-2000

CDM

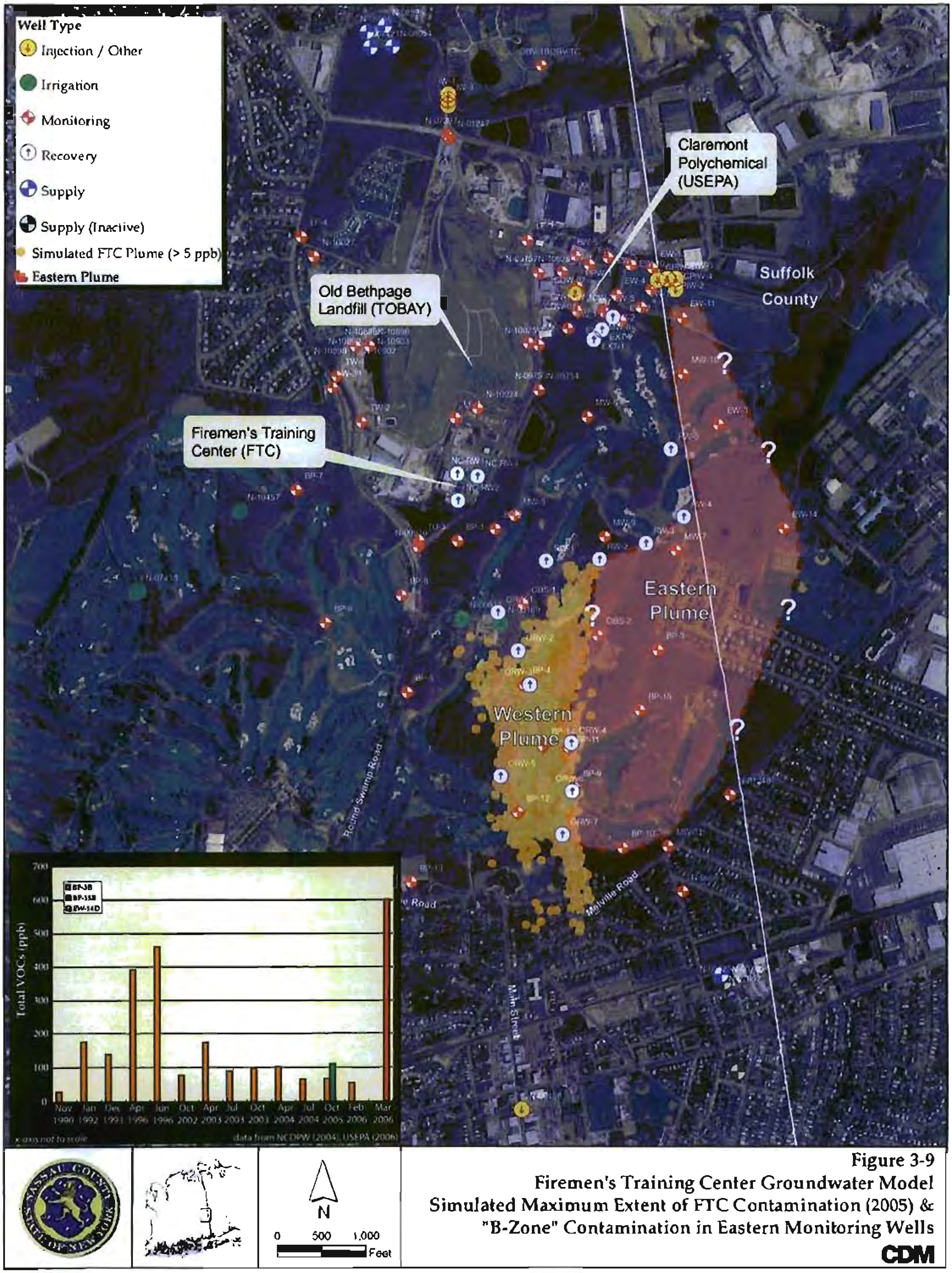


Figure 3-9
Firemen's Training Center Groundwater Model
Simulated Maximum Extent of FTC Contamination (2005) &
"B-Zone" Contamination in Eastern Monitoring Wells

CDM

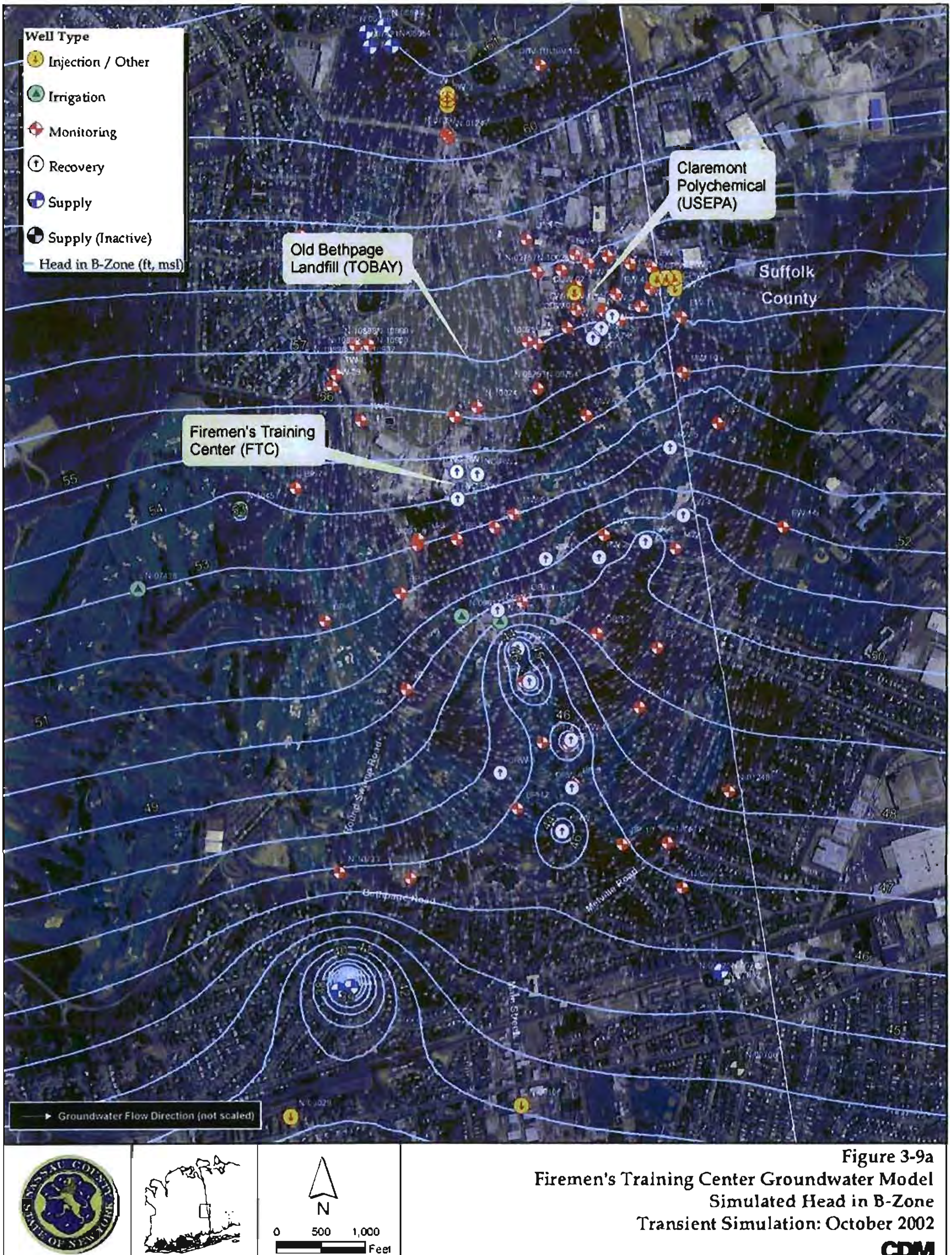


Figure 3-9a
Firemen's Training Center Groundwater Model
Simulated Head in B-Zone
Transient Simulation: October 2002
CDM

chlorinated hydrocarbon plume (source 1970-1980) is considered to have been generated from an FTC source.

Groundwater flow within the B-Zone is extremely dynamic, fluctuating significantly depending on which recovery wells are in operation. Groundwater contours and vector plots simulated during periods when most recovery wells were in operation (Figure 3-9a) show that downgradient County recovery wells (ORW-3, ORW-4, ORW-6, ORW-7), are withdrawing groundwater from eastern portions of the study area, away from any FTC influence, including the region comprising the eastern plume (Figure 3-9). To evaluate potential impact to FTC wells from the eastern plume, a contaminant transport simulation was conducted using actual concentrations of total volatile organic compounds (TVOCs) detected in County monitoring well BP-3B since sampling began in 1990. The transient model simulation was used so that actual monthly pumpage from surrounding water supply wells and all remediation wells in the system could be simulated. Concentrations were fixed at the screen of monitoring well BP-3B, corresponding to sample results shown in Figure 3-9. A retardation factor of 1.5 was used for the simulation and the simulation was run until 2007. Results are shown on Figure 3-10.

The simulated plume originating at BP-3B, a well considered by the NYSDEC to have been impacted by sources other than the FTC in the 1993 Record of Decision (ROD), for the site; migrates in a south-southwest direction and is captured by FTC recovery wells ORW-4, ORW-6 and ORW-7. Using the simulated retardation factor of 1.5, the recovery wells are first impacted in the spring of 2003. As shown on Figure 3-10, the simulated plume intersects County monitoring well BP-15. This monitoring well was sampled in October 2005 and contained TVOC concentrations exceeding 100 ppb (Figure 3-9).

3.3.1 B-Zone Contributing Areas to FTC Offsite Recovery Wells

The majority of groundwater contamination within the study area lies in the B-Zone. Contaminant transport simulations releasing contamination from BP-3B, which is located within the "eastern plume" (Figure 3-9) is being captured by FTC offsite recovery wells. In order to better estimate what portions of the B-Zone were contributing to the offsite recovery wells, contributing area simulations were conducted.

Contributing areas are often modeled for wellhead protection programs or source water assessments to determine the surface area where the source water to a public supply well is recharging. In a typical scenario, particles are spread across the water table and allowed to run forward, following the groundwater flow paths. As described above, once these particles reach a discharge boundary, they are removed from the system. The flow path of these particles can be traced "backwards" to determine the spatial area on the water table from which a particle originates. That area will represent the water table contributing area to the well. In general, deeper wells will have contributing areas that lie further upgradient than shallow wells (see Figure 3-11; NYSDOH, 2003).

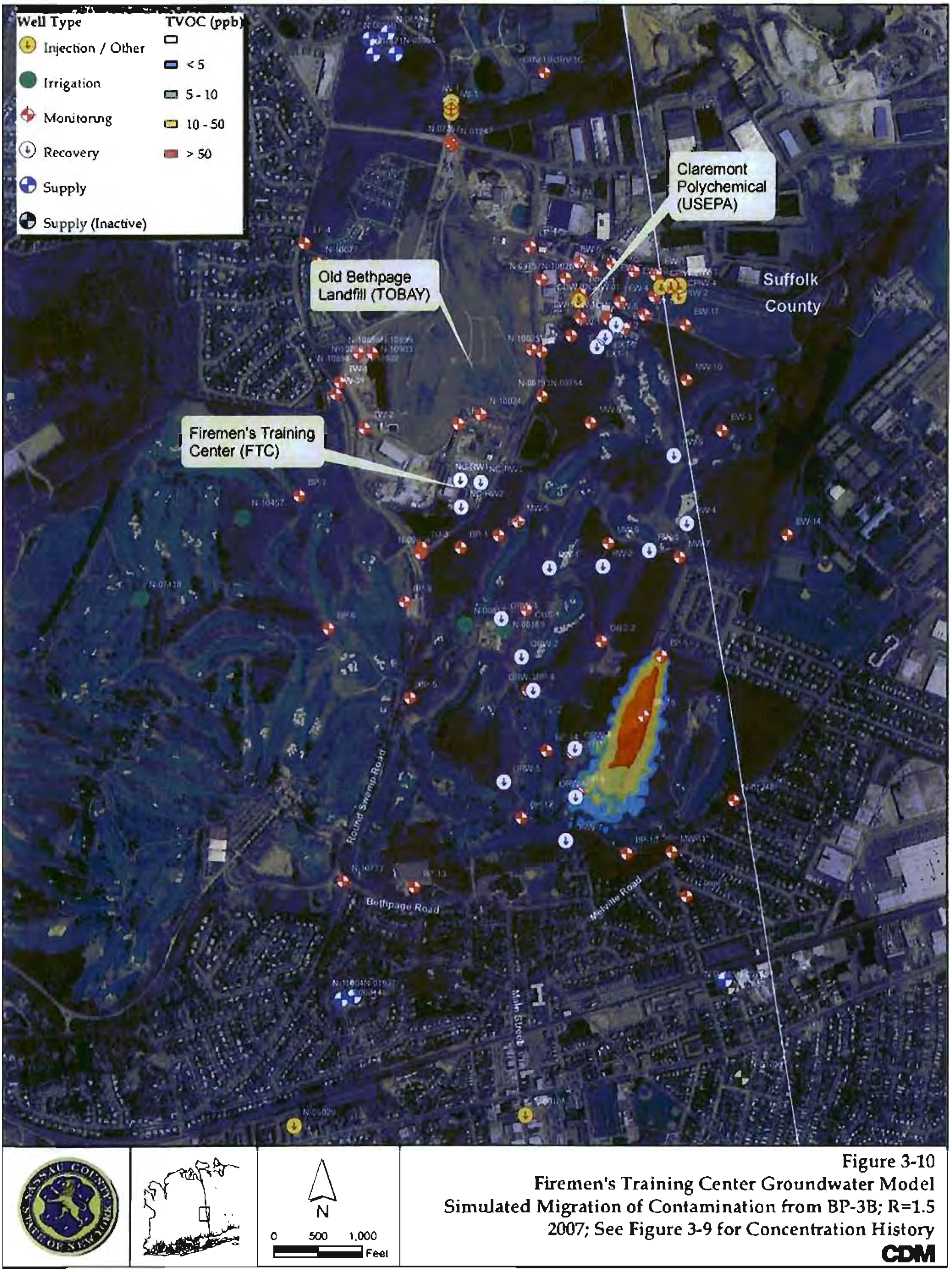


Figure 3-10
Firemen's Training Center Groundwater Model
Simulated Migration of Contamination from BP-3B; R=1.5
2007; See Figure 3-9 for Concentration History
CDM

Figure 3-11 Example of well contributing areas (from Long Island Source Water Assessment Program, NYSDOH, 2003)

Following a similar approach to the one discussed above, particles were spread across the top of the B-Zone and allowed to run forward to determine where within the B-Zone water discharges to the County recovery wells. Therefore, instead of determining where on the surface the water to a well is originating, this simulation targets "where within the B-Zone" water is originating.

Two simulations were conducted, using monthly pumping rates from two periods and keeping those rates steady for 10 years. The contributing area simulations were run under steady-state conditions. As previously discussed, increased VOC concentrations were first observed by NCDPW when sampling several active recovery wells on October 21, 2002. The first contributing area simulation used October 2002 pumping rates. October 2002 rates were also used for TOBAY and Claremont remediation systems, as well for surrounding community public supply wells. A second simulation was conducted, focusing on the contributing areas to the furthest downgradient County owned recovery wells, ORW-4, 5, 6, and 7. For this simulation, December 2002 pumping rates were used as all four wells had a similar pumping rate for that period. Pumping rates for both simulations are shown in Table 3-1.

The "B-Zone contributing areas" to all recovery wells (except ORW-5) using October 2002 pumping rates are shown on Figure 3-12. County recovery wells ORW-4, ORW-5, ORW-6, and ORW-7 are shown in Figure 3-12a. As shown in the figures, during periods when recovery wells are operating, groundwater in areas well east of any FTC influence is being introduced to the recovery wells (also see Figure 3-9a). In addition, there are significant areas of "clean" water from western portions of the B-Zone that are contributing as well.

Table 3-1
Average Monthly Pumping Rates used for
FTC ORW B-Zone Contributing Area Simulations

Well	Pumping Rate (gpm)	
	October 2002	December 2002
ORW-1	1.8	0
ORW-2	185	0
ORW-3	207	0
ORW-4	157	141
ORW-5	0	121
ORW-6	15	145
ORW-7	145	141
TOTAL	711	548

It is important to note that the contributing areas shown on Figures 3-12 and 3-12a each represent a single pumping scenario and are intended to be examples of areas within the B-Zone that contribute flow to the FTC recovery wells. As shown on the figures, contributing areas are dynamic and fluctuate considerably with varying pumping rates. Figure 3-12a may be a more representative contributing area within the B-Zone for FTC offsite recovery wells as ORW-6 would appear to be most impacted by contamination released from BP-3B (see Figure 3-10).

3.4 Potential Upgradient Sources

During recent investigations and water quality sampling conducted at Claremont Polychemical Corp. by the USEPA, it was discovered that monitoring wells installed upgradient of the former Claremont facility contained contaminated groundwater at depth. Since these wells were contaminated, it is likely that there are other source(s) of contamination besides the Claremont facility itself. Therefore, to investigate the possibility of volatile organic contamination from other sources impacting the FTC recovery wells and potentially comprising portions of the "eastern plume", contaminant plumes and forward particle tracks were simulated and released from Claremont and several additional potential sources.

Contaminant transport simulations use a retardation factor of 1.5 for all facilities. While assignment of this retardation factor is somewhat arbitrary, it represents a typical retardation factor for organic compounds. As these simulations are generally hypothetical, varying retardation factors for specific facilities have not been determined. Sensitivity simulations were also run without retardation to evaluate the hydraulic migration of conservative particles.

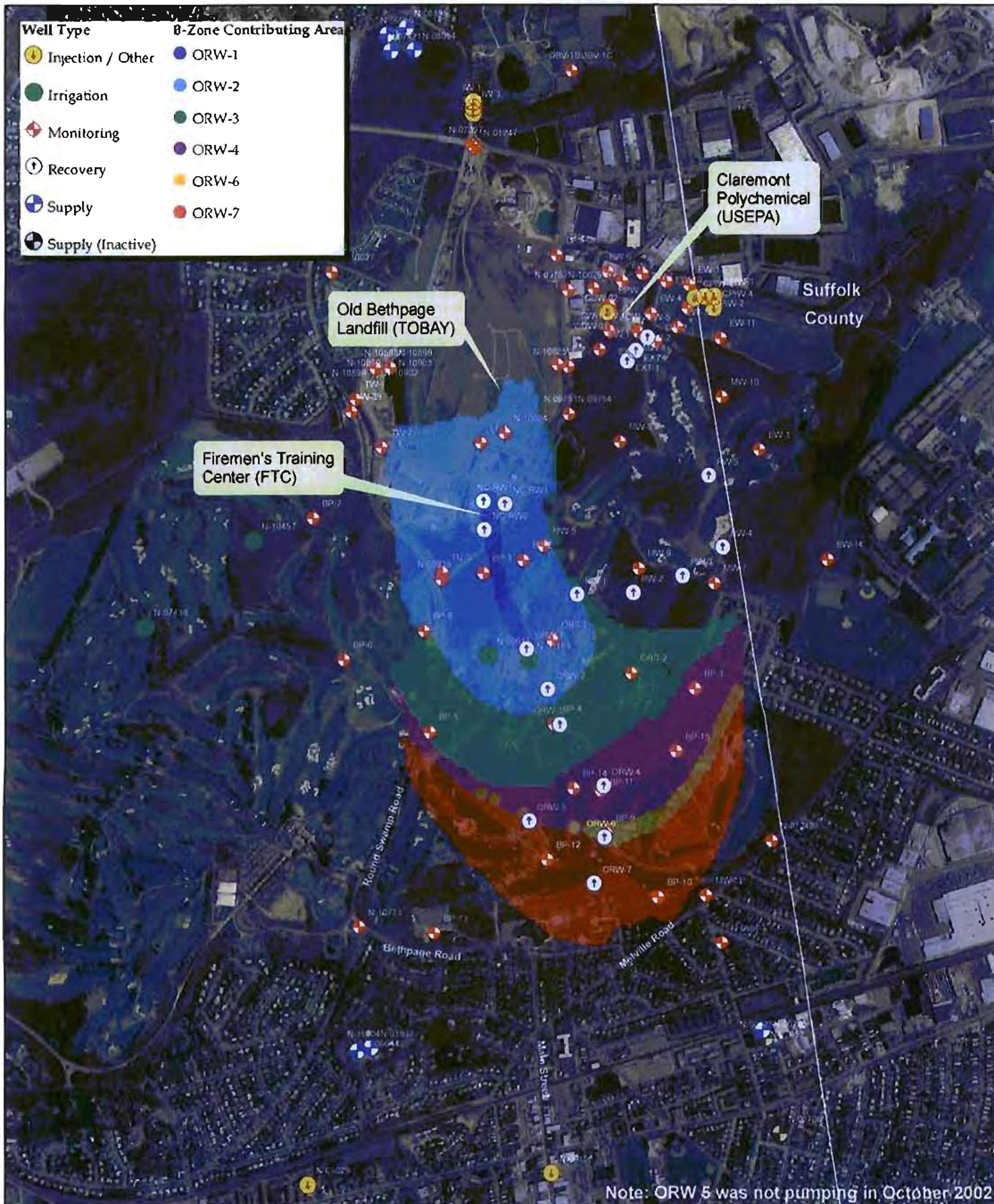
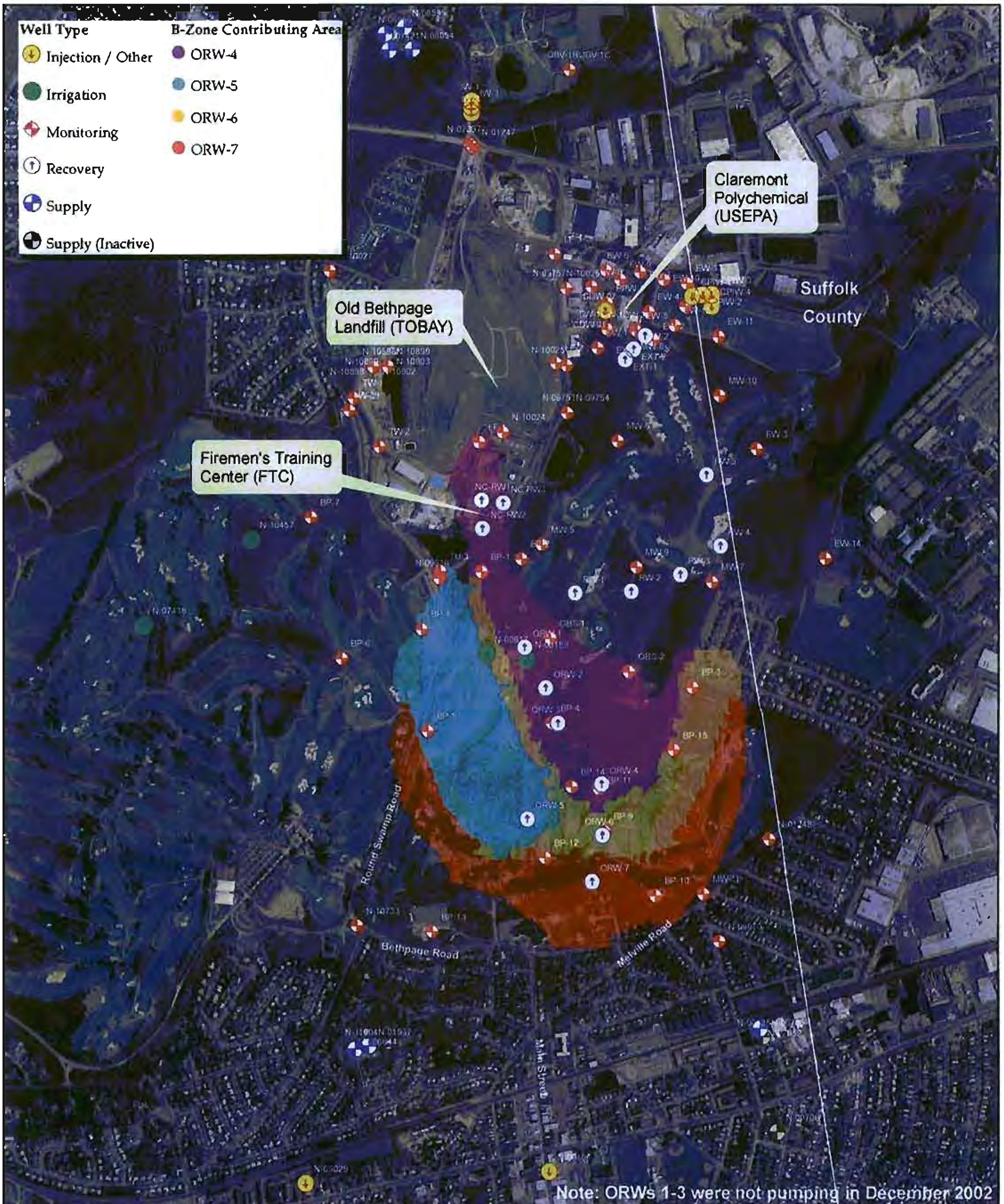


Figure 3-12
Firemen's Training Center Groundwater Model
B-Zone Contributing Area to NCDPW Recovery Wells
October 2002 Pumping Rates Simulated for 10 Years

CDM



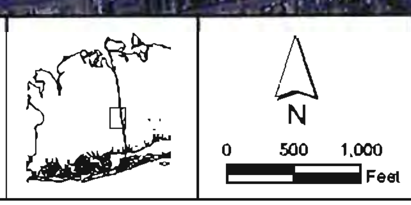


Figure 3-12a
Firemen's Training Center Groundwater Model
B-Zone Contributing Area to NCDPW Recovery Wells
December 2002 Pumping Rates Simulated for 10 Years

CDM

3.4.1 Claremont Polychemical Corporation

3.4.1.1 Contaminant Plume from Claremont Diffusion Wells

Claremont Polychemical Corporation manufactured pigments for plastics and other materials from 1966 to 1980 (USEPA, 2002). When in operation, the former Claremont Polychemical Corporation utilized two diffusion wells onsite to dispose of processing wastewater. One well has a very shallow screen interval (53 to 28 feet above mean sea level (msl)) and the second well has four screened intervals (34 to 24 feet above msl, 15 to 25 feet below msl, 61 to 71 feet below msl, and 101 to 115 feet below msl). These wells were used between 1968 and 1980.

A contaminant transport simulation was conducted in which a contaminant plume was simulated from the Claremont diffusion wells. Concentrations were held fixed at an arbitrary value at model levels which approximate the screened elevation of the diffusion wells from 1968 through 1980 using a retardation factor of 1.5. It is assumed that the wastewater is gravity-fed and no additional injection is applied. The simulation was run until 2007. The simulated plume is shown in plan view and cross section on Figures 3-13 and 3-13a, respectively.

From the figures, the simulated plume originating at Claremont migrates downgradient in a south-southeasterly direction. Shallow portions of the plume are captured by the TOBAY recovery system. Portions of the plume that were released from deeper screen intervals of the diffusion wells migrate into the C-Zone. Currently there are no wells installed that are screened deep enough within the C-Zone to verify this contaminant transport simulation, although it is documented that the TOBAY system is capturing contamination from Claremont (NCDPW, personal communication). The simulated plume from the Claremont diffusion wells does not appear to migrate into the B-Zone within the eastern plume. The sensitivity simulation without retardation also indicates that shallow portions of the plume are captured by the TOBAY system, but most of the plume migrates into the C-Zone. Without retardation, the plume migrates approximately 1,500 feet south of Conklin Street (Rt. 24).

