ENVIRONMENTAL RESOURCES MANAGEMENT

OPERABLE UNIT II EFFECTIVENESS MONITORING PLAN

Harmon Railroad Yard Operable Unit II
Croton-On-Hudson, New York
Site No. 3-60-010

2 November, 2000

Prepared For:

METRO-NORTH COMMUTER RAILROAD
347 Madison Avenue
New York, NY 10017

Prepared By:

ENVIRONMENTAL RESOURCES MANAGEMENT
475 Park Avenue South, 29th Floor
New York, NY 10016

ERM

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1.0 INTRODUCTION

This Effectiveness Monitoring Plan (EMP) was prepared by Environmental Resources Management (ERM) on behalf of Metro-North Commuter Railroad Company (Metro-North) as part of the Remedial Design for Operable Unit II (OU-II) of the Harmon Railroad Yard Wastewater Treatment Area (Site No. 3-60-010). The scope and purpose of the EMP, as well as other Remedial Design deliverables, was described in the OU- II Engineer's Report. The OU- II Engineer's Report was prepared in accordance with: (1) Sections VI.D. and V.B. of the Stipulation of Discontinuance between the New York Department of Environmental Conservation (NYSDEC) and Metro-North (Index 383-89); and (2) the Harmon Yard OU-II Record of Decision (ROD) dated March 27, 1998.

1.1 SITE DESCRIPTION AND HISTORY

The Harmon Railroad Yard (i.e., "Yard") is located in the Village of Croton-on-Hudson, New York, and is bounded by Route 9 on the east and Croton Point Park to the west (Figure 1-1). The Yard is approximately 100 acres in size, and has been an active rail yard for over 100 years. A full site description and history is provided in the OU-II Engineer's Report.

The Harmon Railroad Yard Wastewater Treatment Area was placed on the New York State Inactive Hazardous Waste Disposal Site Registry in 1985. The September 1992 NYSDEC ROD divided the remediation of the Harmon Railroad Yard Wastewater Treatment Area into two operable units, Operable Unit I (OU-I) and Operable Unit II (OU-II). OU-I constituted the remediation of: (1) the lagoon and pond system (the "lagoon"); (2) soils above the seasonal high ground water table adjacent to the lagoon; and (3) the contaminated components of the Old Wastewater Treatment Plant. Construction of the OU-I remedy was completed in September 1996.

The components of the Harmon Yard OU-II were first identified in the OU-I ROD. They were:

- non-aqueous phase liquid (NAPL) located around the former wastewater treatment plant lagoon;
- ground water located in the vicinity of the former wastewater treatment plant lagoon;
- soil located along the former wastewater discharge line; and
- sediment in Croton Bay near the outfall area for the former and the currently active wastewater and storm water discharge lines.

The OU-II NAPL, which is comprised of diesel fuel, is not soluble in water and its density is less that that of water. Hence, it is found as a separate liquid layer above the water table (i.e., free phase NAPL). There is also some NAPL present in residual saturation in the soil above the water table. The OU-II NAPL is located in four areas around the former wastewater treatment plant lagoon. These areas are referred to as NAPL Areas L1, L2, L3 and L4.

The Harmon Yard OU-II ROD, dated March 27, 1998, selected Vacuum Enhanced NAPL Removal (VENR), as the remedial action alternative to be implemented at the site to remove OU-II NAPL. In addition, the ROD also included the installation and sampling of one additional Harmon Yard perimeter ground water monitoring well. The ROD for OU-II concluded that the potential risks to human health and the environment that may be posed by ground water, Croton Bay sediment and discharge line soil at the OU-II site, if any, do not require active remediation.

As a condition of the OU-II ROD, pilot testing of the VENR technology was conducted to confirm the effectiveness of the technology for remediation of the OU-II NAPL and to collect the information needed to prepare the Remedial Design.

VENR is an innovative NAPL remediation technology that combines physical NAPL recovery, in-situ biodegradation of primarily petroleum-related organic compounds and vapor extraction of volatile compounds. In VENR applications, air, which is supplied to the formation through air inlet wells, is drawn through the subsurface soil using a series of vacuum wells. This induced air flow:

- transports free phase NAPL through subsurface soil to the recovery wells where the organic compounds and, in particular, the petroleum-related organic compounds that comprise OU-II NAPL, are then removed from the recovery wells;
- promotes the biodegradation of the NAPL in the unsaturated zone above the NAPL layer (i.e., residual saturation); and
- promotes the volatilization of volatile organic compounds in the OU-II NAPL.

VENR and fluids pilot testing was conducted in the spring and summer of 1999. The results of this pilot testing work were documented in the OU-II Pilot Testing Results Report (PTRR), dated July 1999, and in the Addendum to the PTRR, dated 18 October 1999. These documents were collectively approved by the NYSDEC on 10 November 1999.

The VENR pilot testing demonstrated:

- accumulation of NAPL in the recovery wells with soil gas withdrawal;
- NAPL biodegradation under aerobic conditions;
- minimal volatilization of the NAPL;
- NAPL biodegradation was the predominant removal mechanism;
- NAPL removal using a NAPL-only transfer technology was the most efficient means to physically remove accumulated NAPL from the well;
- variable pneumatic and air effective radii of influence (EROI) in the four NAPL Areas; and
- variable air permeability in the NAPL Areas.

Taken together, these findings: (1) demonstrate that VENR is the most appropriate technology for the OU-II NAPL and (2) provided Remedial Design information.

1.2 *SELECTED OU-II REMEDY*

1.2.1 *OU-II Remedial Components*

The components of the OU-II remedy were defined in the NYSDEC-approved OU-II FS and ROD. With the exception of an additional perimeter ground water monitoring well north of NAPL Area L4, the components of the Harmon Yard OU-II remedy have remained the same. They are:

- annual ground water monitoring in two OU-II perimeter ground water monitoring wells;
- continued access and use restrictions through existing Metro-North procedures;
- site preparation;
- installation of a vertical sheeting barrier in NAPL Area L1;
- installation of VENR systems in the four OU-II NAPL areas (e.g., NAPL recovery wells equipped with VENR systems and air injection/inlet wells in all four NAPL areas);
- off-Site disposal of construction-related waste materials;
- Site restoration following construction;
- operation and maintenance (O&M) of the VENR systems; and
- off-Site disposal of recovered OU-II NAPL.

Information collected during the pilot test was used to design the components of the VENR system. Specifically, variations in the subsurface formation in the four NAPL Areas, which were encountered during the pilot testing, resulted in significantly different pneumatic responses, soil gas extraction rates, and free-phase NAPL accumulation rates in each NAPL Area. This information, which is discussed in additional detail below, was then incorporated into the Remedial Design to ensure appropriate system implementation and operation in each NAPL Area. The key design issues determined were:

- well spacing;
- subsurface air distribution;
- transfer of accumulated NAPL; and
- vapor control needs.

As discussed in the Pilot Test Reports, variable pneumatic responses were observed in the NAPL Areas. NAPL Area L1 exhibited anistropic conditions, while NAPL Area L4 exhibited heterogeneous conditions. In addition, NAPL Area L2 did not contain enough wells to confirm its EROI. To address these conditions: (1) conservative pneumatic EROIs were assumed for all NAPL Areas and (2) provisions were made to test the pneumatic and air response in NAPL Area L4 and L2 during construction, and to install additional wells in these areas if needed. The assumption of conservative EROI resulted in decreased well spacing. Consequently, the number of extraction wells in the Remedial Design is more than assumed in the OU-II FS conceptual design. This was a conservative design modification.

In NAPL Areas L1, L2, and L3, an adequate soil gas extraction rate and resulting pneumatic and air EROI could be achieved at a reasonably low applied vacuum due to the high permeability of the subsurface in these areas. As a result, passive air inlet wells were determined to provide the required oxygen to these NAPL Areas. Conversely, the subsurface formation in NAPL Area L4 was observed to have a very low permeability and thus only a very low soil gas extraction rate was achievable. To address these conditions, air injection wells will be installed in NAPL Area L4 and a blower will force additional air into the subsurface through these wells.

In order to determine the most appropriate removal method for NAPL accumulated in the wells during VENR, NAPL and subsurface characteristics observed during the pilot testing were taken into account. The NAPL in NAPL Areas L1, L2, and L3, is much older and more viscous than that observed in NAPL Area L4. Pilot test results indicated that the volume of NAPL in these NAPL Areas is significantly less than estimated in the OU-II FS. Little free-phase NAPL is present in these NAPL Areas and the majority of the NAPL is present in residual saturation. As a result, the NAPL accumulation and recharge rate into the extraction/ recovery wells was very slow which made continuous recovery of the NAPL unattainable. For this reason, non-automated NAPL-only skimmers were selected to recover the NAPL that accumulates in the extraction/recovery wells in NAPL Areas L1, L2 and L3.