3.4.1.2 Potential Water Table Source at Claremont Polychemical Corporation

In addition to contamination originating from Claremont diffusion wells, a surface source was also simulated (at the water table). Soil and groundwater contamination from leaking drums and storage tanks has been documented by USEPA (USEPA, 2002). Contaminated soil was excavated in March 1997. A continuous source of contamination was simulated between 1968 and 1997 in the eastern portion of the property, immediately north of the remediation system between the former facility and the tree line over an approximate area of 0.80 acres. Again, a retardation factor of 1.5 was used. The simulated plume (in 2007) is shown on Figure 3-13b in plan view and in cross-section on Figure 3-13c.

As shown of Figures 3-13b and 3-13c, much of the contamination at the site is being captured by the Claremont extraction wells and further downgradient by TOBAY remediation wells. However, the TOBAY wells were not operational until April 1992,

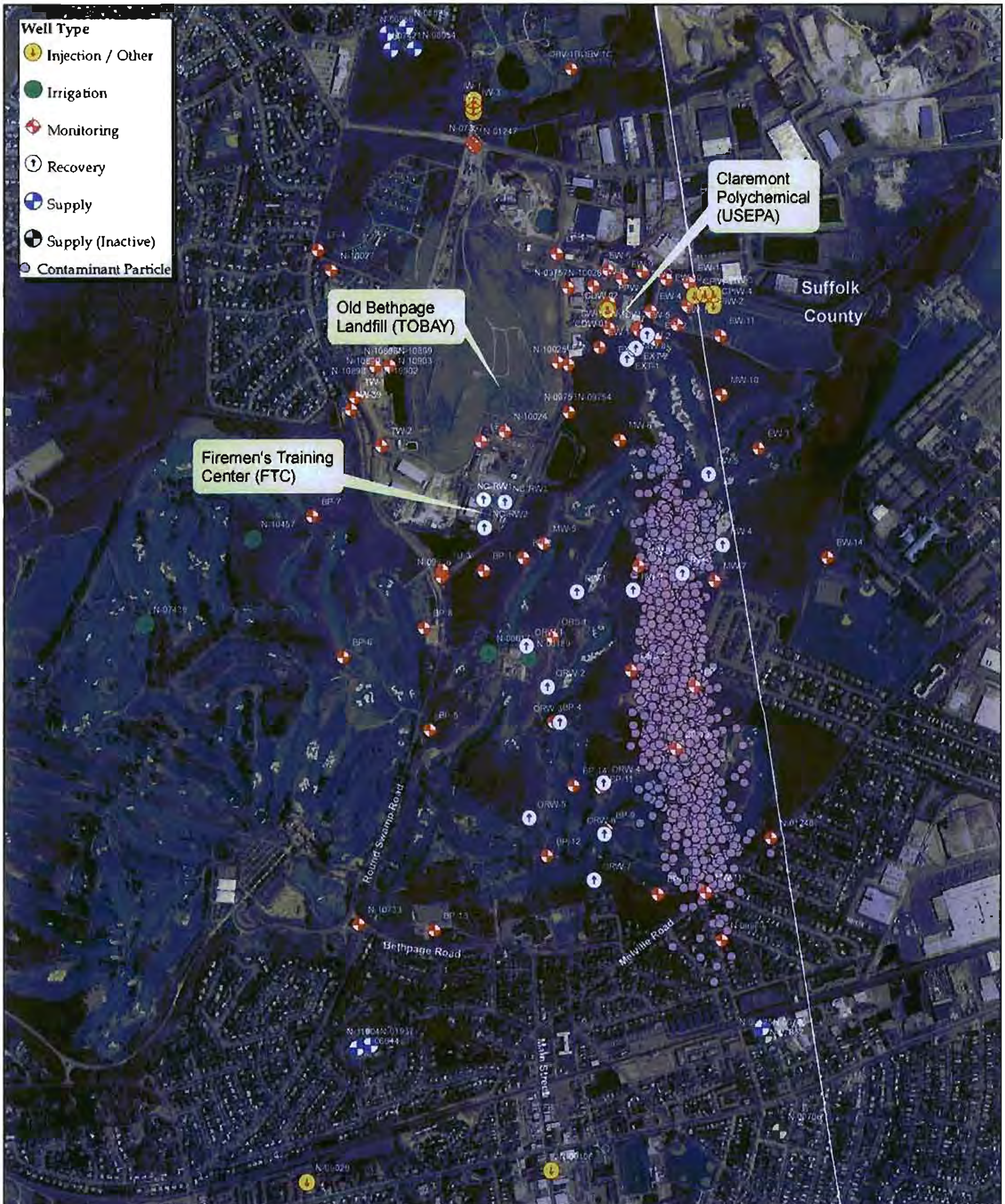


Figure 3-13
Firemen's Training Center Groundwater Model
Simulated Plume from Claremont Diffusion Wells
Particles Released 1968-1981; Retardation = 1.5

CDM

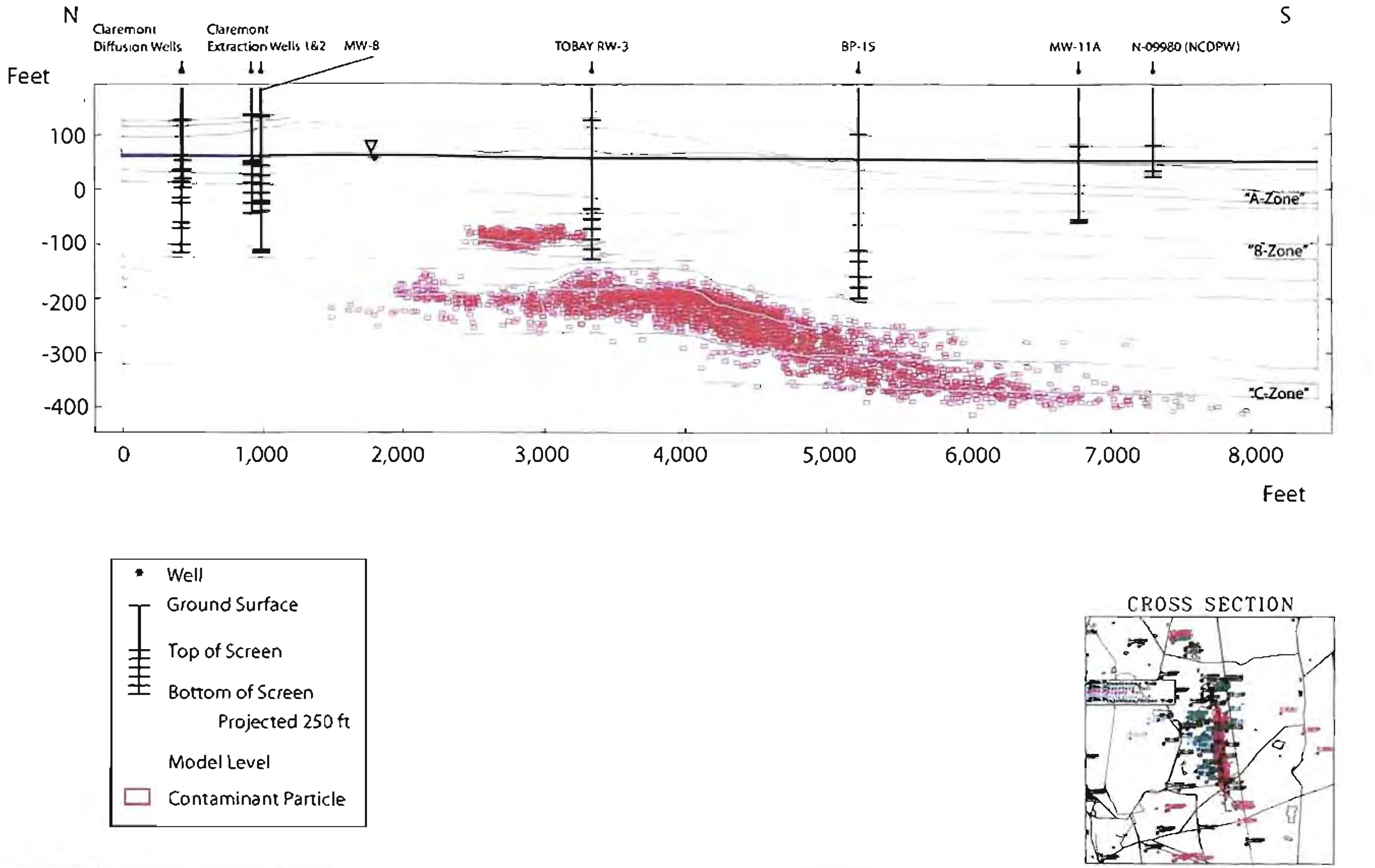


Figure 3-13a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Claremont Diffusion Wells, 2007
Particles Released from Well Screens 1968 - 1981; R = 1.5

CDM

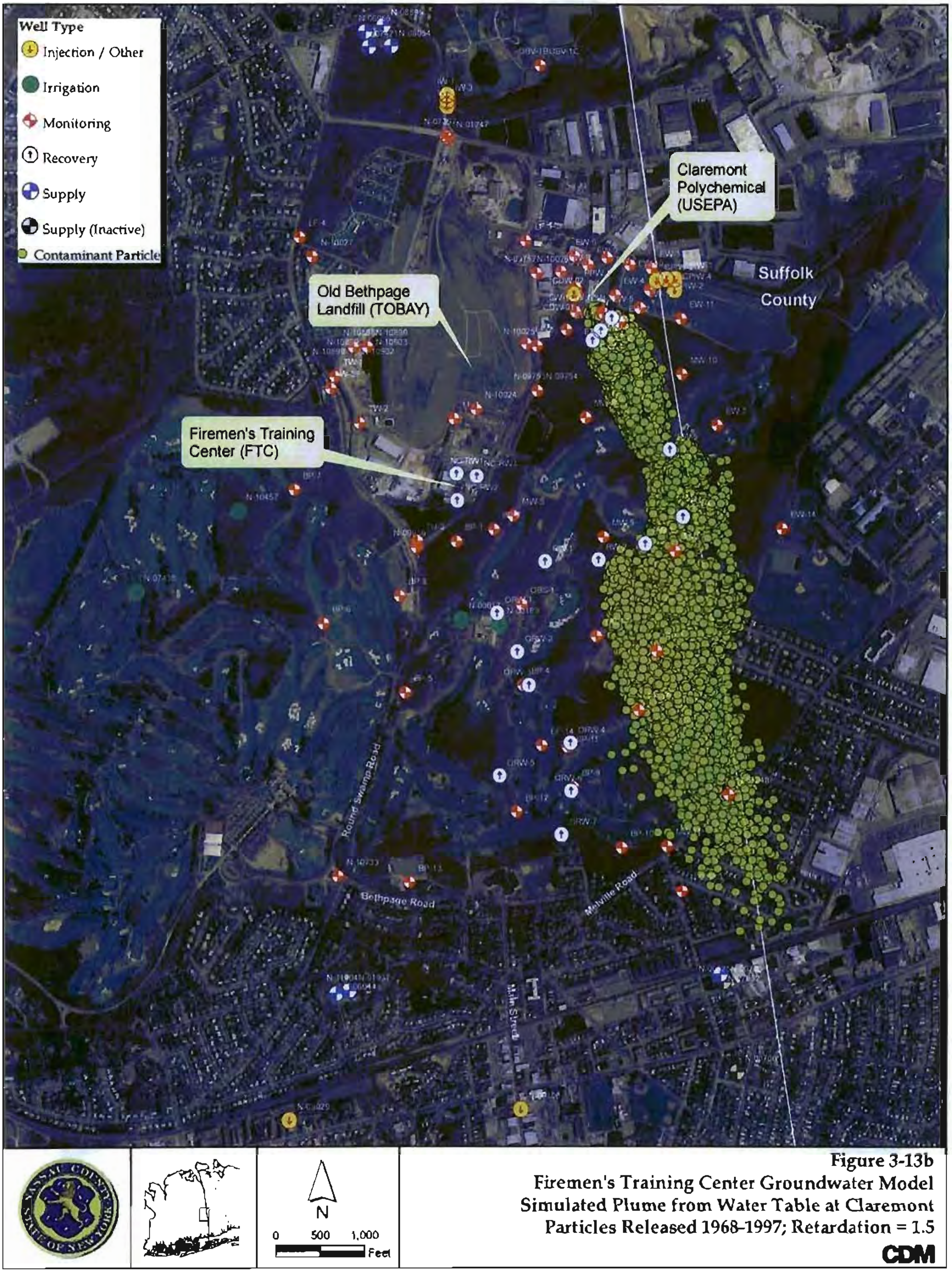


Figure 3-13b
Firemen's Training Center Groundwater Model
Simulated Plume from Water Table at Claremont
Particles Released 1968-1997; Retardation = 1.5

CDM

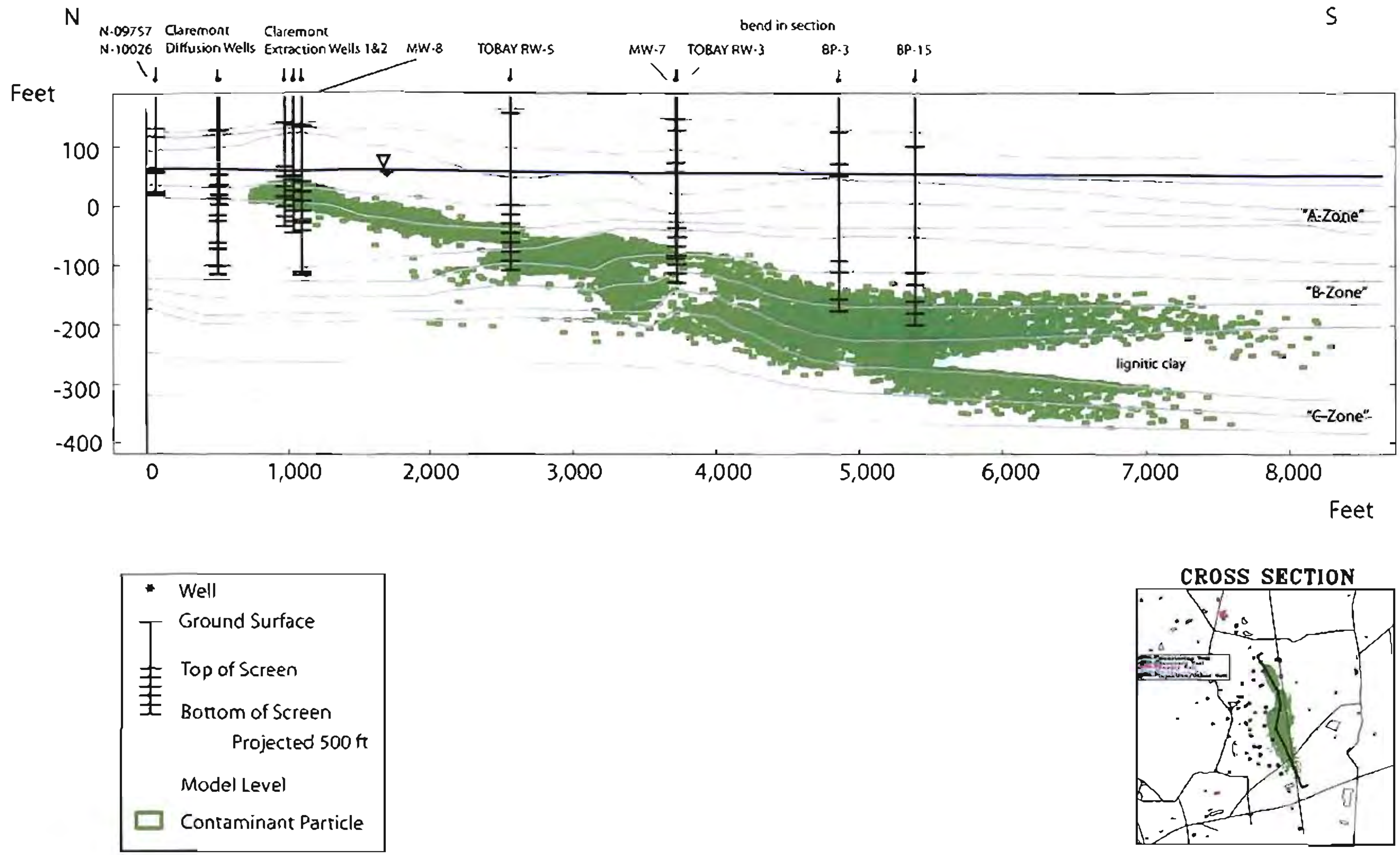


Figure 3-13c
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Water Table at Claremont Facility, 2007
Particles Released from Water Table 1968 - 1997; R = 1.5
CDM

and the model simulation shows that water table contamination from Claremont has migrated downgradient of the TOBAY system before it was operational. As shown on Figure 13c, as the plume moves downgradient, a portion of the plume remains above the lignitic clay in the "B-Zone", while another portion of the plume sinks below the lignitic clay into the "C-Zone". The portion of the plume that remains in the "B-Zone" appears to be under the influence of the Nassau County DPW offsite recovery wells as the centerline of the plume shifts westward by approximately 500 feet. In addition, the western edge of the simulated plume migrates toward the County recovery wells.

The results from the sensitivity simulation without retardation from the Claremont water table source are shown on Figure 13d. As shown on the figure, conservative particles, without retardation, are captured by the County recovery wells ORW-4, ORW-6 and ORW-7.

Although it is not likely that a contaminant plume would not have any retardation, the model indicates that a water table source at Claremont could have migrated downgradient and become influenced and potentially captured by the County recovery wells. As shown in Figure 3-13c, the lignitic clay layer strongly influences the migration of the plume from the water table at Claremont.

It is important to note that the simulated plume does not include decay and concentrations were not simulated. In addition, the water table source area should be verified and further investigated. Should additional water table source(s) at the Claremont site be identified, those sources should be simulated to evaluate contaminant migration and the potential impact to County recovery wells.

3.4.2 Potential Upgradient Sources

Monitoring wells that were recently installed upgradient of Claremont have been sampled and found to contain contaminated groundwater at depth. To investigate the migration of plumes from potential upgradient sources, a series of contaminant transport simulations were conducted. The NCDPW has identified six potential sources in Nassau County, five of which are upgradient of Claremont (Figure 3-14):

- The former Captree Chemical facility (currently Mr. Bar-B-Que);
- The former American Louvre facility;
- Trulite Louvre (formerly Filtron Corporation);
- Hitemco Corporation;
- The former Dyna Force Inc. (currently Molloy Brothers Moving & Storage); and
- The former Life Industries facility (currently GEFA Instrument Corp.)

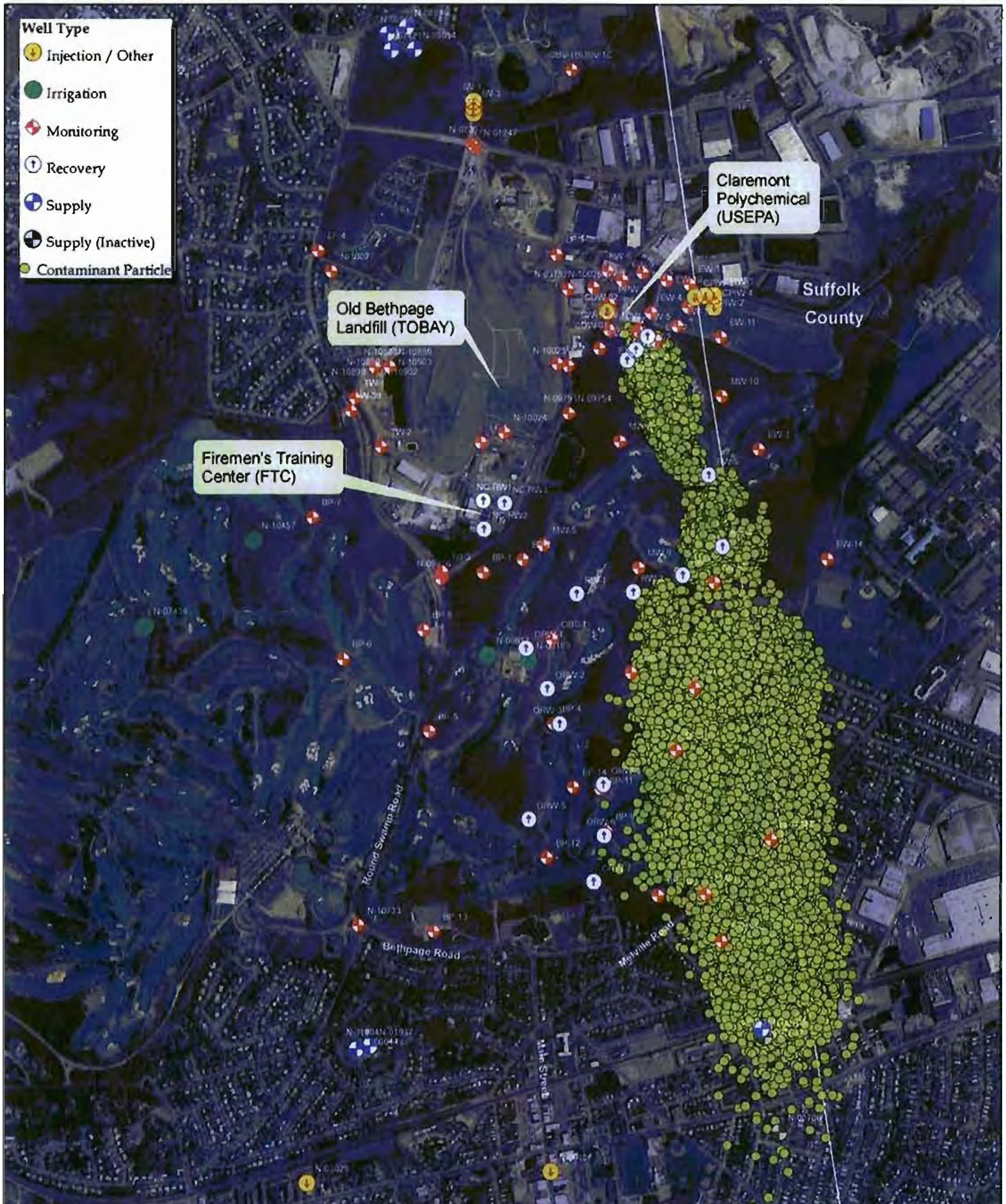


Figure 3-13d
Firemen's Training Center Groundwater Model
Simulated Plume from Water Table at Claremont
Particles Released 1968-1997; No Retardation

CDM

Figure 3-14
Firemen's Training Center Groundwater Model
Potential Upgradient Sources from FTC
Nassau County
CDM

Each of the industrial sites were selected as potential upgradient sources following a review of Nassau County Department of Health, Bureau of Environmental Protection, Toxic and Hazardous Material Storage records. The Nassau County Tax records were used to establish ownership, site use and location. A site was classified as a potential source if it historically stored or handled any of the volatile organic compounds identified in groundwater beneath Bethpage State Park.

For each potential source, arbitrary concentrations were fixed at the water table during its period of operation. One site, Hitemco Corp., fixes concentrations at a diffusion well reported to be located onsite.

It is important to note that these simulations are entirely hypothetical and there are no current investigations being conducted regarding any of these facilities.

3.4.2.1 *Former Captree Chemical Corporation*

The contaminant transport simulation from the former Captree Chemical Corporation used a fixed arbitrary concentration at the water table in the center of the facility from 1984 through 1990, the facilities known period of operation.

Results of the contaminant transport simulation are shown in plan view and cross section on Figures 3-15 and 3-15a, respectively. The hypothetical plume migrated into the top of the B-Zone but is eventually captured by the TOBAY remediation system. Sensitivity simulations without retardation also indicate that the plume is captured by the TOBAY recovery system (recovery wells: RW-3 through RW-5).

3.4.2.2 *Former American Louvre*

The contaminant transport simulation from the former American Louvre facility fixed an arbitrary concentration at the water table in the center of the facility from 1983 through 1995. As with the Captree Chemical simulation, this simulation used a retardation factor of 1.5, representing a typical retardation factor for organic compounds.

Results of the contaminant transport simulation are shown in plan view and cross section on Figures 3-16 and 3-16a, respectively. The hypothetical plume migrates in a south-easterly direction and is eventually captured by TOBAY recovery wells (RW-3 through RW-5). Sensitivity simulations without retardation indicate that the plume is also captured by the TOBAY remediation system.

3.4.2.3 *Trulite Louvre/Former Filtron Corporation*

The contaminant transport simulation from the former Trulite Louvre again used a fixed arbitrary concentration at the water table in the center of the facility. A fixed concentration was used from 1972 through 1992 and continued to run until 2007. The simulation also used a retardation factor of 1.5.

Results of the contaminant transport simulation are shown in plan view and cross section on Figures 3-17 and 3-17a, respectively. The hypothetical plume migrates deeper

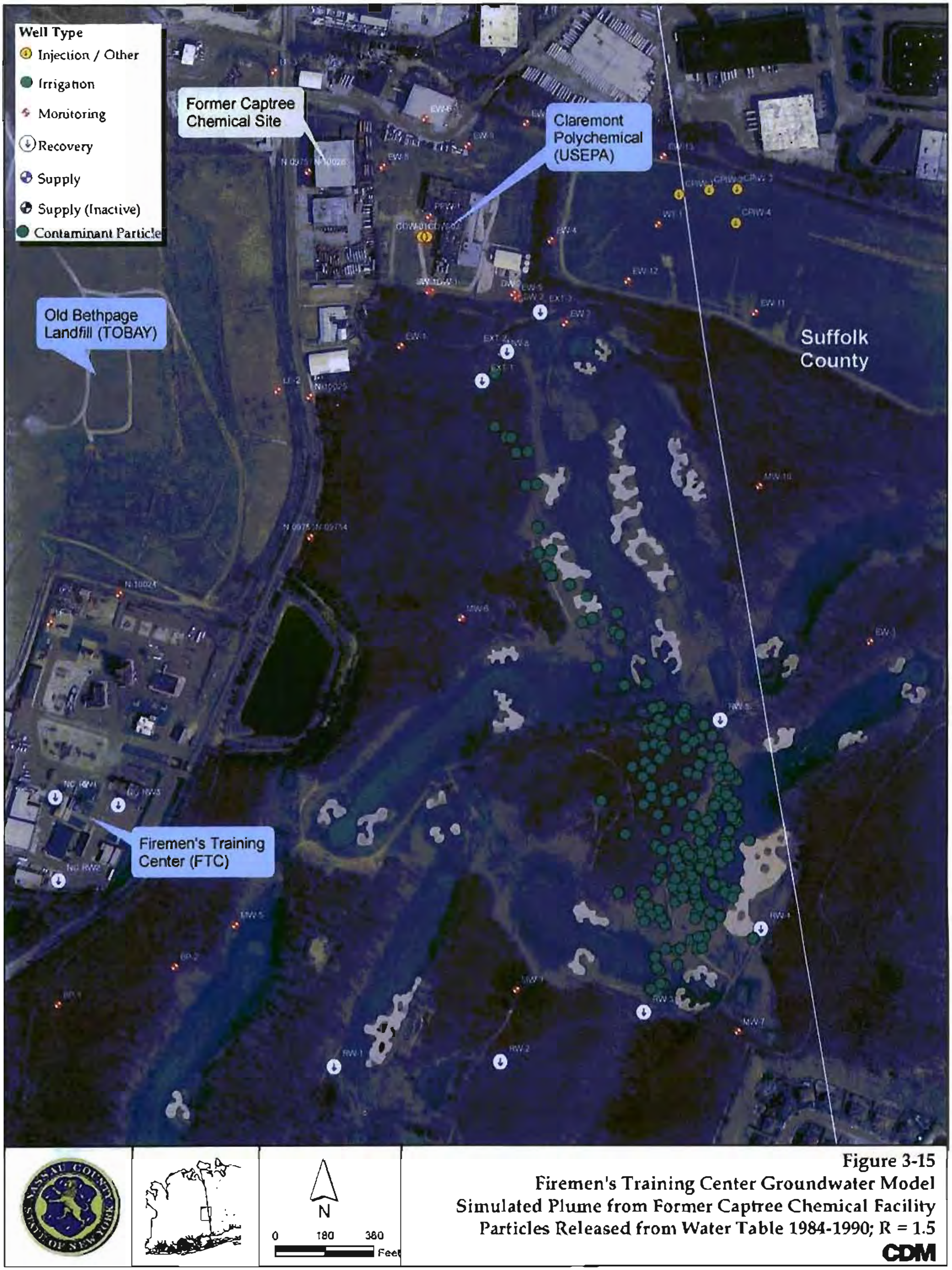


Figure 3-15
Firemen's Training Center Groundwater Model
Simulated Plume from Former Captree Chemical Facility
Particles Released from Water Table 1984-1990; R = 1.5
CDM

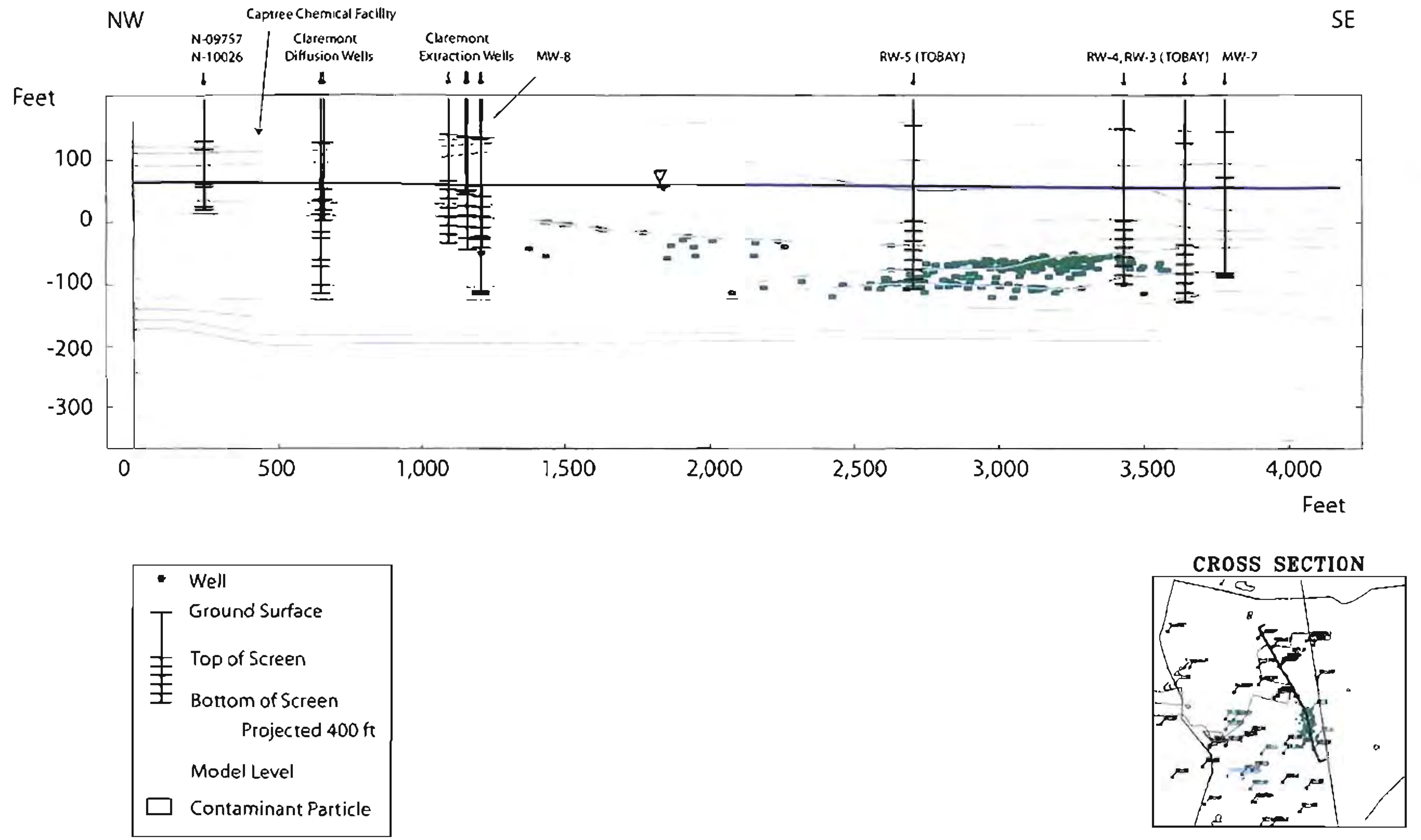


Figure 3-15a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Former Captree Chemical Facility, 2007
Particles Released from Water Table 1984 - 1990; R = 1.5

CDM

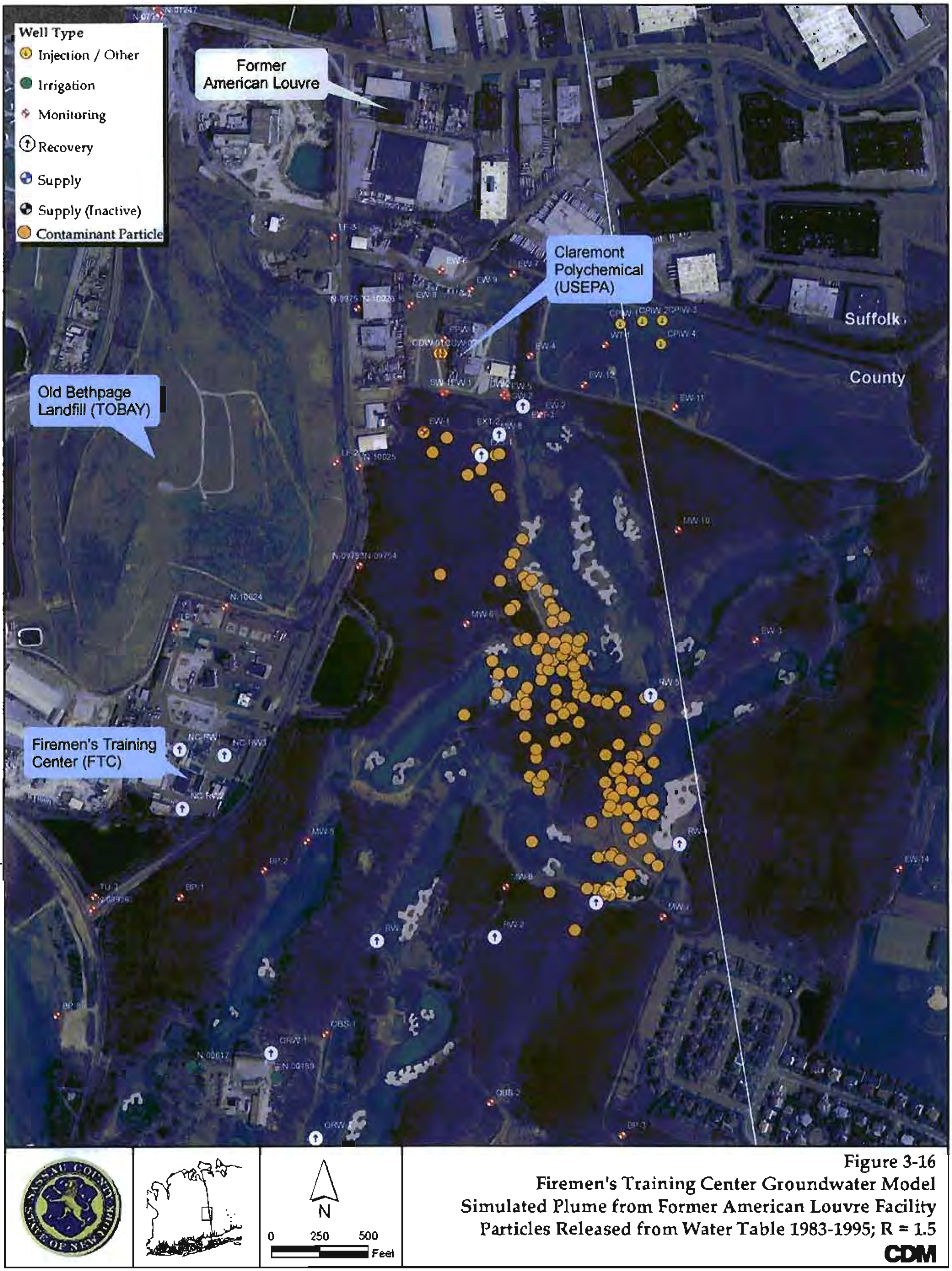


Figure 3-16
Firemen's Training Center Groundwater Model
Simulated Plume from Former American Louvre Facility
Particles Released from Water Table 1983-1995; R = 1.5
CDM

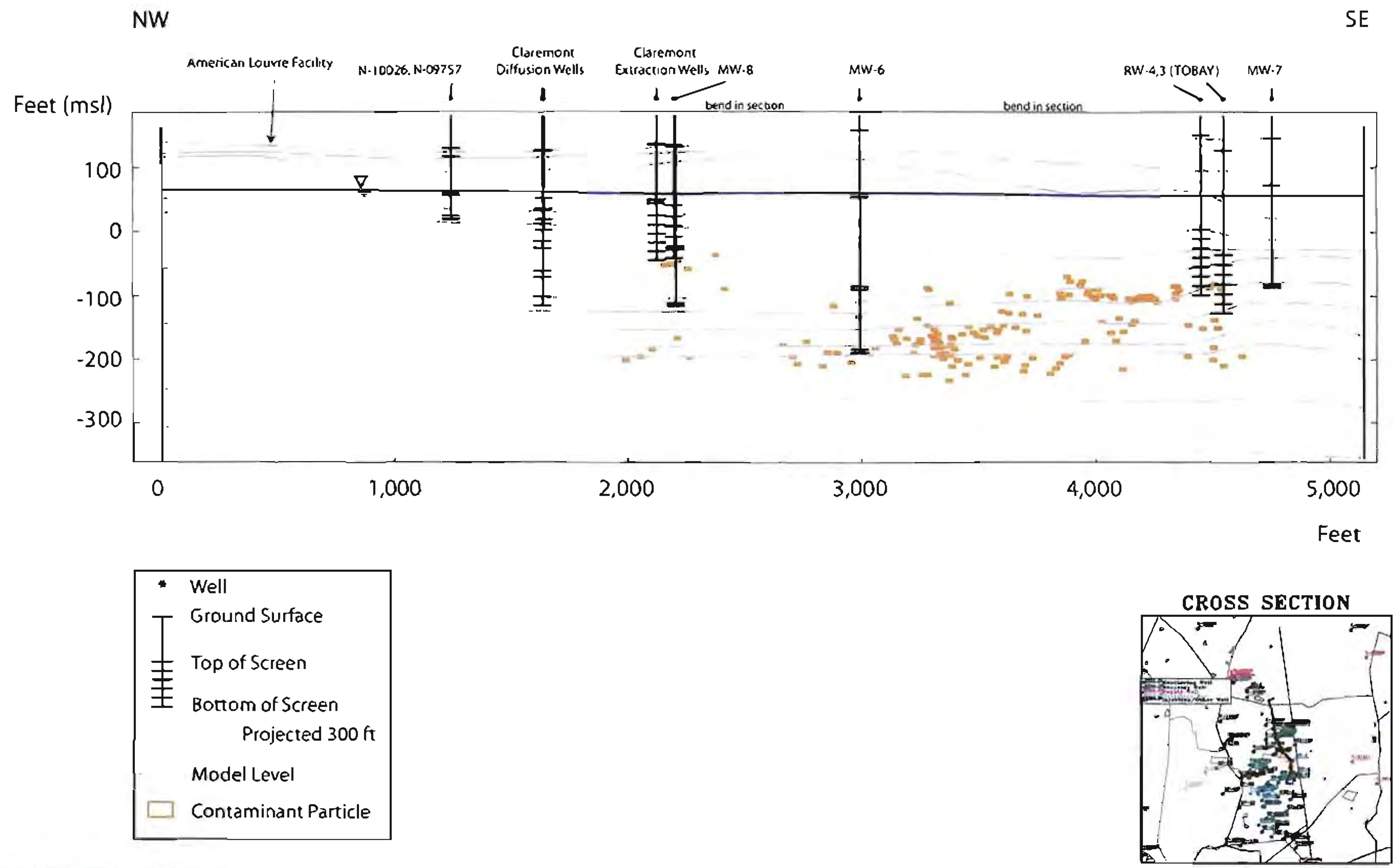


Figure 3-16a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Former American Louvre Facility, 2007
Particles Released from Water Table 1983 - 1995; R = 1.5
CDM

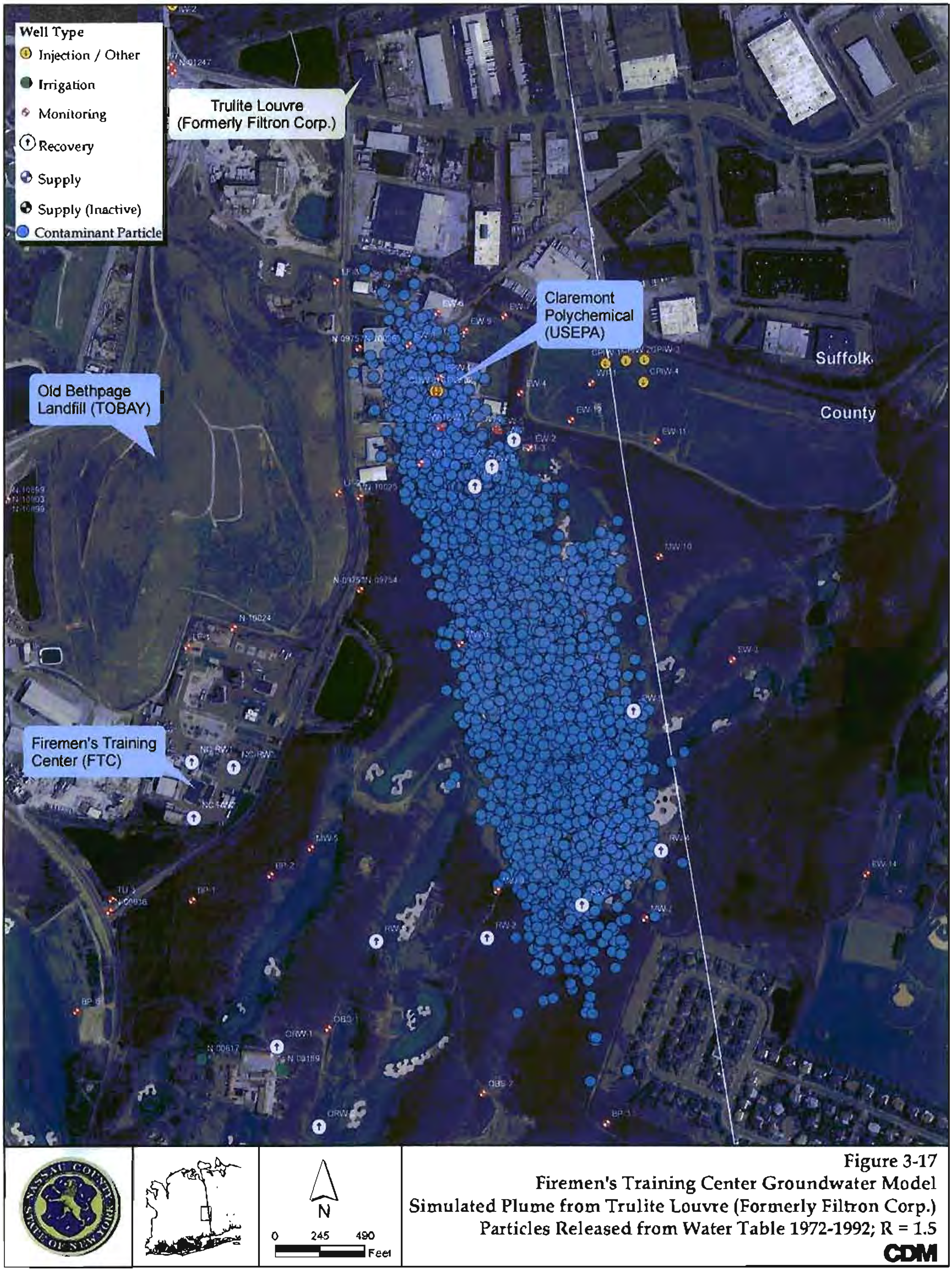


Figure 3-17
Firemen's Training Center Groundwater Model
Simulated Plume from Trulite Louvre (Formerly Filtron Corp.)
Particles Released from Water Table 1972-1992; R = 1.5

CDM

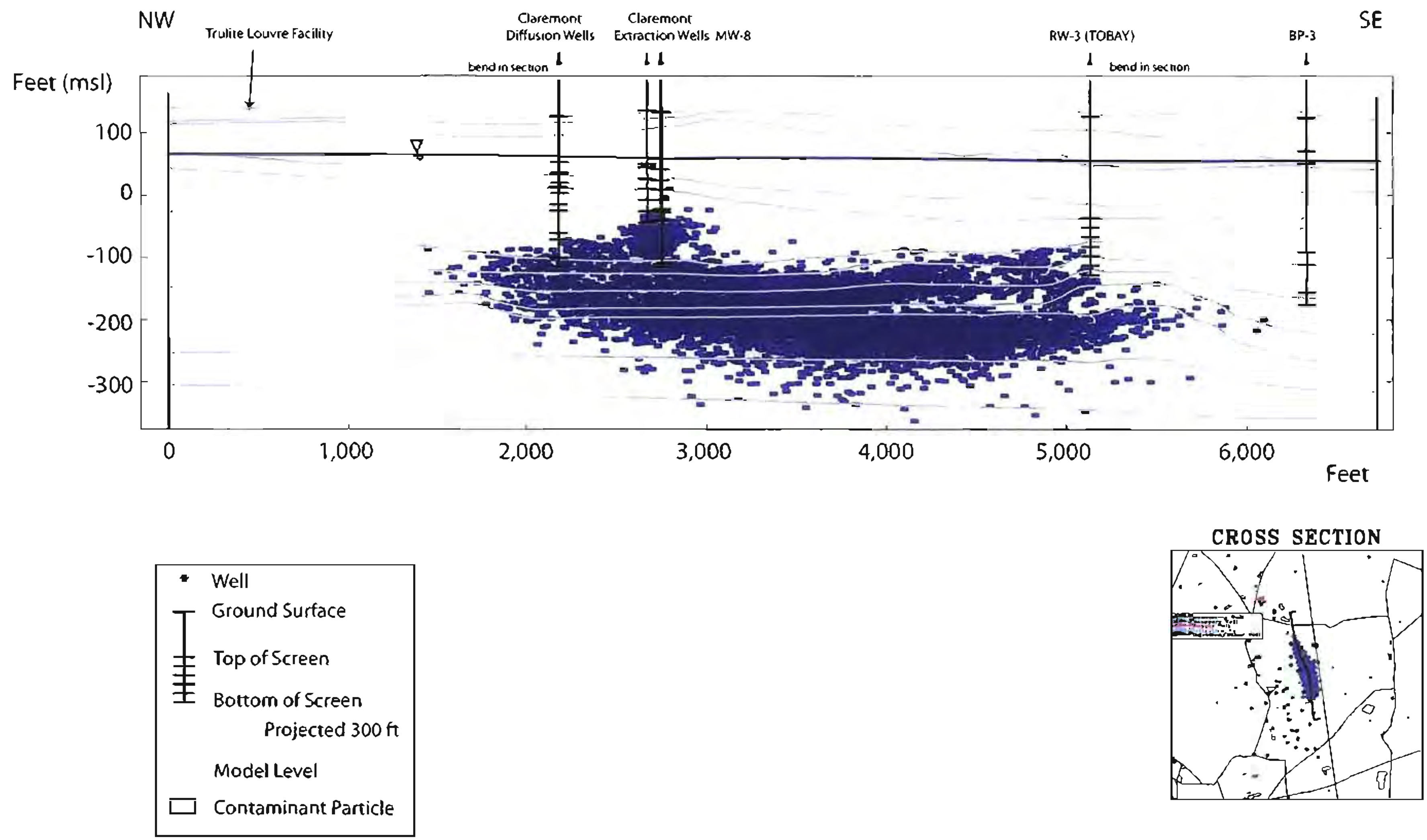


Figure 3-17a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Trulite Louvre (Former Filtron Corp.), 2007
Particles Released from Water Table 1972 - 1992; R = 1.5
CDM

into the B-Zone than the other simulations. The upper portion of the plume is captured by both the Claremont and TOBAY remediation systems, while some of the basal portion of the plume migrates downgradient beneath the TOBAY system and eventually into the C-Zone (Figure 17a). Sensitivity simulations without retardation indicate that the upper portion of the plume is captured by the TOBAY and Claremont systems while basal portions of the plume migrate downgradient into the C-Zone beneath the lignitic clay and south of Melville Road toward the Village of Farmingdale supply well 1-3 (N-07852).

3.4.2.4 Hitemco Corporation

The contaminant transport simulations from the Hitemco facility are slightly different than the other potential upgradient sources since two simulations were conducted: one using a fixed arbitrary concentration at 200 feet below grade, the approximate location of a diffusion well screen on the property, and a second from the water table, at a hypothetical location on the north side of the building. Also, as this facility is still in operation, concentrations were fixed until the present.

A fixed arbitrary concentration was used from 1981 and the simulation continued to run until 2007. As with other facilities, a retardation factor of 1.5 was assigned.

Results of the contaminant transport simulation from the diffusion well are shown in plan view and cross section on Figures 3-18 and 3-18a, respectively. Since contamination is fixed at depth, the hypothetical plume migrates deeper than the other simulations. Shallow portions of the plume are captured by the Claremont Polychemical extraction wells, while other portions of the plume eventually migrate into the C-Zone. The migration of this plume seems to be limited by its movement through the lignitic clay and appears that much of the plume will travel beneath the TOBAY recovery system.

A sensitivity simulation was conducted without retardation to determine if the plume will migrate past the TOBAY system. Results of that simulation suggest that the plume migrates into the C-Zone and follows a south-southeast trend. Without retardation, the plume migrates to just east of Nassau County recovery well ORW-6.

Results of the contaminant transport simulation from the water table at Hitemco are shown in plan view and cross-section on Figures 3-18b and 3-18c, respectively. As shown on the figures, the hypothetical plume is captured by the Claremont extraction wells and TOBAY recovery wells RW-3, RW-4 and RW-5. A sensitivity simulation without retardation indicates that the surface of the plume is captured by these two systems however a portion of the plume sinks into the C-Zone and migrates approximately 1,000 feet downgradient of the TOBAY recovery wells.

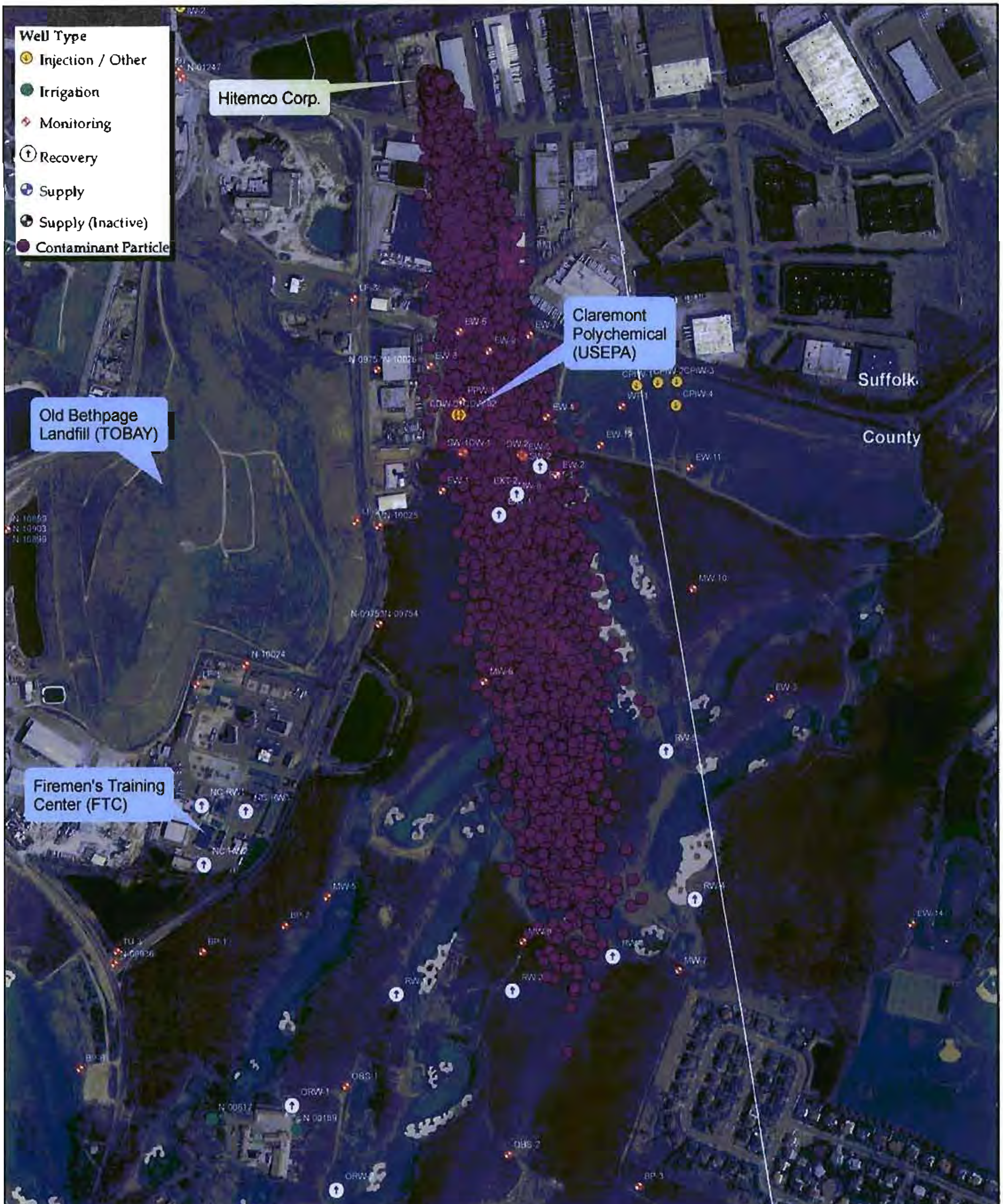
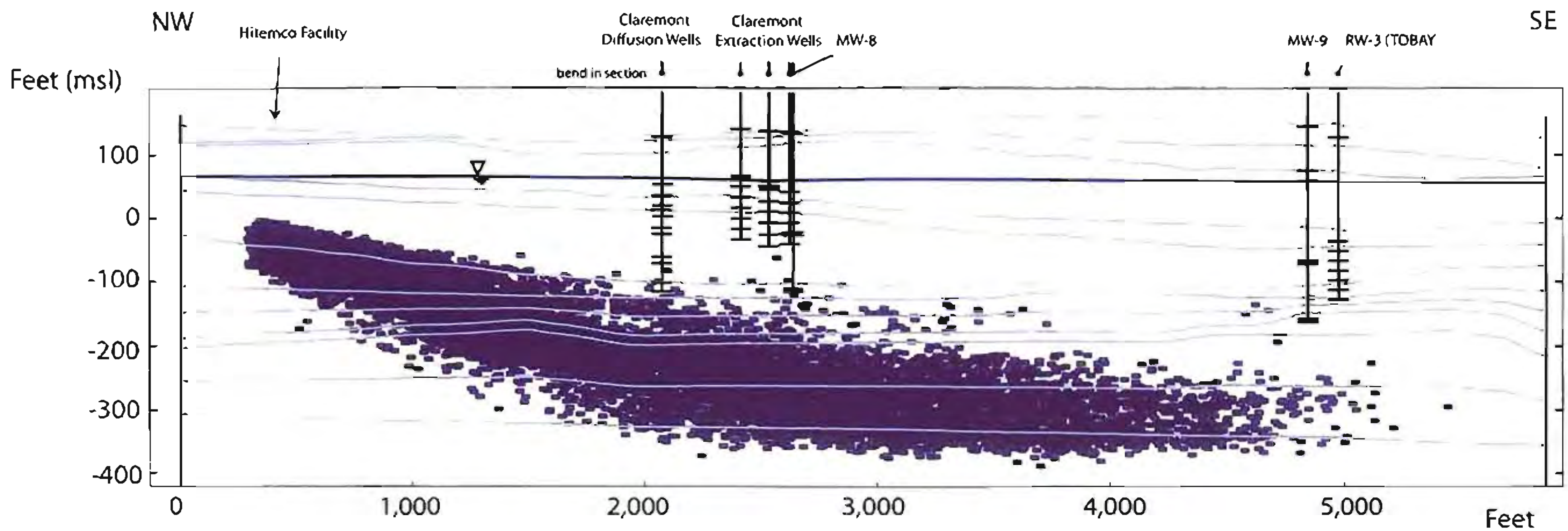


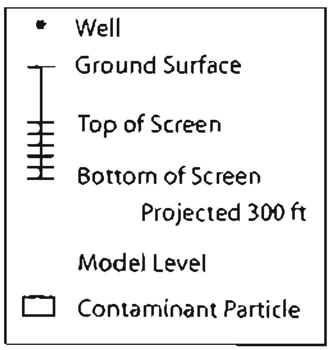
Figure 3-18
Firemen's Training Center Groundwater Model
Simulated Plume from Hitemco Corporation
Particles Released from Diffusion Well 1981-Present; R = 1.5

N

0 245 490 Feet

CDM





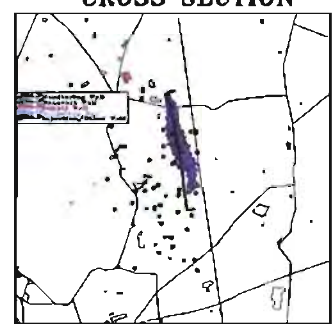


Figure 3-18a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Hitemco, 2007
Particles Released from Diffusion Well 1981 - Present; R = 1.5

CDM

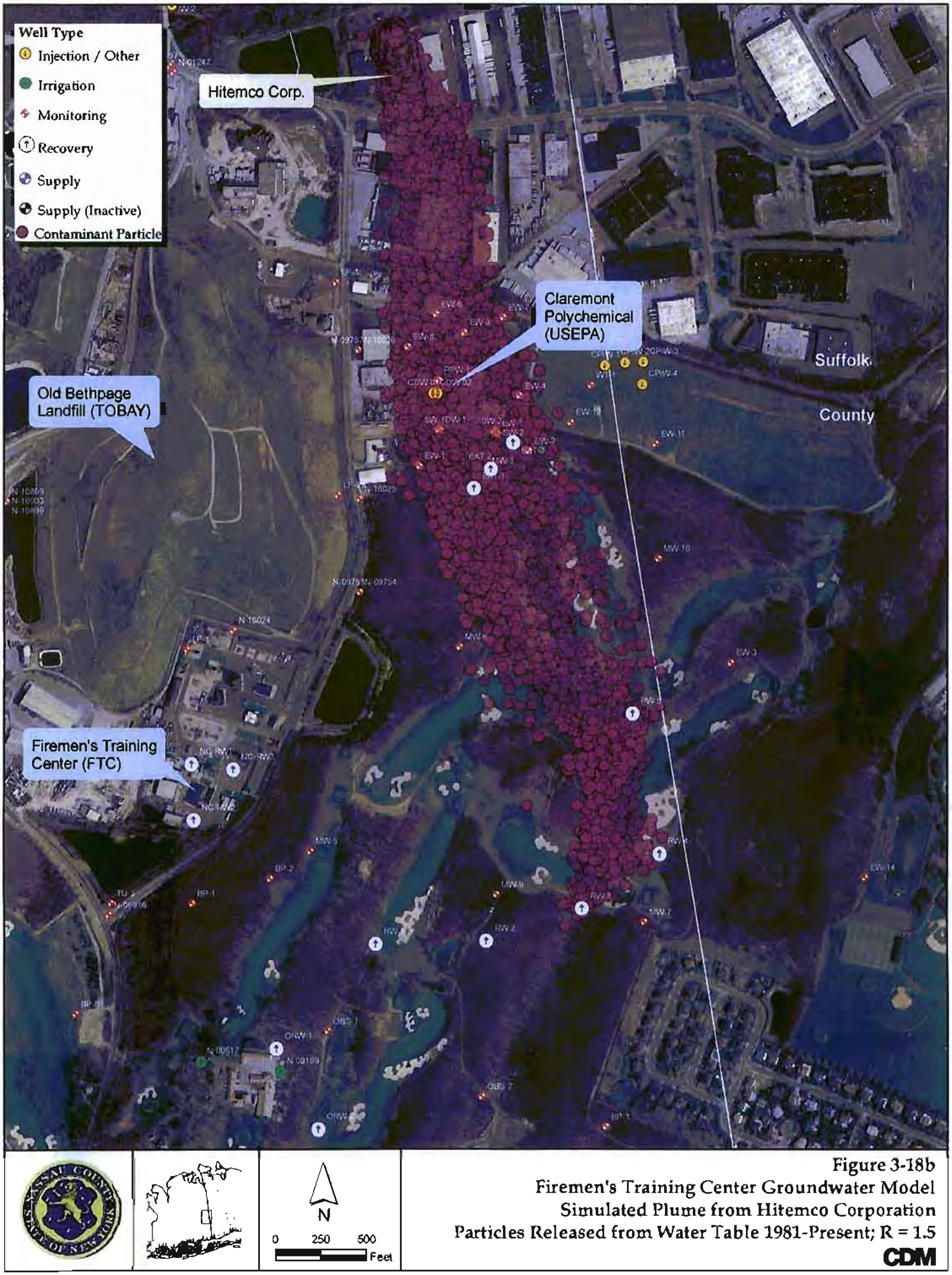


Figure 3-18b
Firemen's Training Center Groundwater Model
Simulated Plume from Hitemco Corporation
Particles Released from Water Table 1981-Present; R = 1.5
CDM

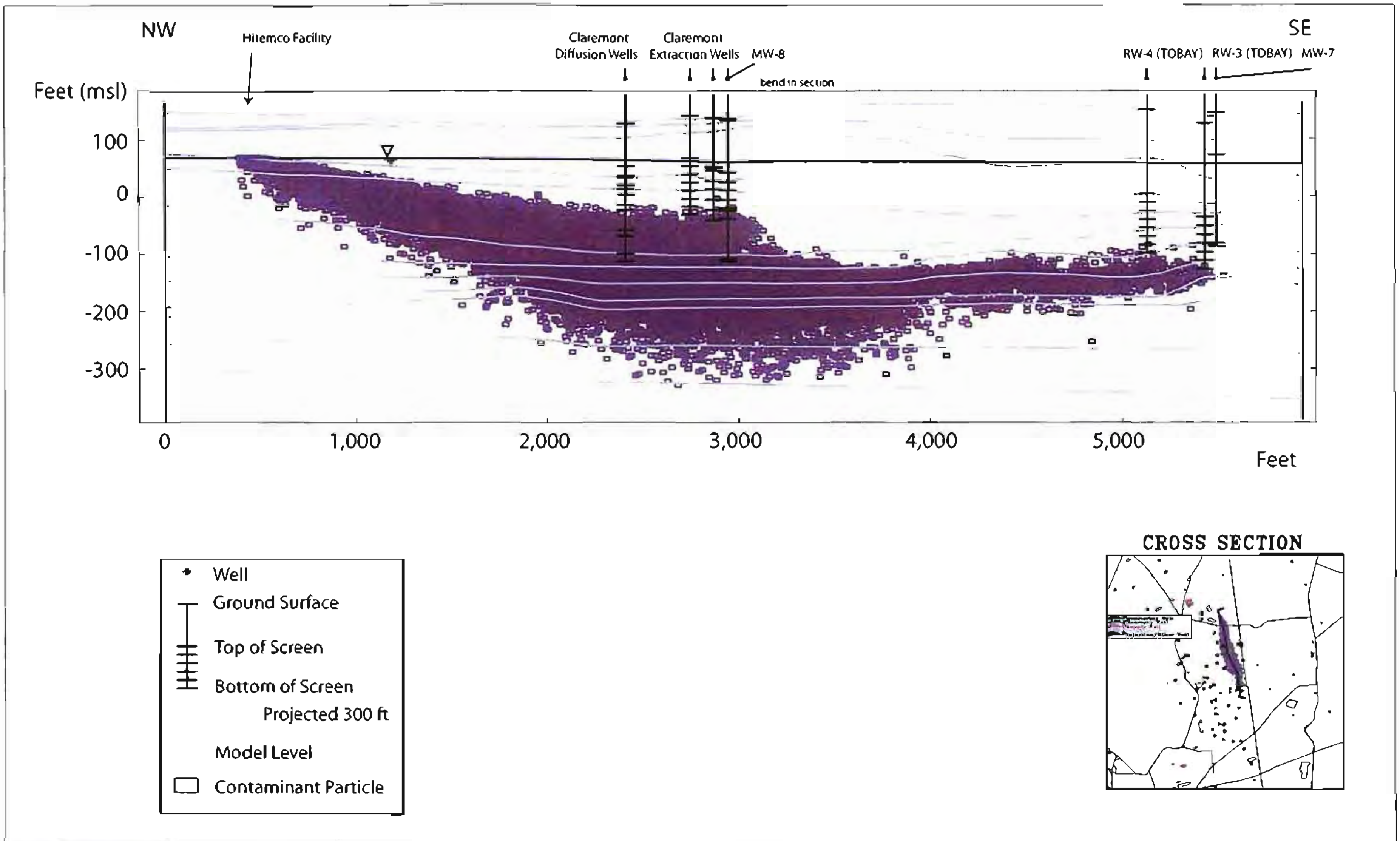


Figure 3-18c
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Hitemco, 2007
Particles Released from the Water Table 1981 - Present; R = 1.5
CDM

3.4.2.5 *Former Dyna Force Inc.*

The contaminant transport simulation from the former Dyna Force Inc. facility used a fixed arbitrary concentration at the water table in the center of the facility. A fixed concentration was used from 1981 through 1993 and continued to run until 2007. The simulation also used a retardation factor of 1.5.

Results of the contaminant transport simulation are shown in plan view and cross section on Figures 3-19 and 3-19a, respectively. The hypothetical plume migrates south-southeast and is eventually captured by the TOBAY remediation system (RW-3, RW-4 and RW-5). Sensitivity simulations without retardation indicate that much of the plume is captured by the TOBAY system, although some particles migrate into the C-Zone beneath the TOBAY system reaching approximately 1,000 feet downgradient of TOBAY recovery well RW-3, approaching BP-3C.

3.4.2.6 *Former Life Industries Facility*

The contaminant transport simulation from the former Life Industries facility used a fixed arbitrary concentration at the water table in the center of the facility. A fixed concentration was used from 1983 through 1996 and continued to run until 2007. The simulation also used a retardation factor of 1.5, representing a typical retardation factor for organic compounds.

Results of the contaminant transport simulation are shown in plan view and cross section on Figures 3-20 and 3-20a, respectively. The hypothetical plume migrates south-southeast and is eventually captured by the TOBAY remediation system. Sensitivity simulations without retardation indicate that a portion of the plume migrates into Suffolk County, but most of the plume is eventually captured by the TOBAY recovery system. A few particles migrate into the C-Zone past the TOBAY system.

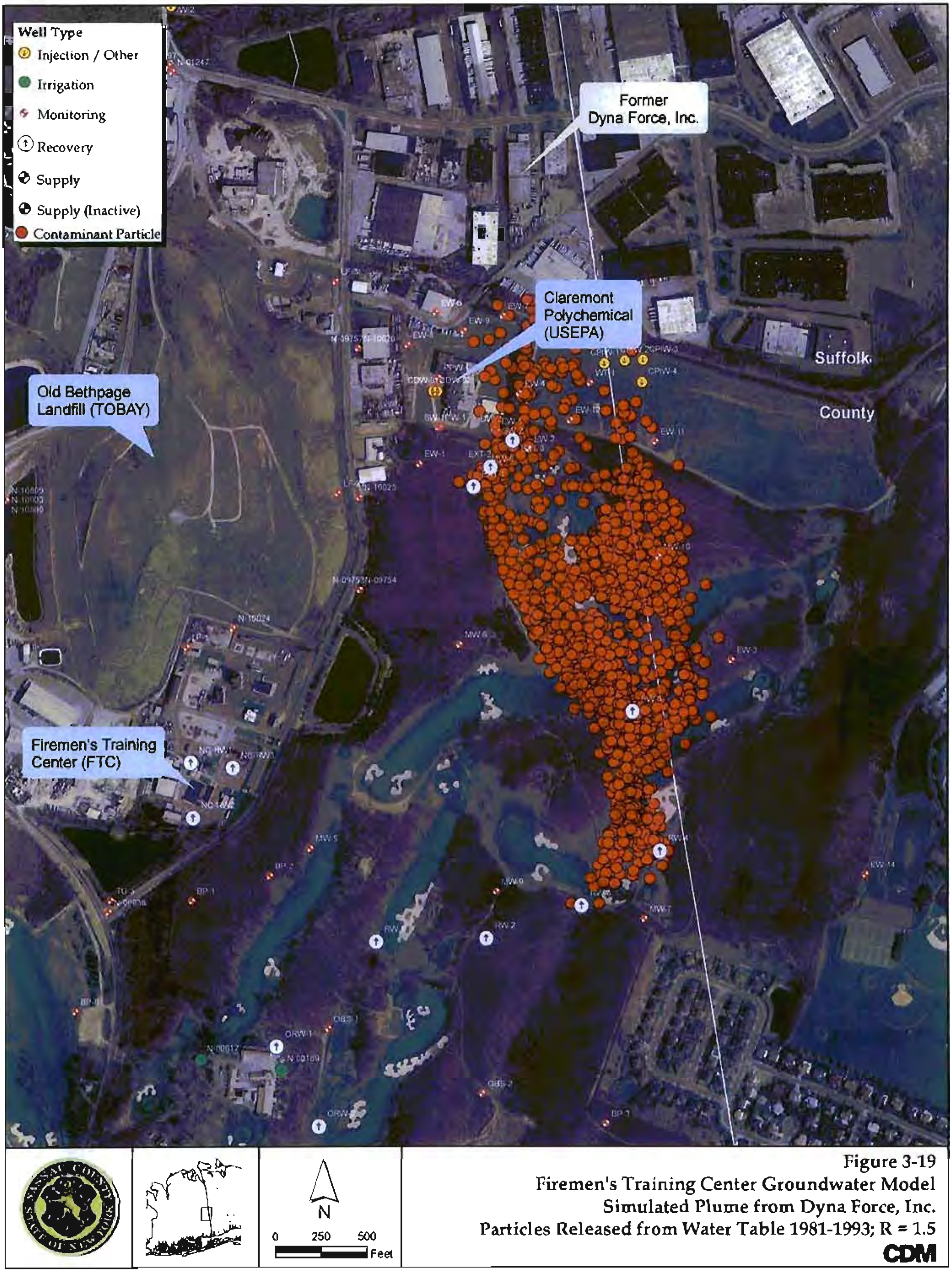
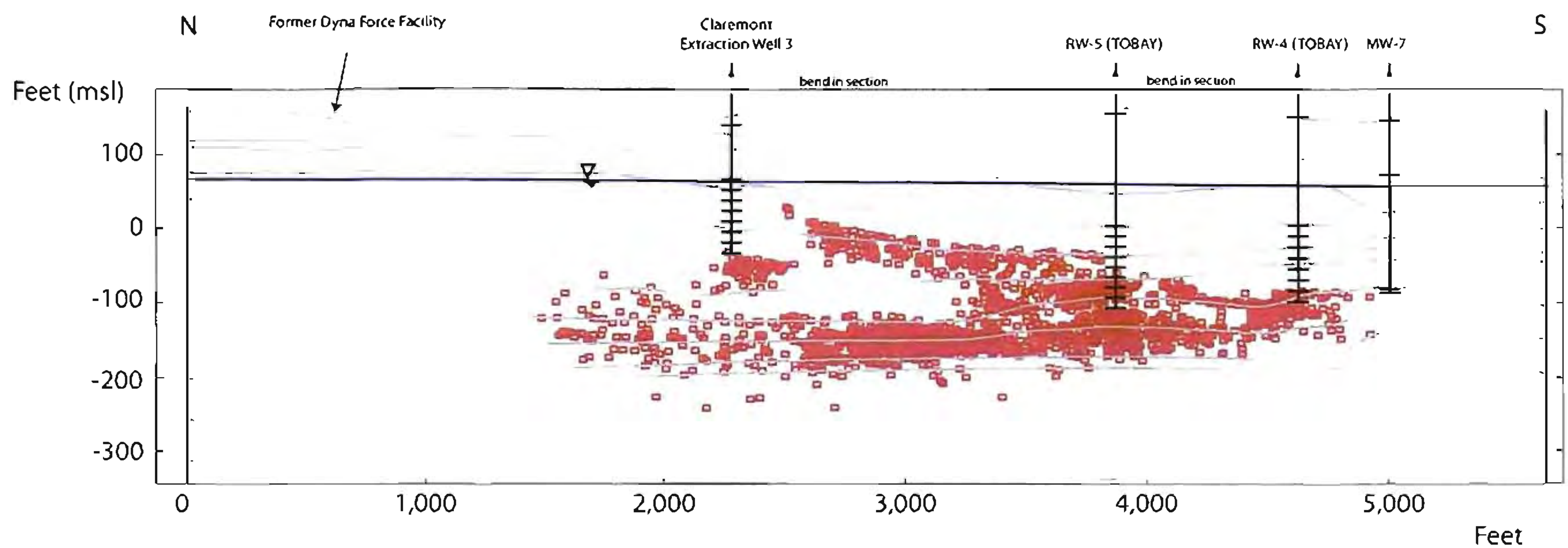
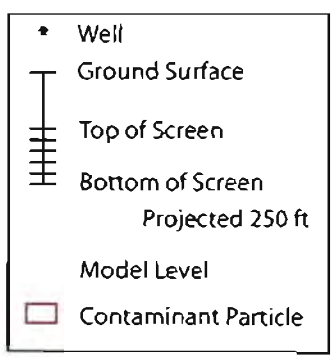


Figure 3-19
Firemen's Training Center Groundwater Model
Simulated Plume from Dyna Force, Inc.
Particles Released from Water Table 1981-1993; R = 1.5

CDM





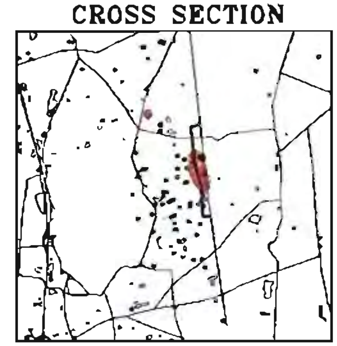


Figure 3-19a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Dyna Force Inc., 2007
Particles Released from Water Table 1981 - 1993; R = 1.5

CDM

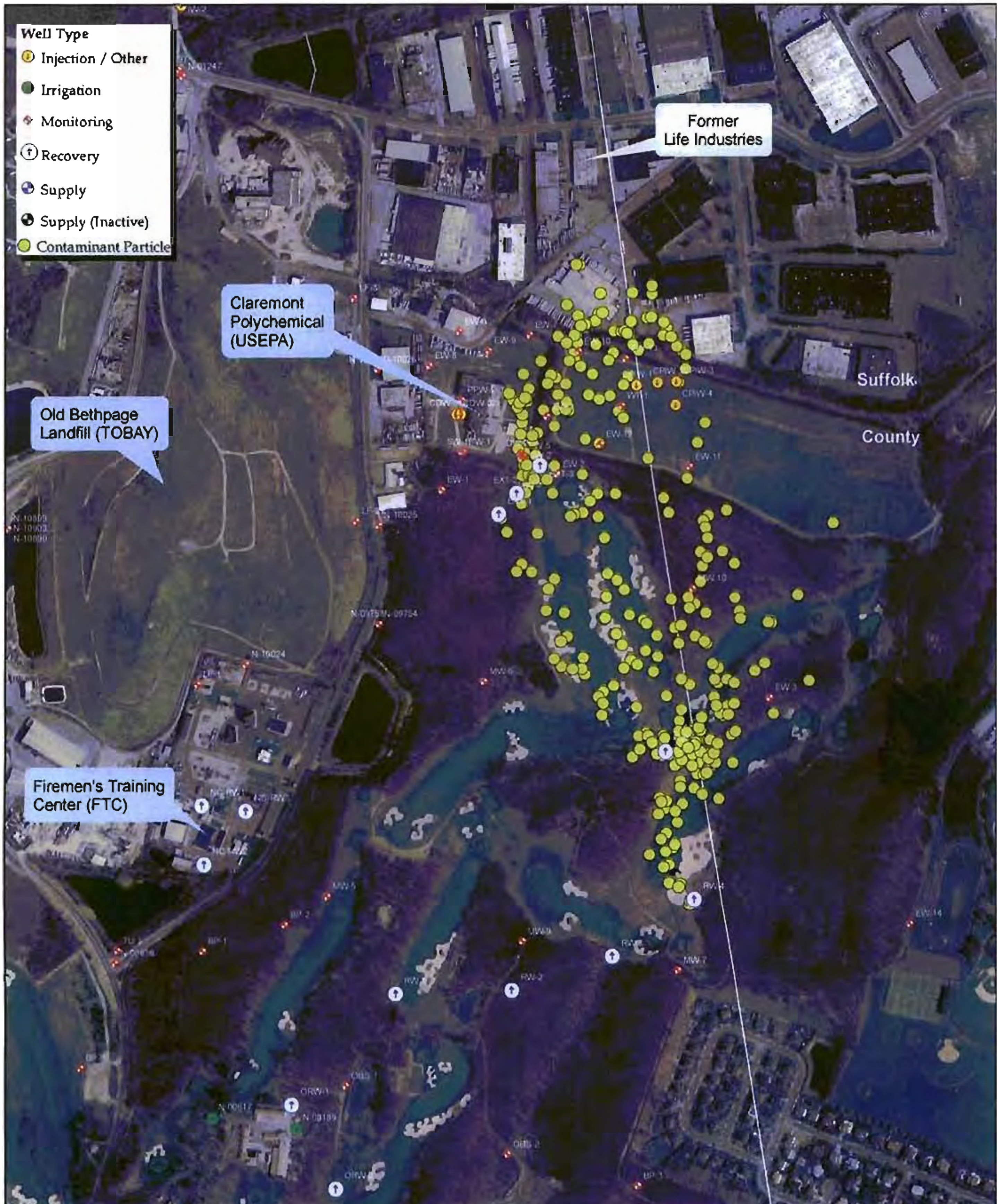
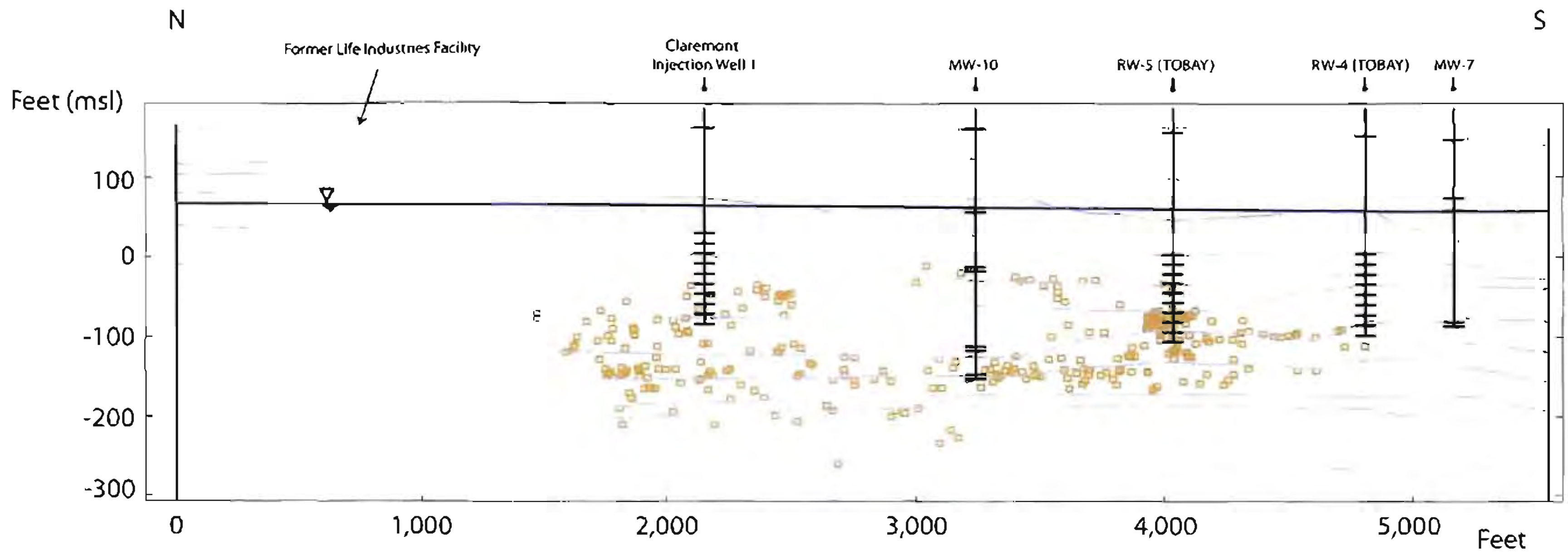


Figure 3-20
Firemen's Training Center Groundwater Model
Simulated Plume from Former Life Industries
Particles Released from Water Table 1983-1996; R = 1.5

CDM



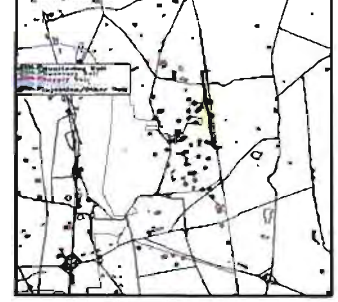


Figure 3-20a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Hydrocarbon Plume from Life Industries, 2007
Particles Released from Water Table 1983 - 1995; R = 1.5

CDM

3.4.2.7 Contaminant Plume Summary

The simulation results indicate that many of the hypothetical plumes generated from potential upgradient sources eventually are captured by the TOBAY recovery system (RW-3 through RW-5).

Although actual pumpage data from the TOBAY system are incorporated where available, some assumptions are included. For example, if only quarterly data were available, it is assumed that the pumping remains constant throughout the quarter.

Hypothetical plumes that migrate into the C-Zone flow through the lignitic clay or migrate into the C-Zone through areas where the lignitic clay is absent. In most cases where the plumes flow through the lignitic clay, it is relatively thin, on the order of 20 feet or so. The properties of this clay may control transport and the thickness of the clay is interpolated in many areas.

The contaminant transport simulations described above use a retardation factor of 1.5. This is a general retardation factor and is used in these simulations since the plumes are hypothetical. A higher retardation factor would simply delay the transport of the hypothetical plume. However, most of the plumes are eventually captured by the TOBAY system. Since the TOBAY system is running continuously in the model through 2025, a higher retardation factor would simply delay its capture. However, a lower retardation factor will cause the plume to migrate faster and therefore, can potentially bypass the TOBAY remediation system.

Sensitivity simulations suggest that the hypothetical plumes originating from the water table at Captree Chemical, American Louvre, Hitemco, and Life Industries would be captured by the TOBAY system **without** retardation (conservative tracer). Without retardation, simulated plumes from the Hitemco facility diffusion well, Trulite Louvre (formerly Filtron Corp.), and the former Dyna Force facility migrate further downgradient. The simulated plume from the Trulite Louvre and Dyna Force facilities migrate considerably further without retardation in which some of the plume sinks into the C-Zone and bypasses the TOBAY recovery system. Although model simulations do not indicate that these sources impact Nassau County offsite recovery wells (through 2006), potential contamination from these sites may explain contaminants found in C-Zone monitoring wells and therefore additional investigation into these sources should be done.

3.4.2.8 Particle Tracking Simulations

In addition to contaminant plume simulations, particle tracking simulations were also conducted from each potential upgradient source. A single particle is released within the aquifer at a specific location (x, y, z) and allowed to travel forward with time along the groundwater flow path. Dispersion was not included in these runs, although retardation of the particle was simulated, as its movement through the aquifer is slowed by adsorption. Following release, the particle is advected through the system without dispersion until a discharge boundary or node is encountered at which time the particle is deleted. The run continues until the particle is deleted (either discharged through the sediment-water interface into a surface water body or is removed from a pumping well) or the end of the simulation is reached. The location of the particle (x,y,z) is saved at each time step.

As with the contaminant plume simulations, results from the transient groundwater model were used for the particle track simulations where the transient flow field (30-day time steps) was utilized throughout the contaminant transport simulations. Particles were released at the water table for each year the facility (or diffusion well) was in operation. For the Hitemco simulation, particles were also released at the well screen of the diffusion well.

For each source, a particle was released each year the facility was in operation. Figure 3-21 shows particle track simulation results for Captree Chemical, Trulite Louvre, Hitemco (diffusion well), and the former Dyna Force facility. As in the contaminant plume simulations, a retardation factor of 1.5 was used for these simulations. As shown on the figure, the TOBAY system captures most of these sources, with the exception of Hitemco (migrates into the C-Zone, not shown on Figure 3-21). Particle tracks from Dyna Force migrate toward Suffolk County, but are redirected as the TOBAY system comes online.

Figure 3-22 shows the results of particle track simulations from the former American Louvre, the water table at Hitemco, and Life Industries facilities. Particles migrate downgradient in a southeasterly direction, but eventually migrate into the capture zone of TOBAY recovery well number 5.

Particle track simulations were also conducted originating from discrete sampling intervals of the wells that were installed upgradient of Claremont by the USEPA. These wells, EW-02, EW-07 and EW-10 were recently sampled and shown to contain contaminated groundwater. Particles were released in contaminated groundwater zones that were collected during the boring of each monitoring well. Particles were released in 5-foot intervals as follows:

- EW-02: 10 to 75 feet below mean sea level (msl);
- EW-07: 30 to 100 feet below msl; and
- EW-10: 5 feet above msl to 75 feet below msl.

Results of the EW particle tracks are shown on Figure 3-23. Most of the simulated particles are captured by Claremont extraction well EXT-3. Particles released from EW-02 are captured by Claremont extraction well EXT-3 within 1 year from release. Particles released from EW-10 from shallow portions of the location (depths to -50 feet msl) are also captured by Claremont extraction well EXT-3 within 2 years and the remaining particles are captured within 3 years of release. Particles that were released from EW-07 down to -85 feet msl are also captured by Claremont extraction well EXT-3 within 4 years.

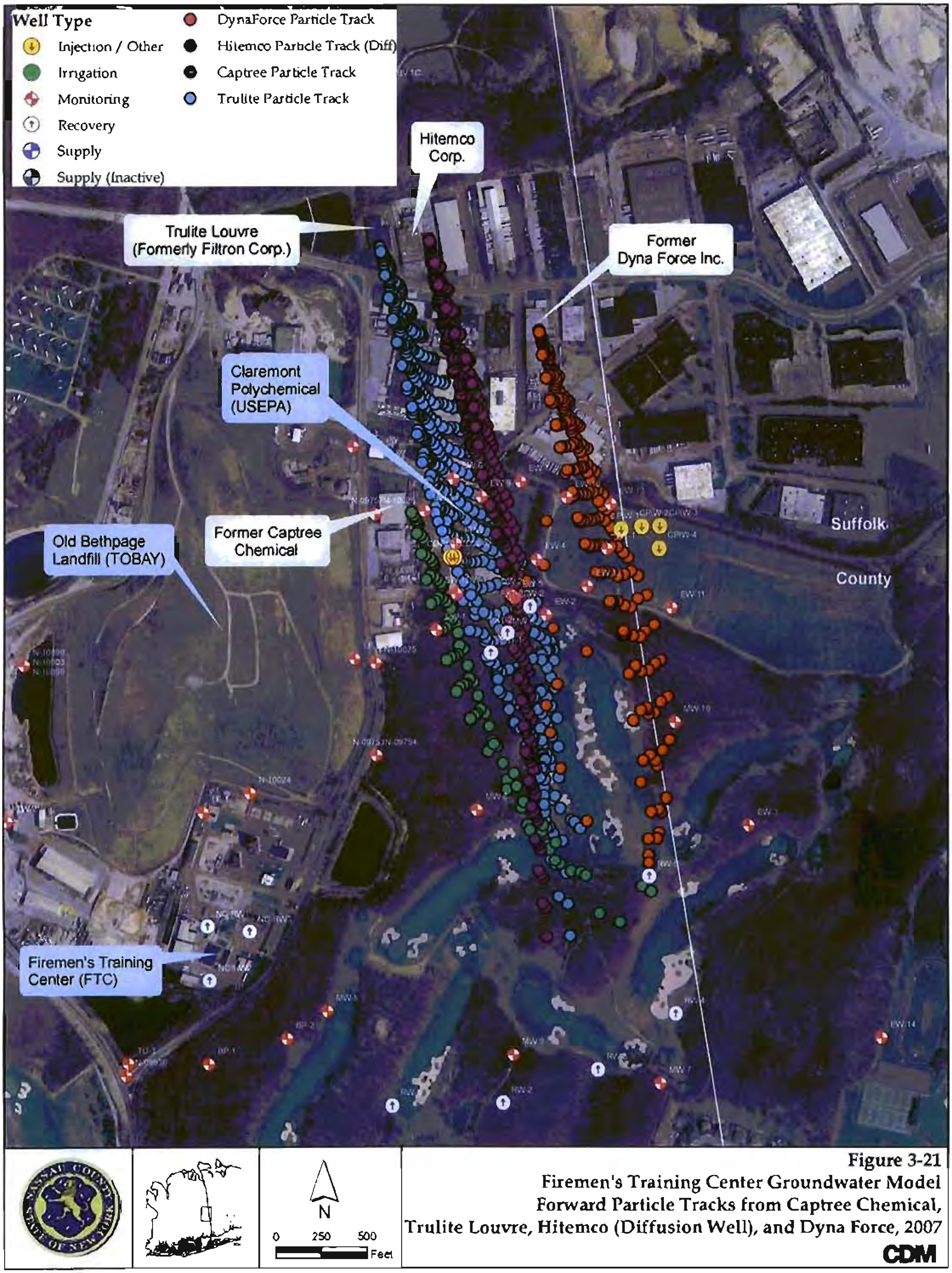


Figure 3-21
Firemen's Training Center Groundwater Model
Forward Particle Tracks from Captree Chemical, Trulite Louvre, Hitemco (Diffusion Well), and Dyna Force, 2007

CDM

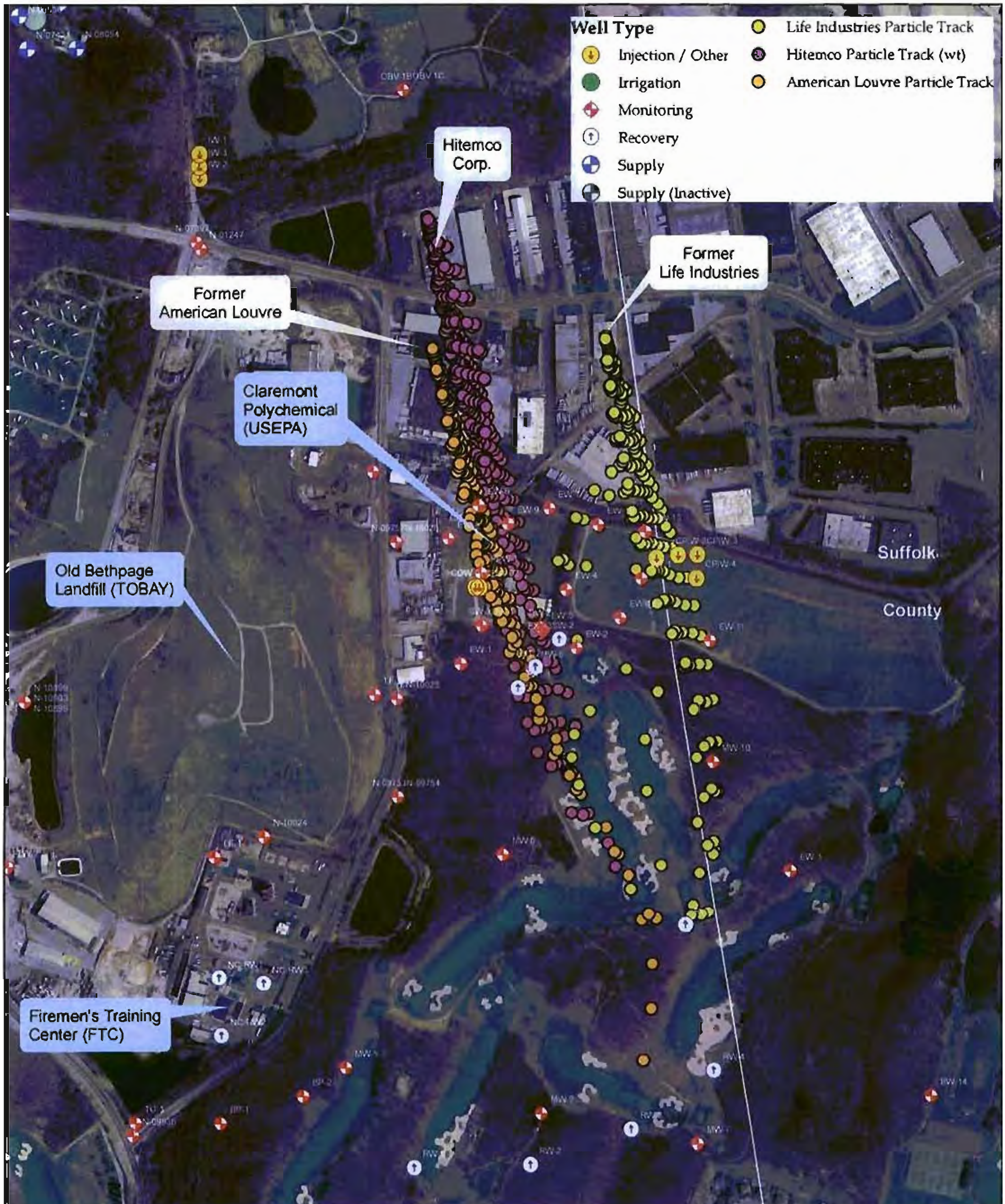


Figure 3-22
Firemen's Training Center Groundwater Model Forward Particle Tracks from American Louvre, Hitemco (Water Table), and Life Industries, 2007

CDM

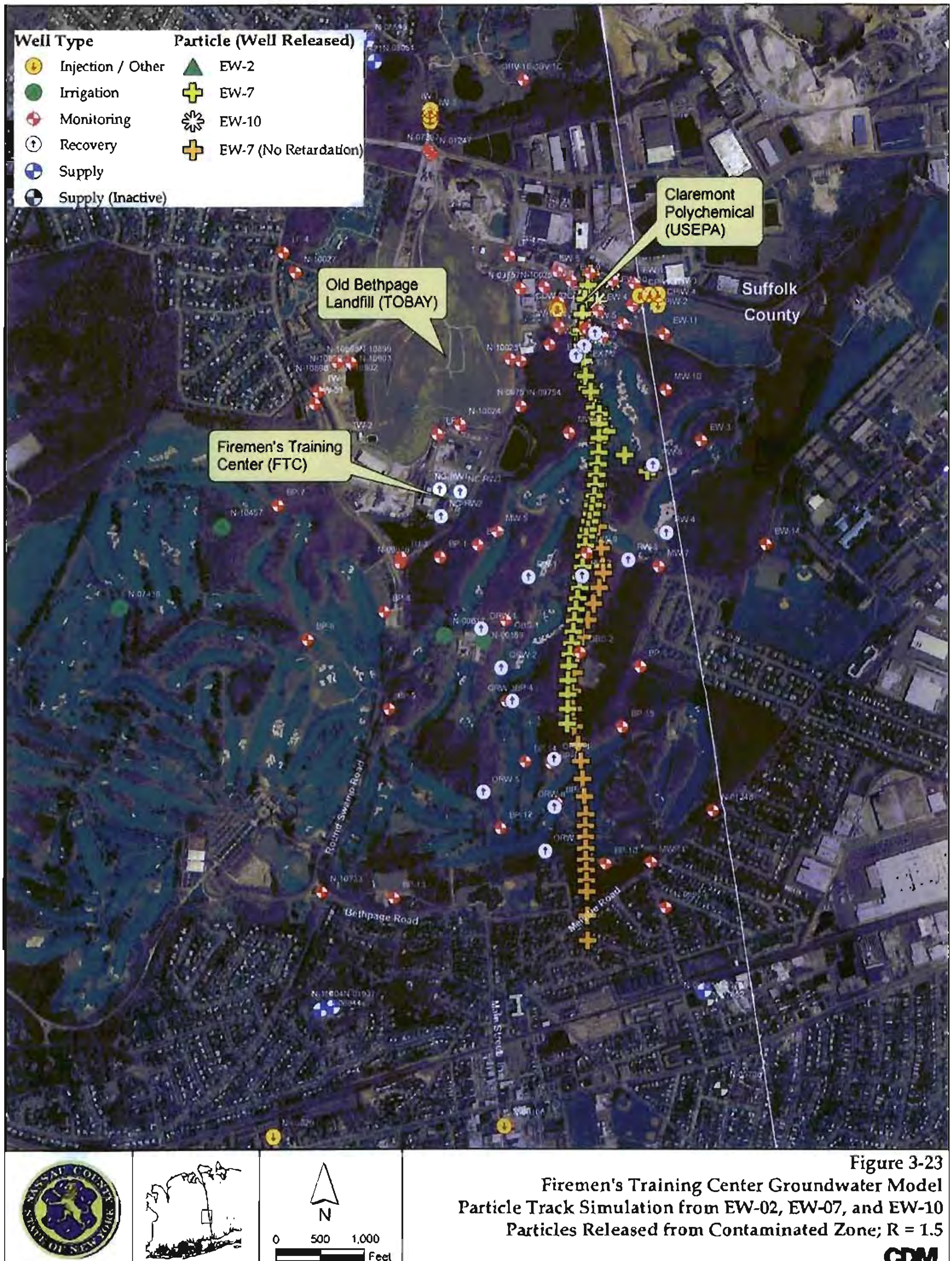


Figure 3-23
Firemen's Training Center Groundwater Model
Particle Track Simulation from EW-02, EW-07, and EW-10
Particles Released from Contaminated Zone; R = 1.5

CDM

Some particles bypass the Claremont extraction system and continue to migrate downgradient. Particles released from EW-07 from -90 and -95 feet msl are captured by the TOBAY recovery system at RW-05 within 14 years. The deepest particles released from EW-07 (at 100 feet below sea level) are not captured by the Claremont or TOBAY recovery systems and continue to migrate downgradient into the C-Zone by 2050.

It is important to note that the particle track simulations use assumed pumpage at the recovery systems and the migration of the particles will change with fluctuating pumping rates. The simulated remediation pumpage between 2007-2025 is shown in Table 3-2. Although not shown on the table, all extracted water is recharged either through recharge basins or injection wells. Pumpage from water supply wells is also included as monthly averages. Wells installed after 2005 are not included in these simulations and it is assumed that currently active wells will remain active through the simulation period (2050). Should pumping rates significantly deviate from monthly averages, the particle migration will change.

The particle track simulations described above use a retardation factor of 1.5. Sensitivity simulations were conducted to evaluate the contaminant migration without retardation. Since the contamination is associated with organic compounds, retardation is likely. The sensitivity simulation represents a conservative simulation, treating the organic compounds as a conservative tracer. Simulation results are very similar to the results using retardation. However, the particles are captured sooner and the particle released from 100 feet below sea level from EW-07 migrates much further downgradient. Without retardation, particles are simulated to migrate within approximately 1,450 feet of N-07852, Village of Farmingdale well number 1-3. It is likely that the supply well would be impacted. However, these simulations evaluate particle migration only. Concentrations are not associated with these simulations and therefore, although it is stated that N-07852 may be impacted, concentrations may be at such a low level that they would be below current detection limits. A cross-section of the particles without retardation is shown on Figure 3-23a.

Table 3-2
Remediation Pumpage for Future Model Simulations (2007 - 2025)

System	Well ID	Pumpage (gpm)
Claremont	EXT-1	126
Claremont	EXT-2	126
Claremont	EXT-3	126
FTC	ORW-1	OFF
FTC	ORW-2	OFF
FTC	ORW-3	OFF
FTC	ORW-4	150
FTC	ORW-5	250
FTC	ORW-6	150
FTC	ORW-7	150
TOBAY	RW-1	200
TOBAY	RW-2	200
TOBAY	RW-3	200
TOBAY	RW-4	200
TOBAY	RW-5	200

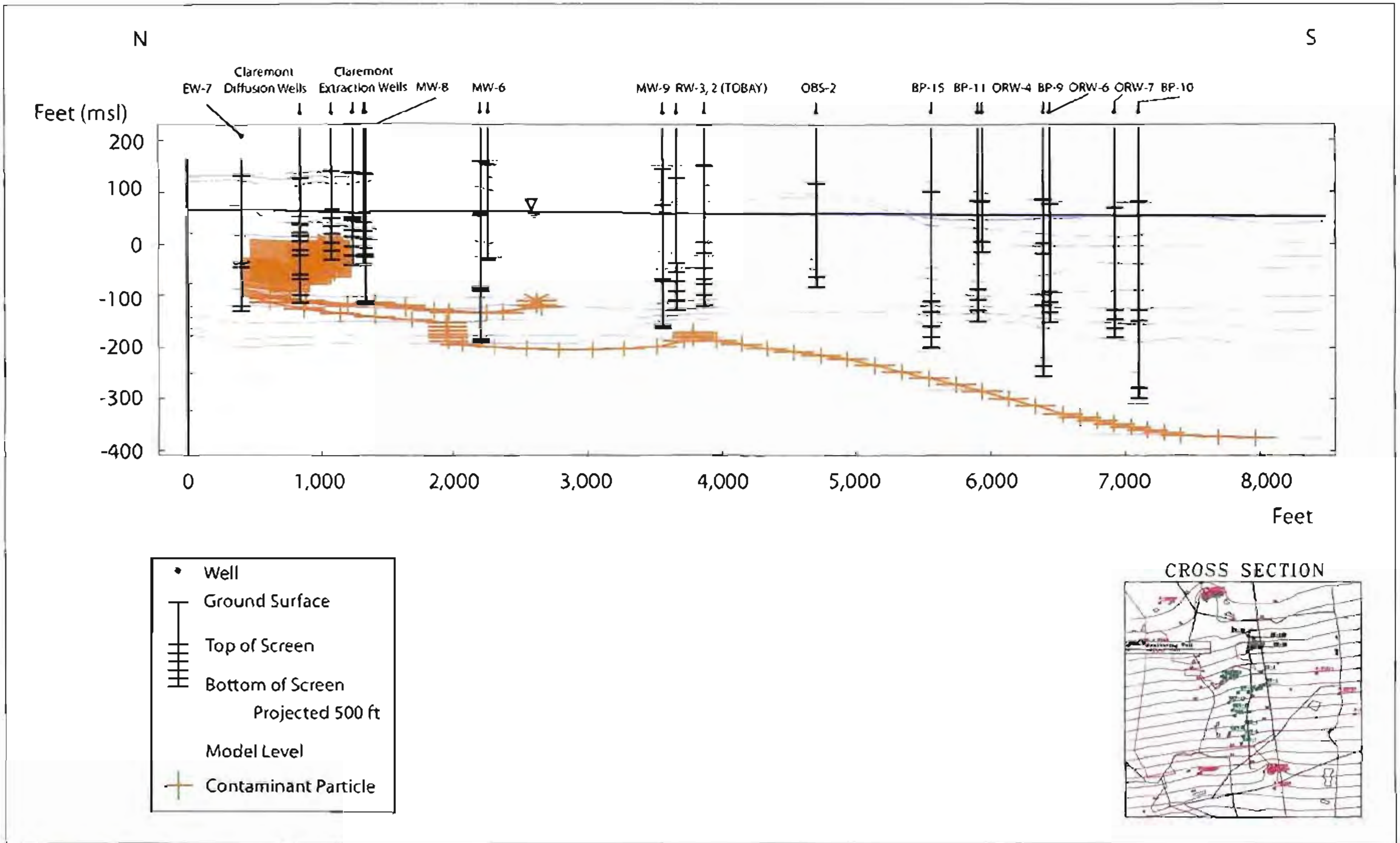


Figure 3-23a
Firemen's Training Center Groundwater Model
Cross Section of Simulated Particle Tracks from Contaninated Zones at EW-2, EW-7 and EW-10
Sensitivity Simulation - No Retardation
CDM

3.5 Pumping Effects on Transport

Groundwater flow, and therefore contaminant transport, is heavily influenced by pumping, both from the three remediation systems as well as Bethpage State Park irrigation wells.

3.5.1 Irrigation Wells

Bethpage State Park operated two irrigation wells (N-00189, N-00617) which are located directly downgradient of the FTC facility. Both of these irrigation wells are screened in the "B" hydrogeologic zone, from approximately 150 - 180 feet below grade and had been in operation since the 1930s through 1981. These wells had influenced the transport of the plume from FTC, both in enhancing the vertical migration, but also the western migration of the plume with the operation of N-00617.

It is important to note that the pumping of each of the old Bethpage irrigation wells is largely assumed since pumpage data are sparse. Data were only available for the 1970s (from NYSDEC). It is assumed that the data reported for 1976 is typical for the period 1950 to 1976 and the data reported in 1979 is typical for the period 1977-1981. Pumpage data used in the model are listed in Table 3-3. Pumpage decreases from these two wells in 1977 due to the installation of a third irrigation well, N-07438.

Simulated head and groundwater flow direction from July 1980 (representing summer pumpage) are shown on Figure 3-24. This figure shows flow conditions at the depth of the well screens (150 feet below grade). As shown on the figure, the irrigation wells capture flow in the vicinity of FTC.

Table 3-3
Irrigation Pumpage from Bethpage State Park Irrigation Wells: N-00189 & N-00617

Month	GPM	
	1950 - 1976	1977 - 1981
January	0	0
February	0	0
March	15	10
April	76	50
May	254	169
June	415	276
July	606	404
August	448	299
September	308	205
October	183	122
November	77	51
December	0	0

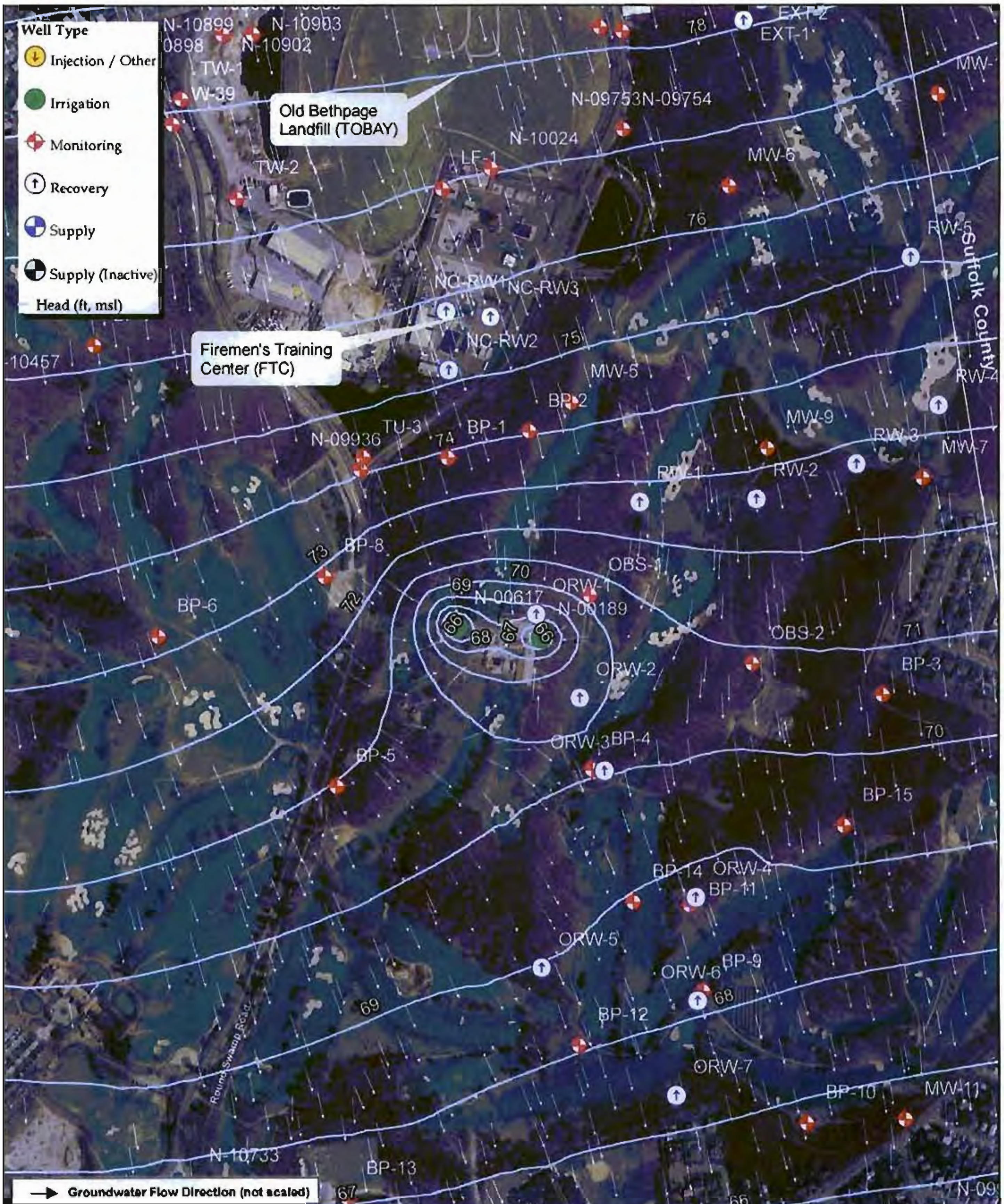


Figure 3-24
Firemen's Training Center Groundwater Model
Influence of Bethpage Irrigation Wells
Simulated Groundwater Head at Well Screens - July 1980
CDM

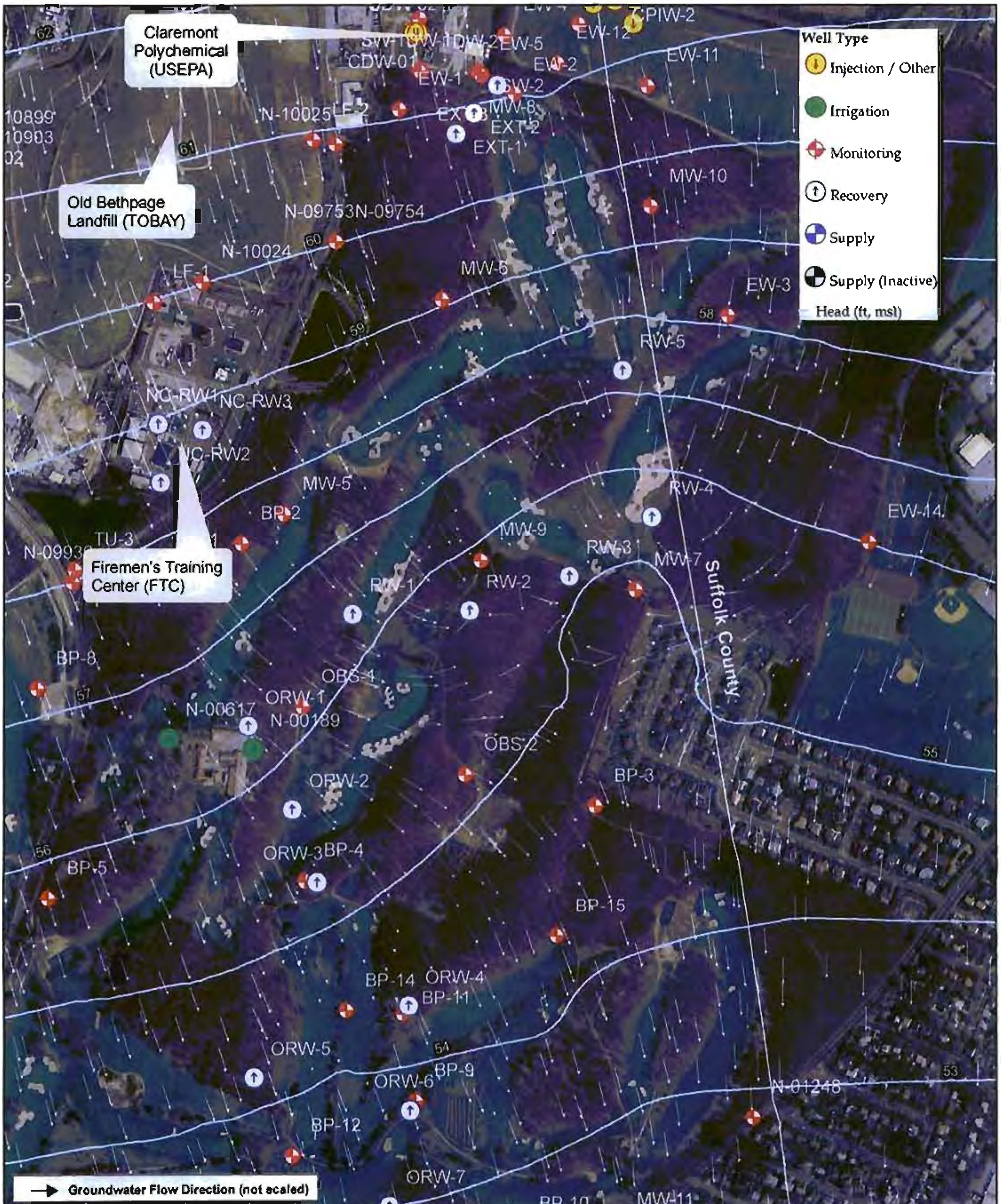
3.5.2 Remediation Pumping

Pumping from all three remediation systems has a significant influence on flow conditions, particularly within the B-Zone. The TOBAY system has been in operation since April 1992 and that system alone has had a significant impact, withdrawing an average of approximately 1.29 million gallons per day (mgd).

The influence of the TOBAY system on groundwater head, both on the water table and within the B-Zone, is illustrated in Figures 3-25 and 3-26, respectively. As shown in the figures, the capture zones for these wells, both at the water table and within the B-Zone extend from the FTC site to areas within western Suffolk County. The influence from these wells also directs groundwater into Nassau County from Suffolk County without capturing it (areas around BP-3). It is possible that the contamination found within the BP-3 cluster and the "eastern plume" of volatile organics may have originated from a source located in Suffolk County. This condition was brought into the region by the influence of the TOBAY system and subsequently further influenced by the effects of the FTC recovery system. This possibility is supported by contamination found in EW-14, located in western Suffolk County (EPA, 2004). The source for this contamination has not been identified.

The FTC and Claremont remediation systems were placed online beginning in 1999. These systems also significantly affect groundwater flow in the area by creating both drawdown from pumping as well as creating localized groundwater mounds through the injection of the effluent from the treatment systems. In 1998, TOBAY added a second recharge basin to their system which accepted the majority of their treated effluent (assumed 60% in model simulations).

Simulated head in June 2004 (when all remediation systems are running) at the water table and within the B-Zone is shown in Figures 3-27 and 3-28, respectively. More than five feet of mounding is simulated at the eastern TOBAY recharge basin (Figure 3-27). Also, note that flow within the area of the "eastern plume" (Figure 3-9) is being captured by FTC recovery wells (ORW-6 and ORW-7; Figure 3-28). This capture is more clearly evident during periods of increased pumping and when "eastern" contamination was first detected (October 2002; Figure 3-28a). Corresponding pumpage is shown in Table 3-4.



N

0 275 550 Feet

Figure 3-25
Firemen's Training Center Groundwater Model
Influence of TOBAY Recovery Wells; April 1996
Simulated Water Table and Groundwater Flow Direction

CDM

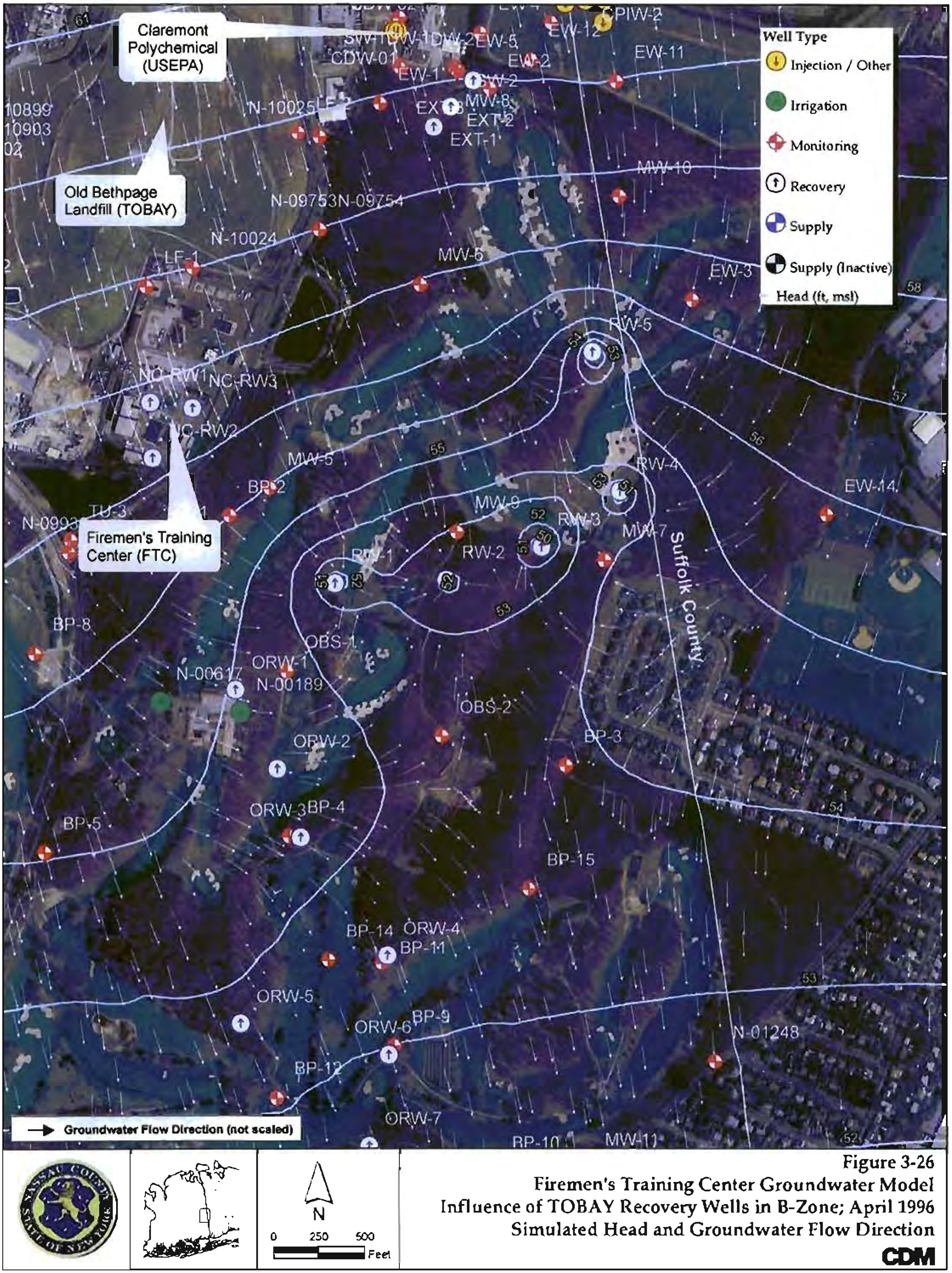


Figure 3-26
Firemen's Training Center Groundwater Model
Influence of TOBAY Recovery Wells in B-Zone; April 1996
Simulated Head and Groundwater Flow Direction
CDM

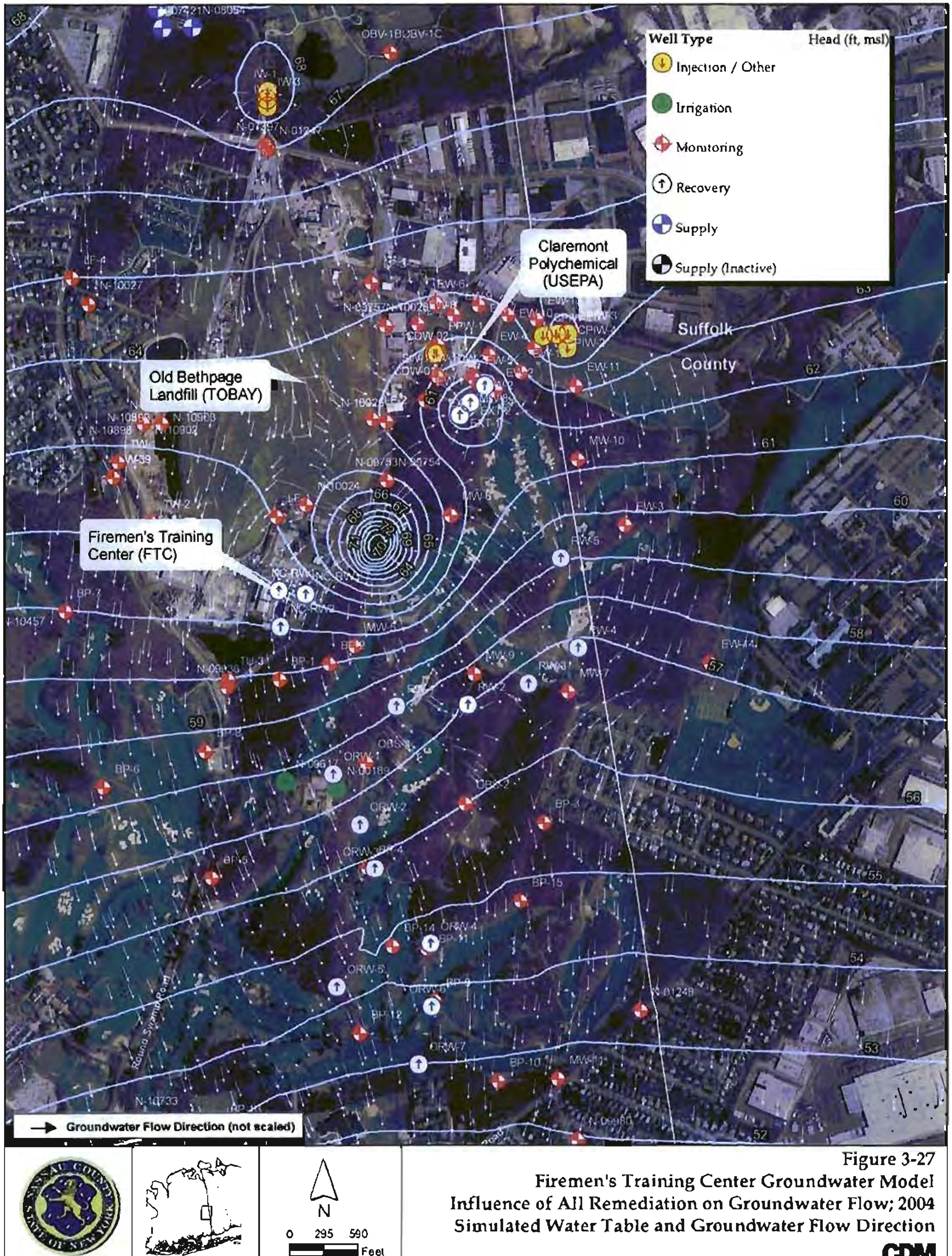


Figure 3-27
Firemen's Training Center Groundwater Model
Influence of All Remediation on Groundwater Flow; 2004
Simulated Water Table and Groundwater Flow Direction
CDM

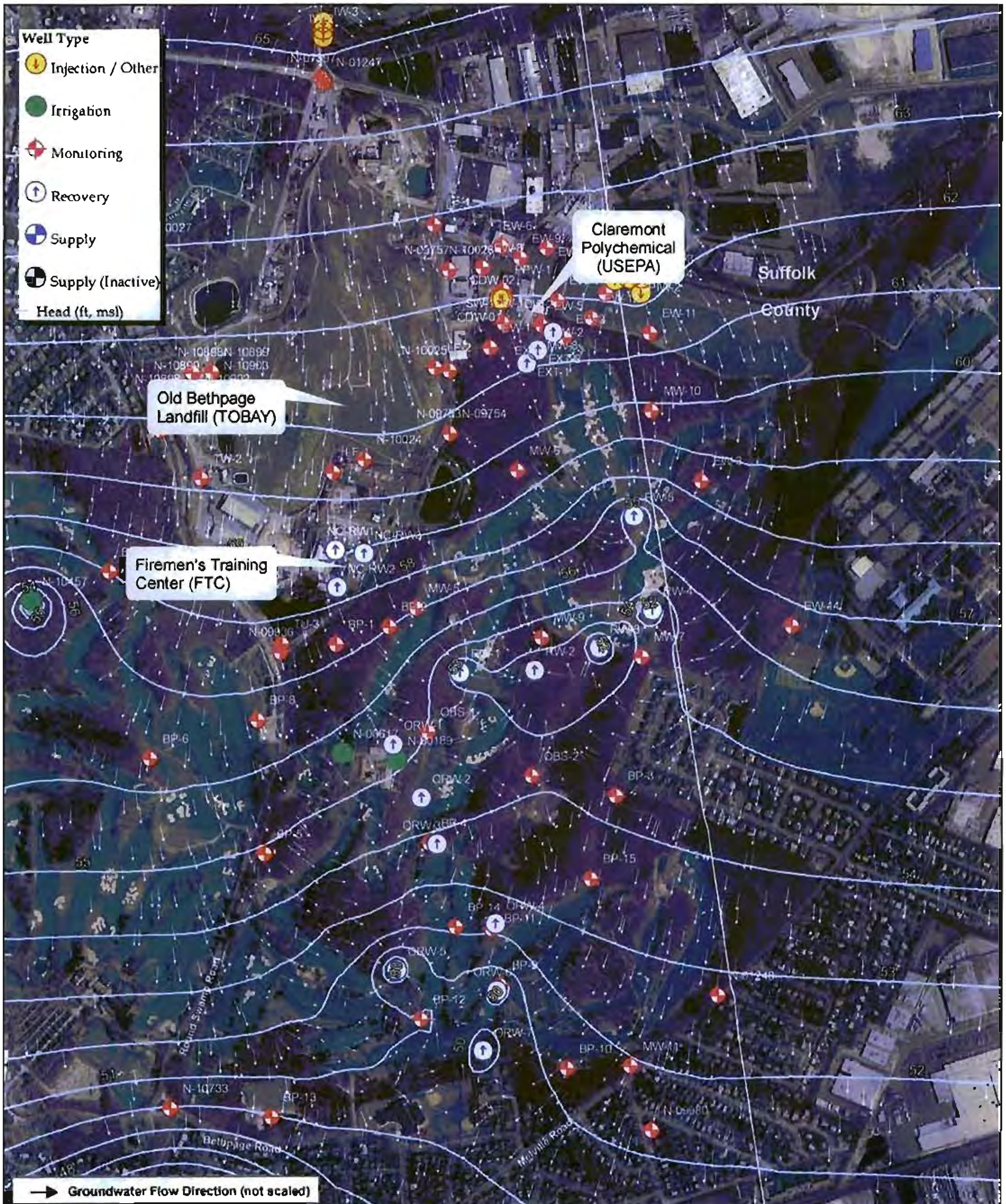
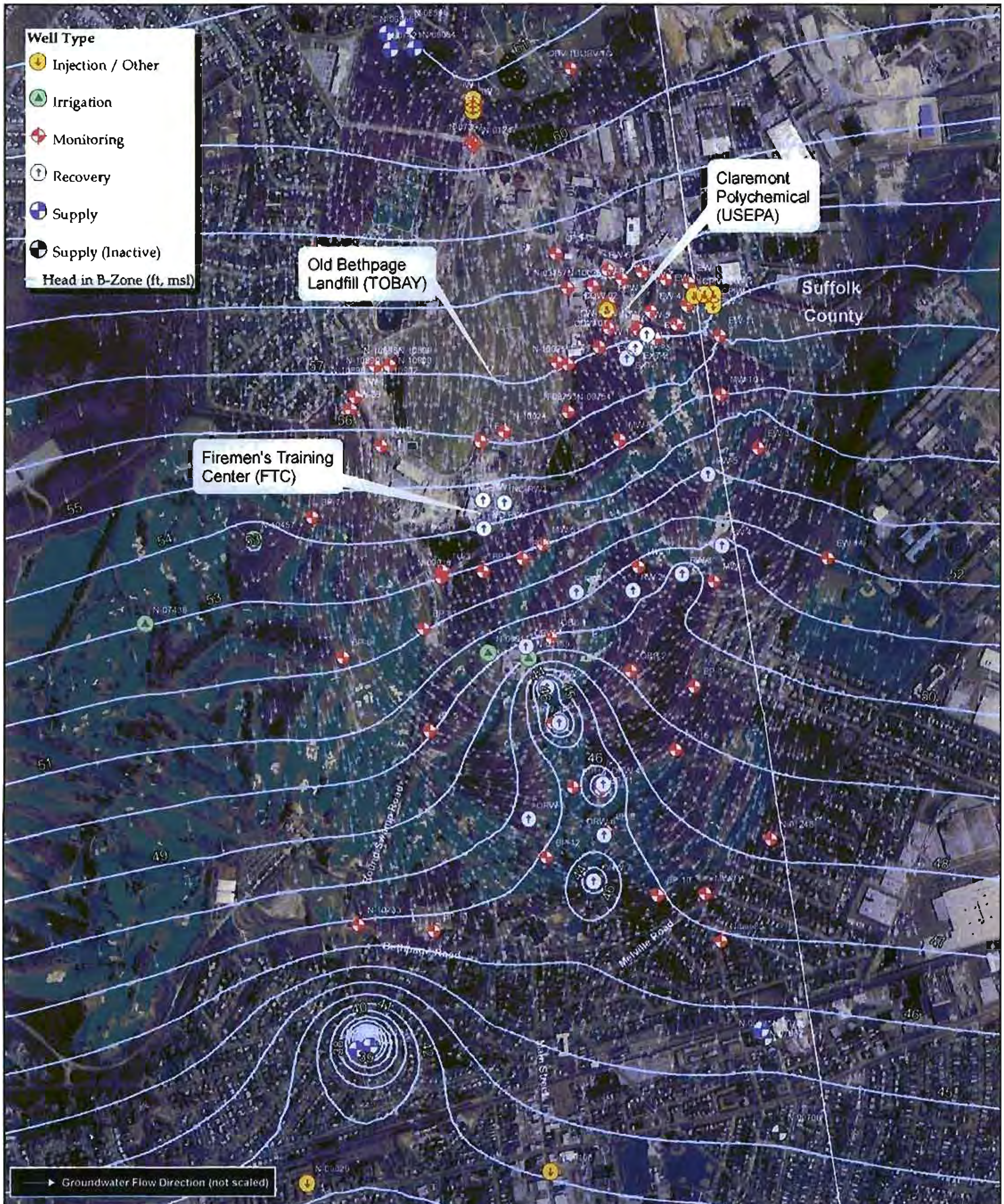


Figure 3-28
Firemen's Training Center Groundwater Model
Influence of All Remediation on Groundwater Flow; 2004
Simulated Head and Groundwater Flow Direction in B-Zone

CDM



N

0 500 1,000 Feet

Figure 3-28a
Firemen's Training Center Groundwater Model
Simulated Head in B-Zone
Transient Simulation: October 2002
CDM

Table 3-4
Simulated Remediation Pumpage - June 2004

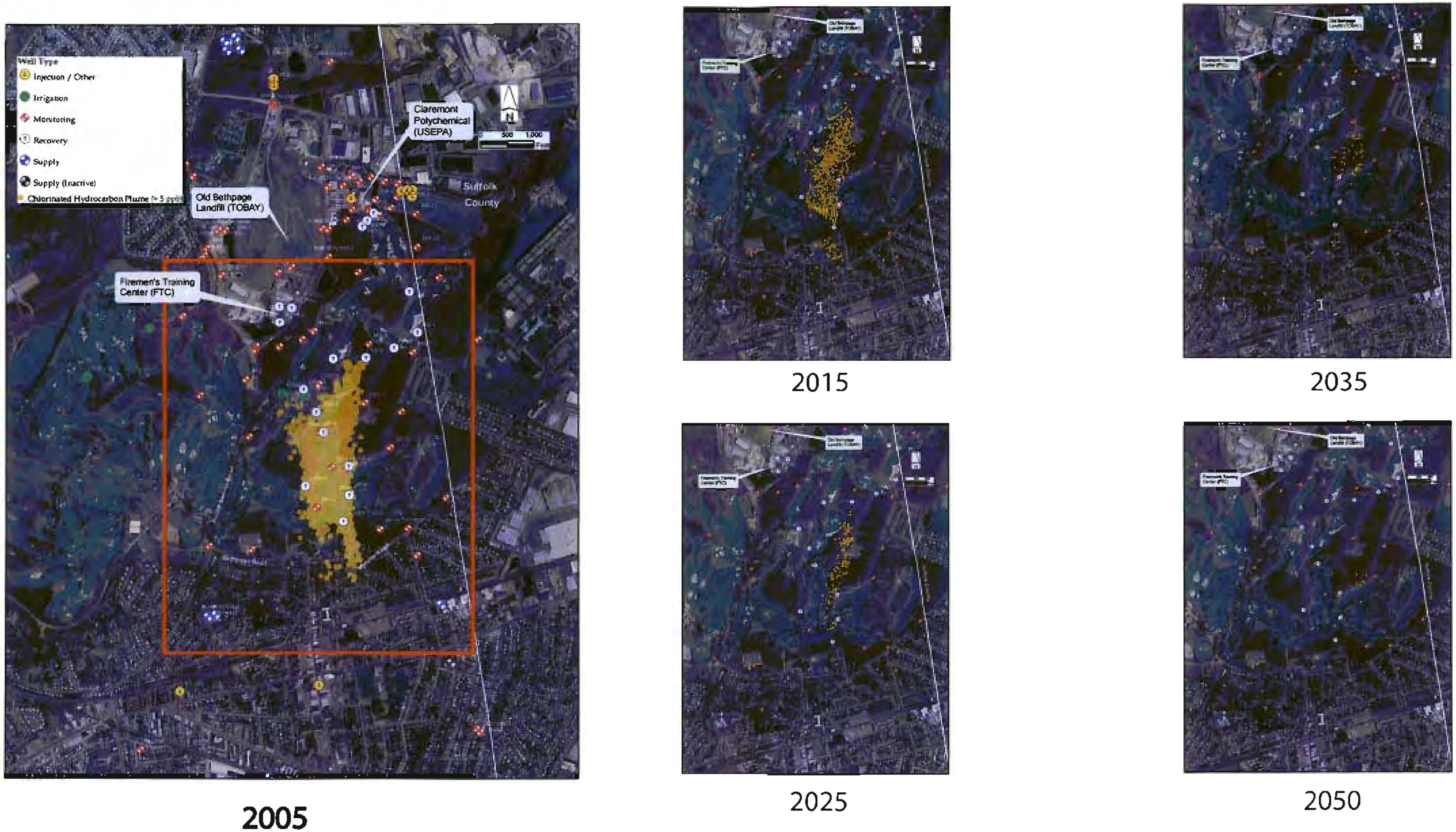
System	Well ID	Pumpage (gpm)	
		June 2004	October 2002
Claremont	EXT-1	126	110
Claremont	EXT-2	126	110
Claremont	EXT-3	126	110
FTC	ORW-1	OFF	2
FTC	ORW-2	OFF	185
FTC	ORW-3	OFF	207
FTC	ORW-4	OFF	157
FTC	ORW-5	200	OFF
FTC	ORW-6	100	15
FTC	ORW-7	100	145
TOBAY	RW-1	200	6
TOBAY	RW-2	200	132
TOBAY	RW-3	200	158
TOBAY	RW-4	200	175
TOBAY	RW-5	200	175

3.6 Impact to Public Supply

The Village of Farmingdale currently operates three public supply wells which are located immediately downgradient of Bethpage State Park. Although there are currently three separate remediation systems running continuously, the extent of contamination within the study area represents a threat to the supply system. Contaminant transport simulations into 2050 were conducted to evaluate the potential for contamination to reach downgradient public supply wells. The FTC plume was simulated using three different NCDPW remediation scenarios (Table 3-5). In addition, particle tracking simulations were conducted from monitoring wells with known concentrations of volatile organics within the B-Zone and the C-Zone. Contributing areas were also simulated for Village of Farmingdale public supply wells.

3.6.1 FTC Plume

The simulated FTC plume was run through 2050 to evaluate its migration and determine if it would impact downgradient public supply wells. Three remediation scenarios were simulated (Table 3-5). Simulation results for the portion of the plume greater than 5 ppb (clean-up criteria) through 2050 are shown on Figures 3-29, 3-30, and 3-31 for remediation scenarios 1, 2, and 3 respectively.



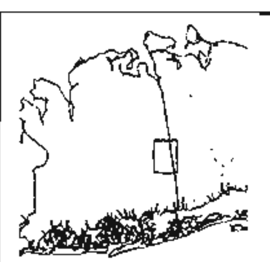


Figure 3-30
Firemen's Training Center Groundwater Model
FTC Plume Remediation
Remediation Scenario #2

CDM

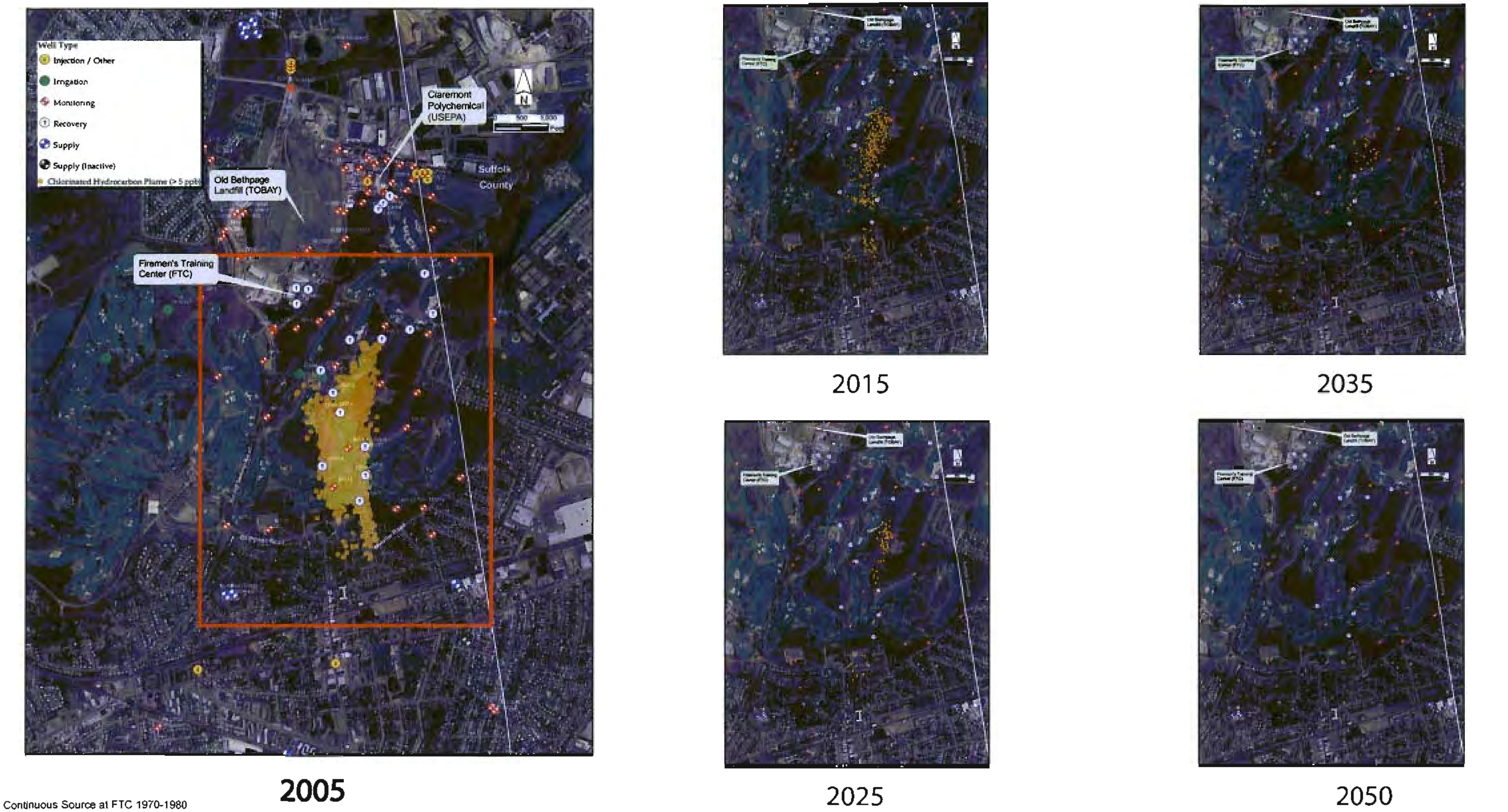


Figure 3-31
Firemen's Training Center Groundwater Model
FTC Plume Remediation
Remediation Scenario #3

CDM

Table 3-5
FTC Remediation Scenarios

Recovery Well	Pumpage (gpm)		
	Scenario #1	Scenario #2	Scenario #3
ORW-01	OFF	OFF	OFF
ORW-02	OFF	OFF	OFF
ORW-03	200	OFF	OFF
ORW-04	175	OFF	150
ORW-05	OFF	200	250
ORW-06	180	150	150
ORW-07	150	150	150
TOTAL	705	500	700

The simulated results indicate that the FTC plume is contained from the downgradient public supply wells. The results also indicate that remediation scenarios 1 and 3 are very similar, in that both leave only a small portion of the plume by 2035. In fact, much of the plume is cleaned up by 2025 in both scenario 1 and 3. However, remediation scenario 1 leaves a smaller volume of the plume by 2025. Remediation scenario number 2 is the least favorable of the three alternatives as a relatively large portion of the plume remains by 2035.

From Table 3-5, the primary difference between scenario 1 and 3 is the operation of wells ORW-3 and ORW-5. Although the simulated plume is captured by ORW-5 by 2005, it would be expected that operating ORW-5 would be required. However, the influence of the TOBAY system, specifically recovery wells RW-1 and RW-2, has resulted in the FTC plume having a northeasterly component and it appears that this is the portion of plume that remains throughout the simulation. Contaminated areas around ORW-5 are eventually captured by ORW-6 and 7. Operation of ORW-3 captures portions of the plume that has been shifted northeast due to the influence of the TOBAY system.

Model results indicate that operating either remediation scenario 1 or 2 will contain the plume generated from the FTC site so that it will not impact the downgradient supply wells. It should be noted that should a significant increase in pumping from the supply wells occur, the migration of the plume may be different from what is presented in Figures 29-31.

3.6.2 B-Zone Contributing Areas to Village of Farmingdale Supply Wells

Section 3.3.1 of this report discussed the contributing areas to the FTC offsite recovery wells within the B-Zone. The purpose of that discussion was to evaluate what portions of the B-Zone were contributing to the wells and to evaluate the effectiveness of the wells at capturing the FTC plume.

A similar analysis was conducted for the Village of Farmingdale public supply wells. Particles were spread across and released at the top of the B-Zone and allowed to run forward to determine where groundwater within the B-Zone will discharge to Farmingdale public supply wells. As discussed in Section 3.3.1, contributing area simulations are run under steady-state conditions. Two simulations were conducted. The first simulation used pumping rates from December 2002 to coincide with the ORW simulation (Figure 3-12a). A second simulation evaluated potential future "B-Zone contributing areas" using long-term average water supply pumping rates for July, representing a high demand month. Pumping rates of each simulation are shown in Table 3-6. The simulation utilizing average July supply pumping rates was run using FTC remediation scenario #3.

Contributing area simulations were run through 25 years. Although the contributing area to the supply wells far exceeds 25 years, it is expected that the remediation systems will be shut down after a 25 year period. Shutting down the remediation system will

Table 3-6
Pumping Rates used for Village of Farmingdale "B-Zone Contributing Area" Simulations

NYSDEC Well ID (Farmingdale ID)	Pumping Rate (gpm)	
	December 2002	Average July
N-07852 (1-3)	212	270
N-06644 (2-2)	37	287
N-11004 (2-3)	424	695

have a large influence on the contributing area to the supply wells. Therefore, only a 25 year contributing area was simulated. Results are shown on Figures 3-32 and 3-33.

As shown on the figures, the "B-Zone contributing areas" to the public supply wells are generally outside the primary area of contamination from the FTC and the "eastern plume" as well as areas immediately upgradient of the TOBAY system. As expected, the contributing areas are larger for the average July simulation than the simulation using December 2002 pumping rates. With the remediation systems operating, the contributing area to N-07852 extends well into Suffolk County. Contamination has been found in the B-Zone at USEPA/Claremont monitoring well EW-14. The current extent of this contamination is not known, but should be investigated as it may be within the contributing area to N-07852 and eventually impact the supply well.

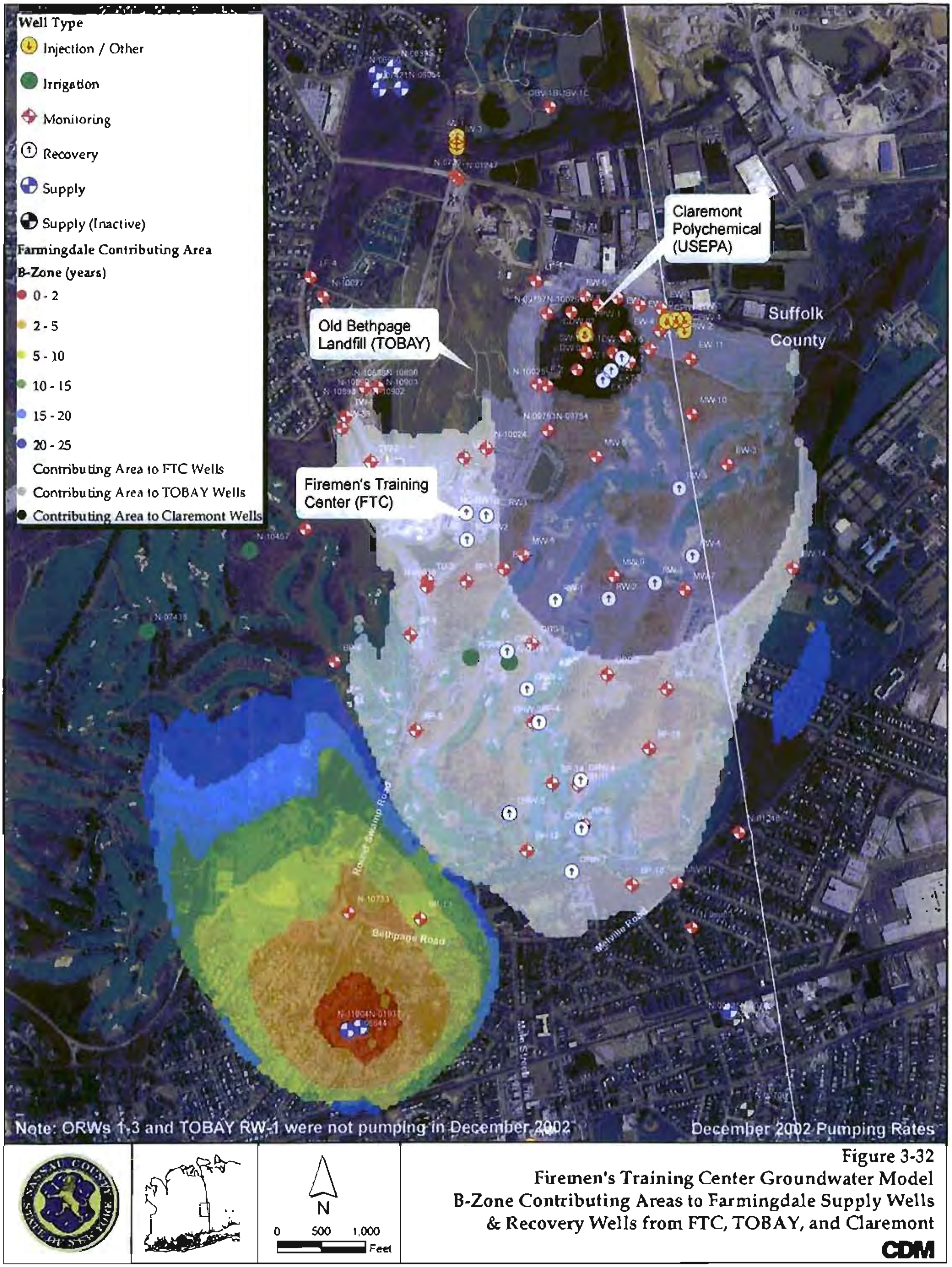
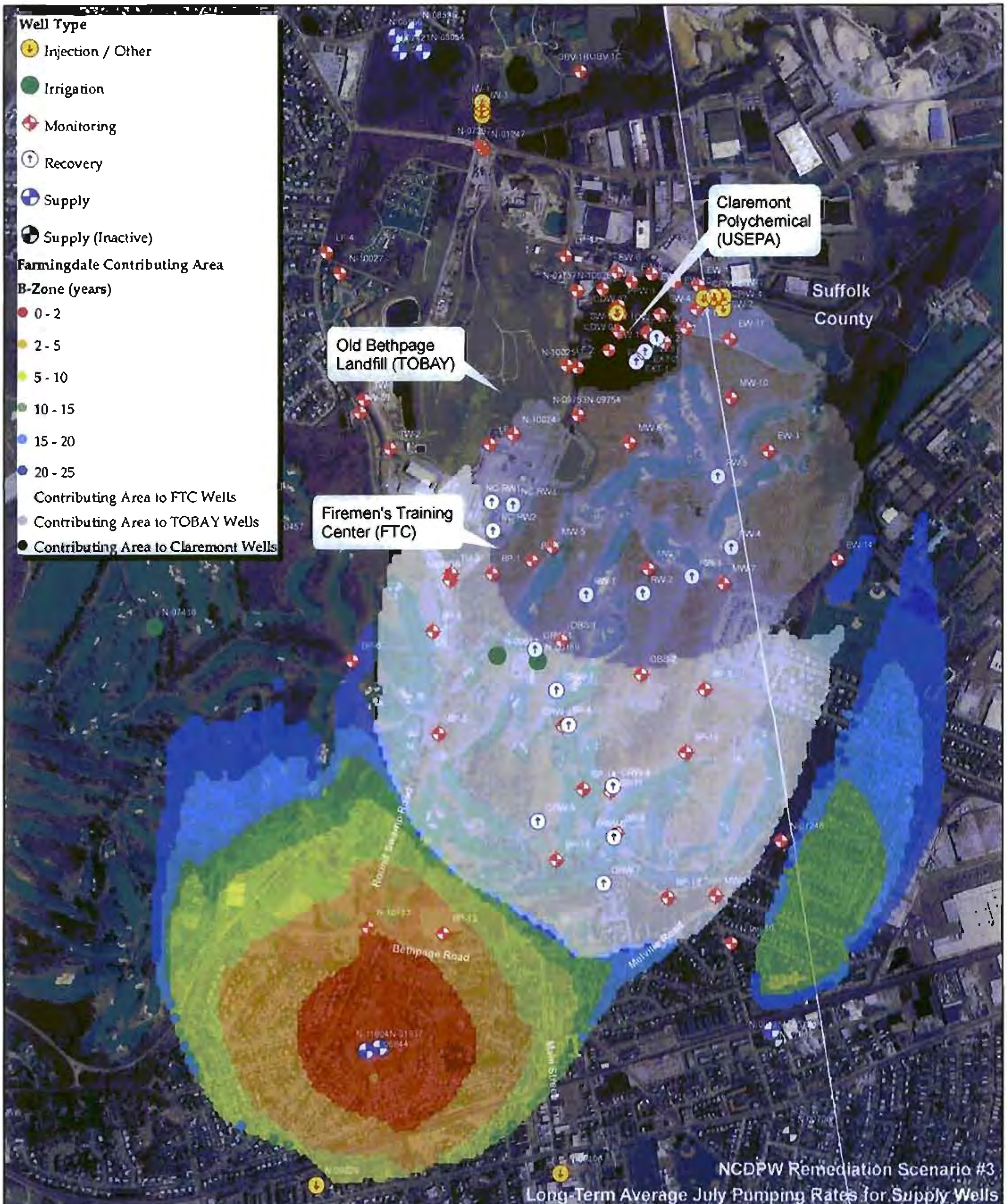


Figure 3-32
Firemen's Training Center Groundwater Model
B-Zone Contributing Areas to Farmingdale Supply Wells
& Recovery Wells from FTC, TOBAY, and Claremont

CDM



N
0 500 1,000
Feet

Figure 3-33
Firemen's Training Center Groundwater Model
B-Zone Contributing Areas to Farmingdale Supply Wells
& Recovery Wells from FTC, TOBAY, and Claremont
July Pumping Rates (Supply Wells)

CDM

It is important to note that the contributing areas shown in Figures 3-32 and 3-33 are quite different than those simulated for the Source Water Assessment Program (SWAP; NYSDOH, 2003). The Source Water Assessment Program evaluated contributing areas from the water table and did not include pumpage from remediation systems in Nassau and Suffolk Counties.

3.6.3 Contamination within the C-Zone

As described throughout this report, the majority of contaminated groundwater is found within the B-Zone. In most places throughout the study area, the lignitic clay unit separates the B-Zone and the C-Zone. Although there are holes in this clay, it impedes the migration of contamination into the C-Zone in many areas. However, there are areas within the C-Zone that have exhibited organic contamination based on routine water quality sampling.

The first Nassau County monitoring well to exhibit measurable concentrations of organic compounds in the C-Zone is BP-4C. This well is screened below the lignitic clay. FTC plume simulations indicate that the plume remains in the B-Zone and does not migrate into the C-Zone, particularly at BP-4C. Therefore, contamination found in BP-4C can either be due to a hole in the lignitic clay, or a point of origin from an upgradient source.

Contamination was first detected in BP-4C in 1992. Assuming that there are no major holes in the lignitic clay between the FTC facility and BP-4C, a particle backtrack was simulated to determine where the contamination may have originated.

Particle backtracks are identical to forward tracks with the exception that the simulation runs backwards, using preceding flow conditions. A particle was introduced at the screen of BP-4C in 1992 and the model was run backwards, using monthly time steps and the flow conditions as simulated in the transient simulation. Simulation results indicate that the particle enters the water table upgradient of the FTC facility, just to the northwest of the Old Bethpage Landfill around 1965 (Figure 3-34). These results are influenced by the current extent of the lignitic clay. Should the extent or thickness of the clay change from what is included in the model, the particle track path will likely change as well.

Sampling of County monitoring wells has revealed contamination in two additional wells screened within the C-Zone: BP-3C and BP-10C. Contamination was first detected in BP-3C during routine water quality sampling in 1996. Contamination was first detected in BP-10C in December 2004. Since these wells are immediately upgradient of the Village of Farmingdale supply well 1-3 (N-07852), forward particle track simulations were conducted to determine if and when contamination originating from these wells would impact the supply well.

A particle was released from BP-3C in 1996 and from BP-10C in 2004 and the model was run through 2050. Most of the contamination is cis-1,2-dichloroethene, a relatively

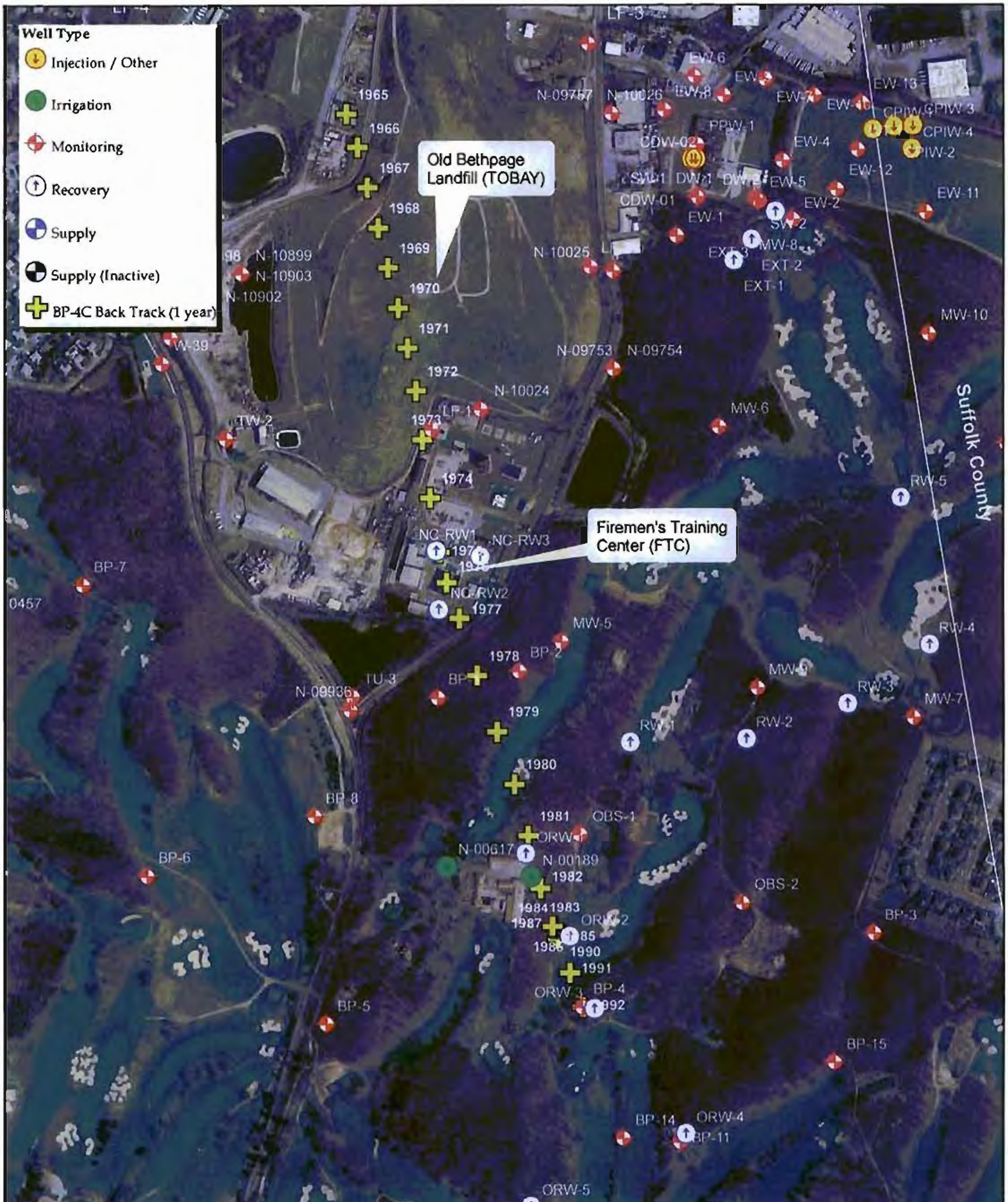


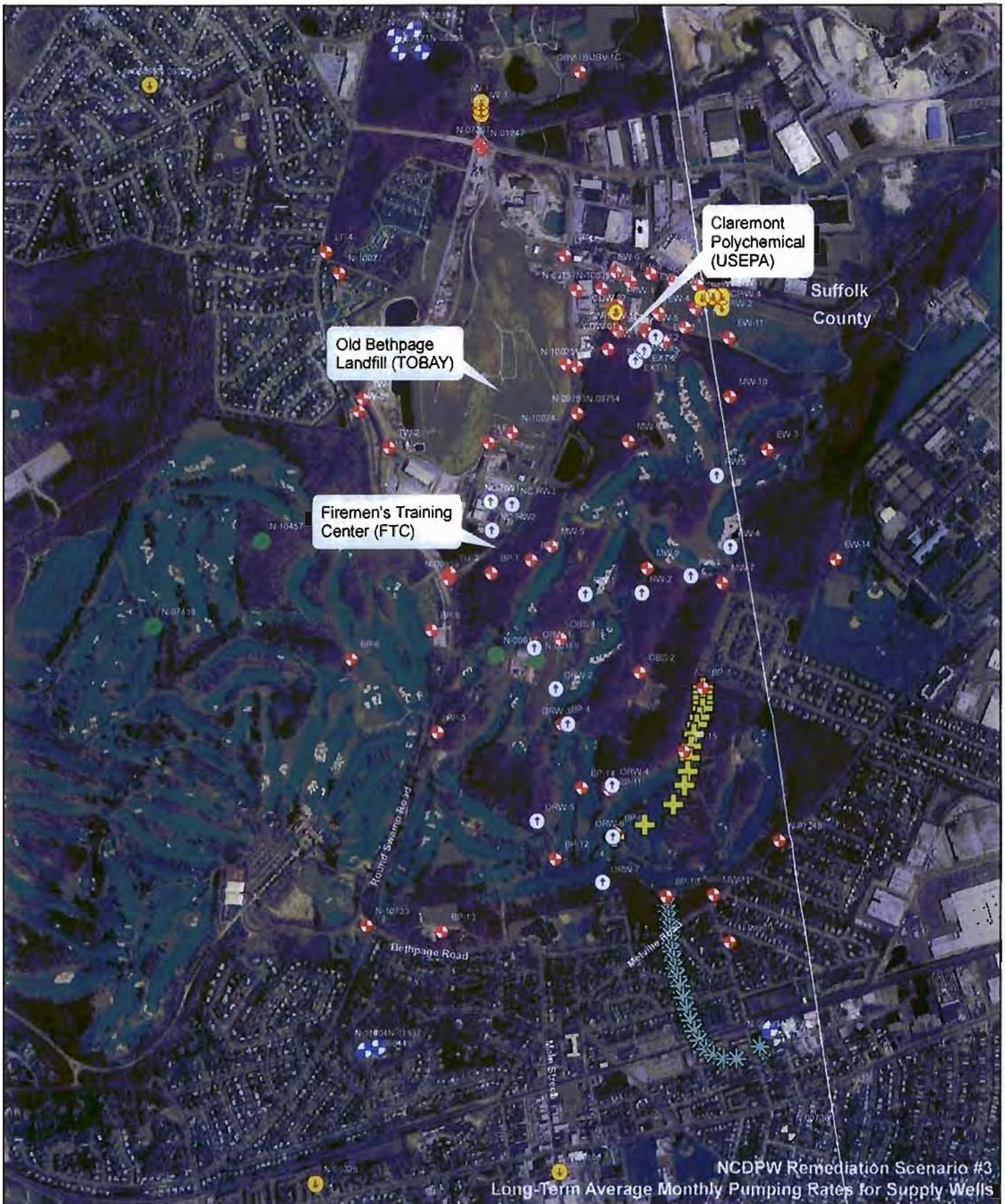
Figure 3-34
Firemen's Training Center Groundwater Model
Back Track Simulation from BP-4C; Starting 1992
No Retardation

CDM

mobile organic compound. A retardation factor of 1.3 was used for this simulation. Results are shown on Figure 3-35. The contamination originating at BP-3C migrates in a southwesterly direction toward the FTC recovery wells and is eventually captured by ORW-6 in 2010. Contamination at BP-10C is also captured by the Village of Farmingdale supply well (#1-3) by 2027.

As mentioned above, these simulations use a retardation factor of 1.3, representing a general retardation factor for DCE. Should retardation be higher, the contamination would still likely impact the supply well, but will take longer to reach the well. Similarly, if the retardation is lower than 1.3, the well would be impacted sooner than 2027. A sensitivity simulation was conducted without retardation to determine the travel time to the supply well of a conservative tracer released from each well. Without retardation, the supply well is impacted from contamination in BP-10C by 2023. Without retardation, model simulations indicate that contamination from BP-3C also is captured by the supply well by 2040. The particle tracks without retardation are shown on Figure 3-35a.

The particle track simulations show the path of a single particle of contamination released at a specific time, but do not give an indication of concentration at the supply well. A second contaminant transport simulation was conducted, fixing concentrations at BP-3C and BP-10C at maximum observed concentrations. Concentrations were fixed at 150 ppb in BP-3C in 1996 and 5 ppb in BP-10C in 2004 and the model was run through 2050. The simulated plume at 2050 is shown on Figure 3-36. While in operation (simulated through 2025) FTC recovery wells capture the contamination originating at BP-3C (see Figure 3-36a). However, following shut-down of the recovery wells, the plumes migrates downgradient and eventually impact the Village of Farmingdale supply well (#1-3). The simulated contaminant plume uses a fixed source throughout the simulation at BP-3C and BP-10C using maximum concentrations. This is likely overly conservative, but is included to represent a "worst-case" scenario.



N
0 500 1,000 Feet

Figure 3-35
Firemen's Training Center Groundwater Model
Forward Particle Tracks from C-Zone
Particles Released from BP-3C (1996) & BP-10C (2005); R = 1.3

CDM

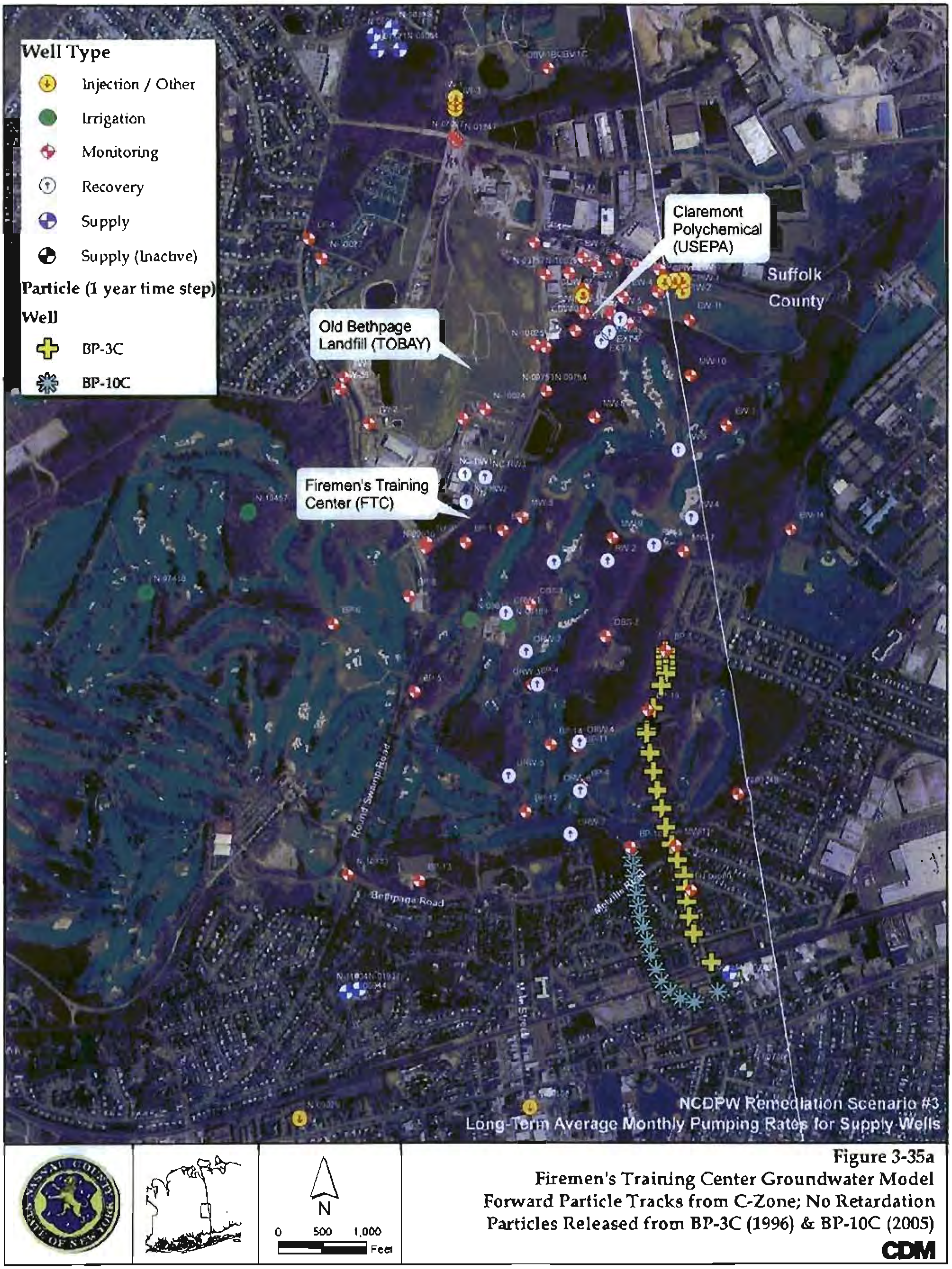


Figure 3-35a
Firemen's Training Center Groundwater Model
Forward Particle Tracks from C-Zone; No Retardation
Particles Released from BP-3C (1996) & BP-10C (2005)

CDM

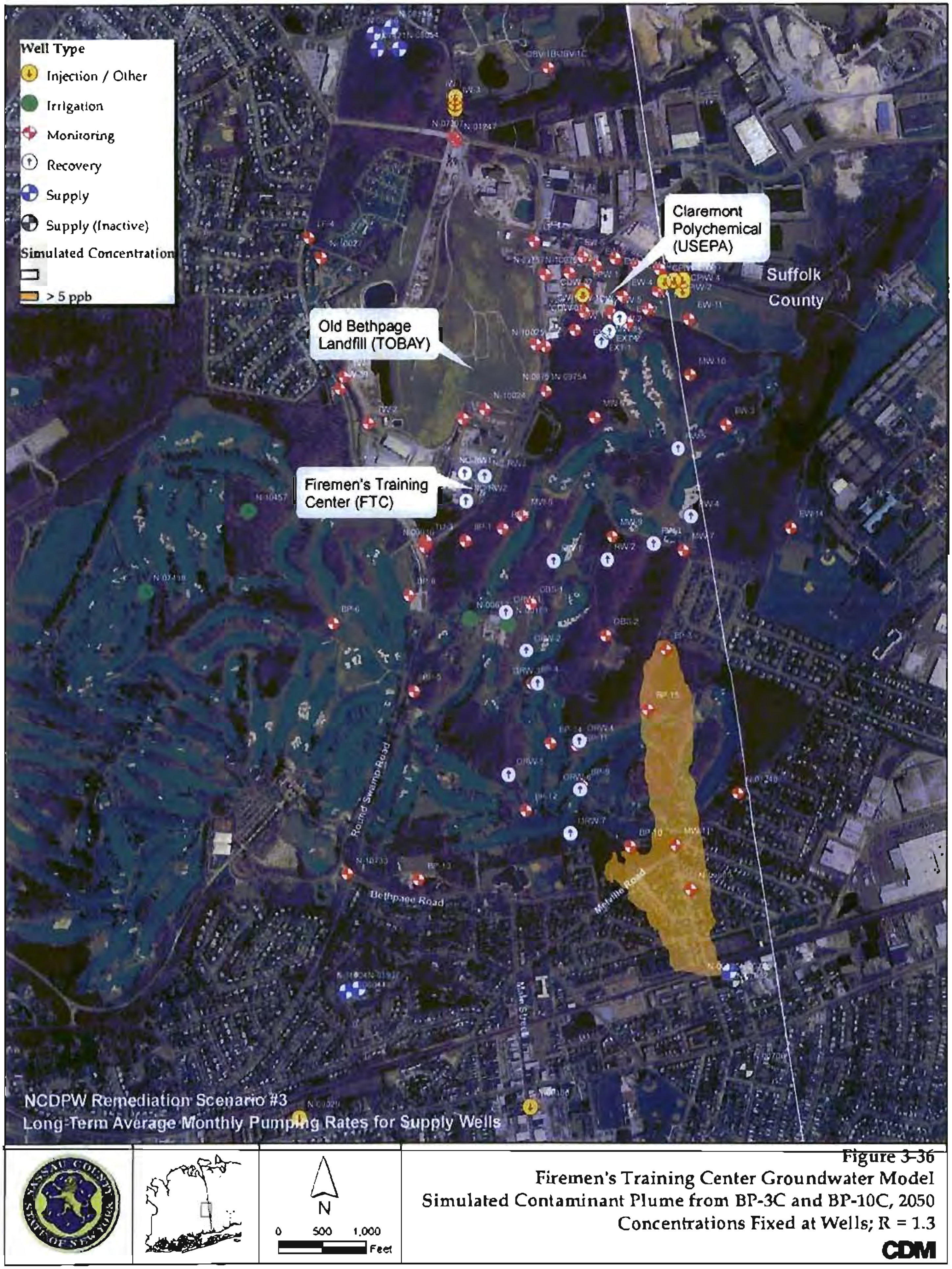


Figure 3-36
Firemen's Training Center Groundwater Model
Simulated Contaminant Plume from BP-3C and BP-10C, 2050
Concentrations Fixed at Wells; R = 1.3

CDM

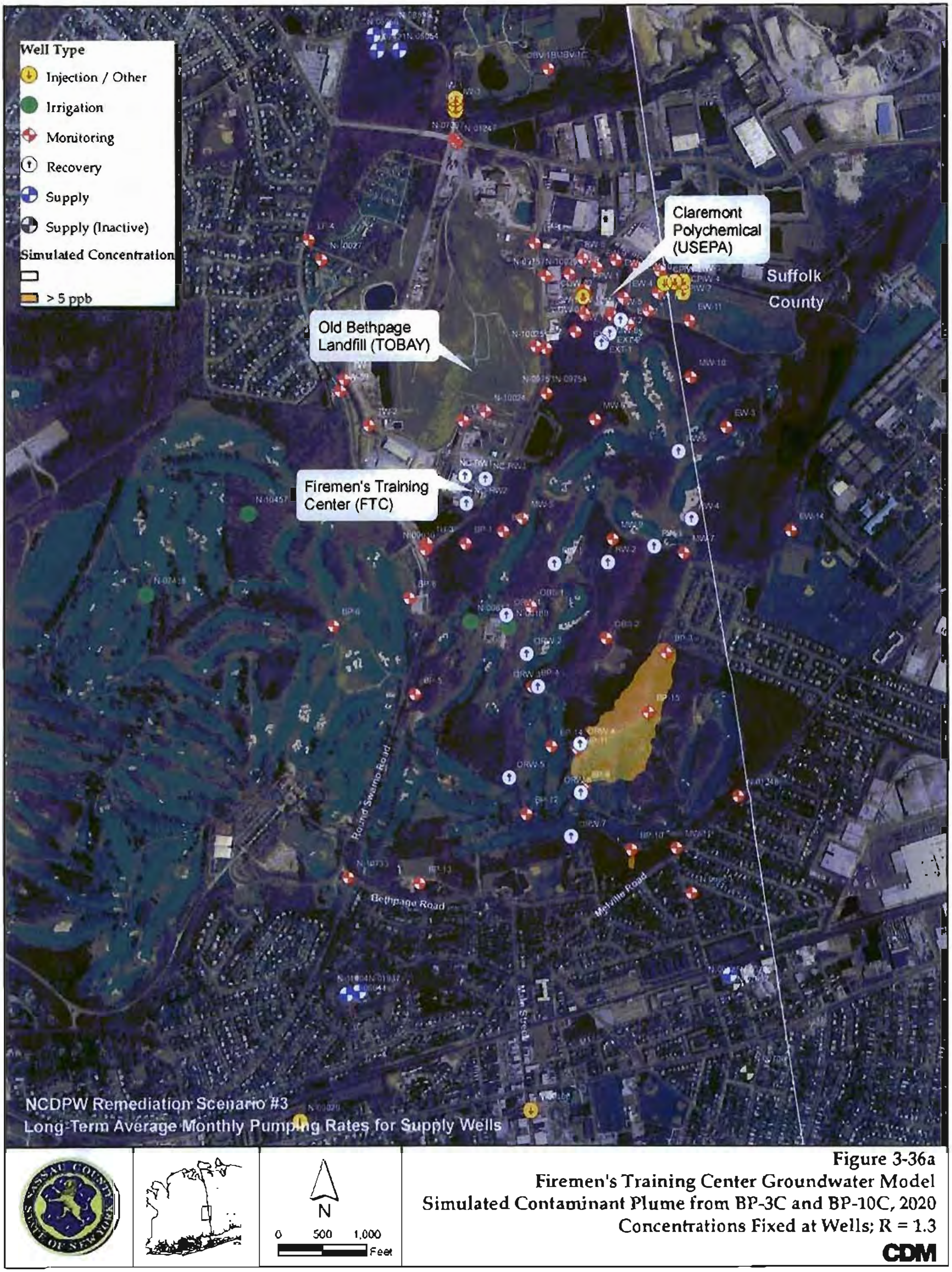


Figure 3-36a
Firemen's Training Center Groundwater Model
Simulated Contaminant Plume from BP-3C and BP-10C, 2020
Concentrations Fixed at Wells; R = 1.3

CDM

Section 4
Conclusions and Recommendations

An updated model for the Firemen's Training Center has been developed and calibrated. Various contaminant transport simulations were conducted to define the extent of the FTC plume and to evaluate the migration of contamination from a variety of other non-FTC sources. From the model results, the following conclusions can be drawn:

FTC Plume

- The FTC plume (Figure 3-3), migrates in a southeasterly direction and is captured by its offsite recovery system. It is bounded to the east by County recovery wells ORW-4, ORW-6, and ORW-7; a portion of the plume is influenced by TOBAY recovery wells RW-1 and RW-2 and therefore extends slightly northeast. The western component of the plume extends just beyond County recovery well ORW-5 and former Bethpage State Park irrigation well N-00617. County monitoring wells BP-5 and BP-13 are not impacted by the plume, which is consistent with water quality data. A small portion of the modeled plume extends downgradient and outside of the influence of the recovery system.
    - <u>Recommendation</u>: No monitoring wells are currently located south of the recovery system along Main Street or Bethpage Road to determine whether a portion of the FTC plume has migrated beyond the influence of ORW-7. A monitoring well should be installed within the B-Zone to monitor for the presence of contamination.
- Simulating the FTC plume as benzene only, the plume degrades dissipates and does not extend beyond ORW-7. However, simulations were unable to match observed benzene concentrations in BP-14B. It is possible that anaerobic conditions are present that would slow biodegradation and allow higher than predicted concentrations of benzene to occur in this well.
    - <u>Recommendation</u>: Dissolved oxygen data should be collected during routine water quality sampling of offsite monitoring wells to determine if oxygen levels are sufficient for biodegradation.
- Model simulations show that the pumping effects occurring beneath Bethpage State Park, caused by the three remediation systems (FTC, TOBAY landfill and (Claremont / USEPA) have a large influence on the flow regime within the study area. Historic pumpage from certain Bethpage State Park irrigation wells has influenced the migration of contamination originating from the FTC facility.
- Three remediation scenarios (Table 3-5) were tested using various pumping schemes for offsite FTC recovery wells through 2025. Model simulations suggest that either

scenario 1 or 3, coupled with dispersion, dilution and natural degradation, will allow the FTC operators to achieve remedial objectives by 2025, although pumping scenario 1 is slightly more effective. FTC remediation scenario 2 does not clean up portions of the plume by 2050 and therefore should not be implemented.

- Recommendation: Based upon an evaluation of the results of the simulated remedial pumping scenarios, Nassau County could continue to extract and treat contaminated groundwater until the year 2025 using pumping scenario # 1, pending water quality data.

Eastern Plume

- Groundwater model simulations indicate that contamination found in County monitoring well clusters BP-3, BP-10 and BP-15 is not from an FTC source. The source of this contamination is not currently known, but may be from a source in western Suffolk County.
    - Recommendation: While a portion of the "eastern plume" is currently being captured and treated by FTC offsite recovery wells, screened within the "B" hydrogeologic zone, the full extent of this contamination is unknown and should be investigated further.
- Although a fair amount of data on the extent of the lignitic clay is included, this clay has significant influence on groundwater flow and therefore contaminant transport.
    - Recommendation: Investigate additional potential sources of the "eastern plume" in Nassau County and western Suffolk County. Run additional contaminant transport simulations to evaluate the migration of contaminants from other potential sources. Update the existing groundwater model as additional lithologic information becomes available.

Upgradient Source(s)

- Contaminant transport simulations from several hypothetical sources in Nassau County suggest that C-Zone contamination may have originated from Claremont and/or Hitemco diffusion wells. Contamination in BP-3C may have also originated from Trulite Louvre (former Filtron Corporation). Sensitivity simulations (without retardation) suggest that contamination from a hypothetical source at the former DynaForce facility also may migrate into the C-Zone. There is no active groundwater recovery from within the "C" hydrogeologic zone. However, model simulations indicate that contamination originating at BP-3C in 1996 is partially captured due to the absence of the lignitic clay by Nassau County recovery wells by 2010 (using a retardation factor of 1.3). Contamination from other potential upgradient sources located within the "B" zone is captured by the TOBAY recovery system.

Recommendation: Investigate Trulite Louvre (former Filtron Corporation) and the former DynaForce facility as potential contamination sources. In addition, an investigation should be conducted at Hitemco as a potential source from both the water table and diffusion wells.

- Model simulations indicate that although a potential surface source from Claremont Polychemical is currently captured by the Claremont and TOBAY recovery systems, a portion of the source may have migrated downgradient, past the TOBAY system prior to its operation. This hypothetical plume is of significance as a portion of it remains in the B-Zone. Contaminant transport simulations (without contaminant retardation) indicate that it migrates toward the Nassau County offsite recovery wells, with the western portion of the plume captured by the wells.
    - Recommendation: A potential water table source at Claremont should be fully investigated. Additional model simulations should be conducted using any additional data that may become available regarding the spatial and temporal extent of a water table contamination source at Claremont.
- Particle track simulations suggest that contamination released from EW-02 and EW-10 (Figure 3-23), is captured by Claremont Polychemical extraction well #3. Shallow contamination from EW-07 is also captured by the Claremont recovery system, although some of the deeper contamination migrates downgradient and is captured by the TOBAY system. Contamination simulated from -100 feet msl at EW-07 bypasses all recovery systems and will likely impact Village of Farmingdale well 1-3, N-07852.

Public Supply Well Impacts

- Model simulations suggest that volatile organic contamination (originating from a non-FTC source) detected in County monitoring wells BP-3C and 10C will impact the Village of Farmingdale well 1-3 (N-07852) by 2027, but potentially as early as 2022.
    - Recommendation: One or two monitoring wells should be installed upgradient of the Village of Farmingdale well 1-3 within the 5 or 10 year "B-Zone" contributing area to the supply well (Figure 3-33). This would provide the water district with sufficient lead time to mitigate any possible impacts to well 1-3.

Section 5
References

Buxton, H.T. and D.A. Smolensky, 1999, Simulation of the Effects of Development of the Ground-Water Flow System of Long Island, New York, U.S. Geological Survey Water Resources Investigations Report 98-4069, 57 p.

CDM, Nassau County Regional Groundwater Model Development and Calibration. November, 1990.

CDM, Nassau County Groundwater Model, Long Island Source Water Assessment Program (SWAP) Task 3A.1 Report, March, 2003.

Fetter, C.W. 1999. *Contaminant Hydrogeology*, 2nd Edition. Prentice-Hall. Upper Saddle River, NJ.

Ku, H.F.H., N.W. Hagelin, and H.T. Buxton. 1992. Effects of Urban Storm-Runoff Control on Ground-Water Recharge in Nassau County, New York. Ground Water 30, no. 4: 507-514.

Nassau County Department of Public Works (NCDPW), 1992, Fireman's Training Center, Bethpage, New York Remedial Investigation Report.

Nassau County Department of Public works (NCDPW), 2001, Firemen's Training Center Groundwater Remediation, Annual Operations and Environmental Monitoring Summary

Nassau County Department of Public works (NCDPW), 2002, Firemen's Training Center Groundwater Remediation, Annual Operations and Environmental Monitoring Summary

Nassau County Department of Public works (NCDPW), 2003, Firemen's Training Center Groundwater Remediation, Annual Operations and Environmental Monitoring Summary

Nassau County Department of Public works (NCDPW), 2004, Firemen's Training Center Groundwater Remediation, Annual Operations and Environmental Monitoring Summary

Nassau County Department of Public Works (NCDPW), 2004, Review of Offsite Volatile Organic Plume Characteristics, March 4, 2004, unpublished presentation.

New York State Department of Health, 2003, Long Island Source Water Assessment Summary Report, 52 p.

New York State Office of Parks, Recreation, and Historic Preservation, 2007, Website:

Bethpage State Park: http://nysparks.state.ny.us/

Stumm, F., 2001, Hydrogeology and Extent of Saltwater Intrusion of the Great Neck Peninsula, Great Neck, Long Island, New York, U.S. Geological Survey Water-Resources Investigations Report 99-4280.

United States Environmental Protection Agency (EPA), 2002, Remediation System Evaluation Report, Claremont Polychemical Superfund Site, Old Bethpage, New York, EPA 542-R-02-008n, 38p.

United States Environmental Protection Agency (EPA), 2003, Data Report, Claremont Polychemical Superfund Site, Long Term Groundwater Monitoring, Old Bethpage, New York.

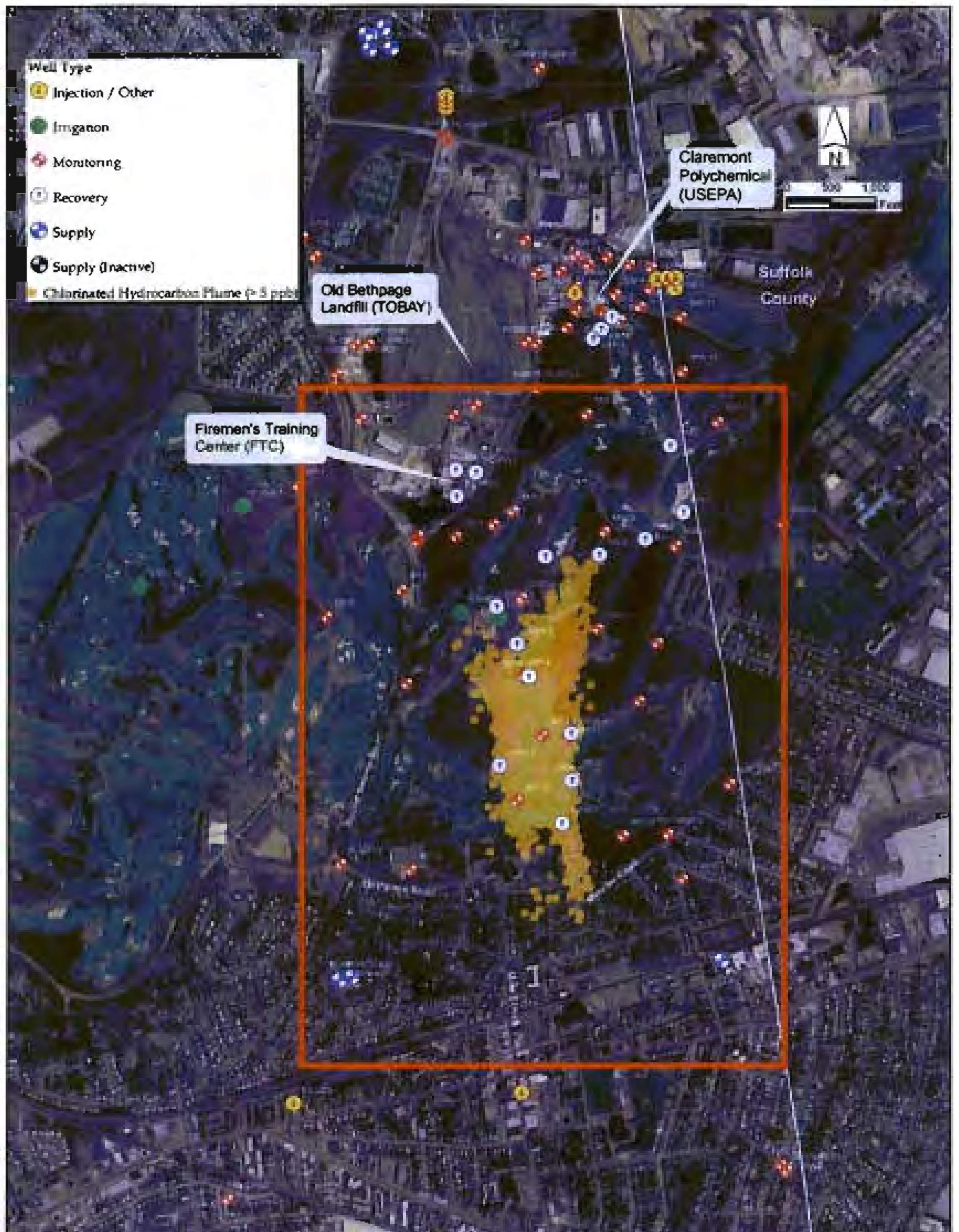
United States Environmental Protection Agency (EPA), 2004, Data Report, Claremont Polychemical Superfund Site, Long Term Groundwater Monitoring, Old Bethpage, New York.

United States Environmental Protection Agency (EPA) 2005, (Draft) Groundwater Database and Plume Modeling Report for the Claremont Polychemical Superfund site, Old Bethpage, New York.

United States Environmental Protection Agency (EPA), 2006, Well Completion Report for the Installation of Additional Monitoring Wells - Phase I and II at the Claremont Polychemical Superfund site, Old Bethpage, New York.

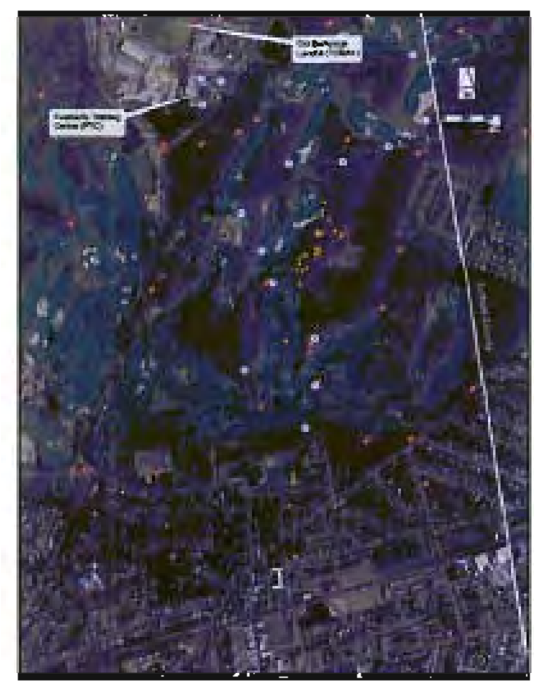
van der Heijde, Paul K.M. 1985. "Review of DYNFLOW and DYNTRACK Ground Water Simulation Codes." International Ground Water Modeling Center (IGWMC) Report 85-15.

van der Heijde, P.K.M. 1999. *DYNFLOW Version 5.18: Testing and Evaluation of Code Performance.*

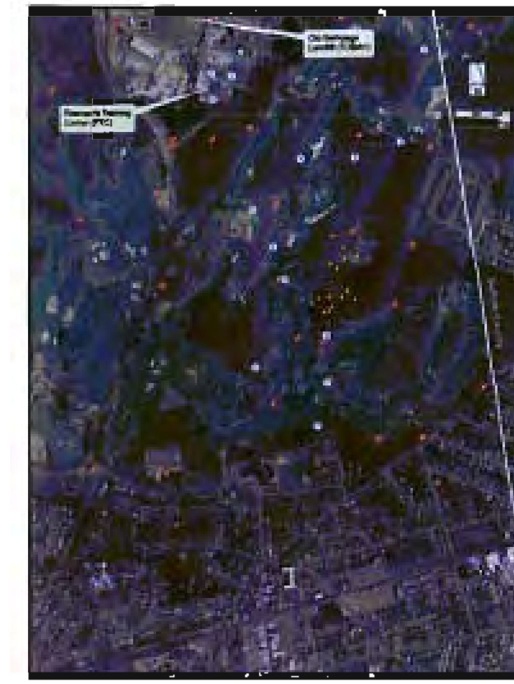


2005

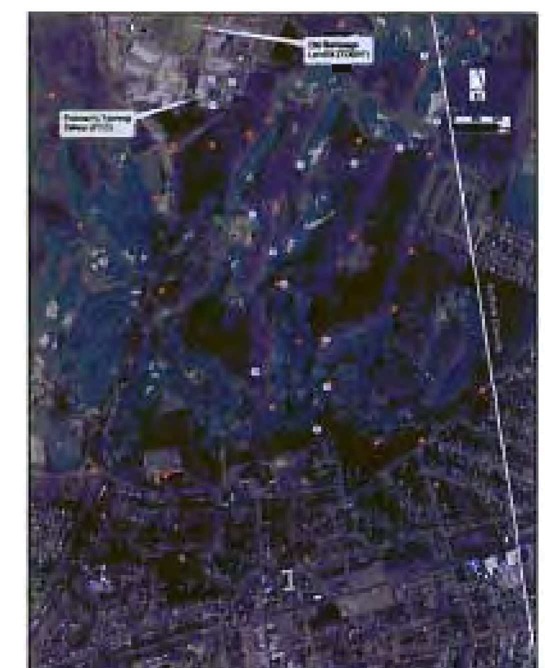
2015



2025



2035



2050

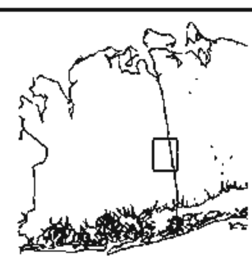


Figure 3-29
Firemen's Training Center Groundwater Model
FTC Plume Remediation
Remediation Scenario #1

CDM