Similar to the other NAPL Areas, low recharge rates in NAPL Area L4 indicated that the volume of free-phase NAPL is significantly less than estimated in the OU-II FS and the majority of the NAPL is present in residual saturation. However, the free-phase NAPL observed in NAPL Area L4 is less viscous than the other NAPL Areas and better recharge was observed during the pilot tests. Automated NAPL-only recovery was therefore selected for NAPL Area L4. However, since limited sustainable free-phase NAPL recovery is expected, the automated NAPL-only recovery devices will initially be installed in three of the ten extraction/recovery wells and will be rotated to the other wells as needed.

Through a combination of air monitoring and air sampling, the emissions from the VENR pilot tests were determined. These results were used to determine the vapor control needs for the full-scale operation. Based on these results and potential odor concerns, vapor controls were selected for all VENR systems.

1.2.2 *OU-II ROD Remedial Action Objectives*

As indicated in the 27 March 1998 OU-II ROD, the remedial action objectives (RAOs) for the OU-II Site are:

- prevent further migration of on-site OU-II NAPL;
- remove free-phase NAPL to the extent practicable; and
- continue to prevent direct contact with subsurface OU-II NAPL in the vicinity of the former lagoon.

The components of the OU-II have been designed to meet these RAOs. In addition, the OU-II remedy has been designed to:

- remove NAPL present in residual saturation to the extent that it contributes to free phase NAPL; and
- continue to ensure that OU-II ground water does not pose an unacceptable risk to human health and the environment.

As discussed in the Pilot Test Reports, additional off-site migration of OU-II NAPL will be prevented since: (1) the degraded NAPL in this area is relatively immobile; (2) operation of the VENR systems will reduce the mobility of on-site OU-II NAPL; and (3) the sheeting wall will ultimately block the OU-II NAPL.

Operation of the VENR system in the four NAPL Areas will also eliminate free phase NAPL to the extent practicable and remove NAPL present in residual saturation, to the extent that it contributes to free phase NAPL. Removal of free phase NAPL will be accomplished through all three VENR removal mechanisms and removal of NAPL present in residual saturation will be accomplished through biodegradation and volatilization. Perimeter ground water monitoring will be conducted downgradient of NAPL Areas L1 and L4 to continue to ensure that OU-II ground water does not pose an unacceptable risk to human health and the environment. Finally, existing Metro-North access restrictions will remain in place to prevent direct contact with subsurface OU-II NAPL in the vicinity of the former lagoon.

1.3 *PURPOSE OF THE EMP*

The purpose of the EMP is to identify the activities needed to evaluate the effectiveness of the remedy and to determine when the remedial action is complete. This will be approached in a multifaceted manner by evaluating both performance and effectiveness criteria. While performance relates to the adequacy of the operating elements of the combined VENR system, effectiveness pertains to the degree of success of the system in meeting the individual OU-II RAOs discussed above. The effectiveness of the remedy at achieving the OU-II RAOs contained in the OU-II ROD for removal of free phase NAPL will be evaluated based upon the amount of NAPL removed (See Section 2.0). Unlike the removal of free-phase NAPL, the effectiveness of the other two RAOs contained in the OU-II ROD (i.e., preventing further migration of on-site OU-II NAPL and continuing to prevent direct contact with subsurface OU-II NAPL in the vicinity of the former lagoon) do not need to be evaluated on an on-going basis and therefore are not addressed in this EMP.

Since the effectiveness of the remedial action relies upon optimum performance of the remedial system components, the EMP also provides a means of performance evaluation and adjustments. By operating the VENR systems properly the additional non-ROD NAPL removal objective (i.e., removing NAPL in residual saturation to the extent that it contributes to free-phase NAPL) will be addressed. The performance aspect identifies the adjustable components and record keeping procedures for each of the VENR system components. This part of the EMP establishes performance parameters and defines monitoring requirements, methods of data analysis and decision making processes that will prompt operational changes or design modifications to the VENR system to achieve, or substantially improve the ability of the remedy to achieve the remedial goals (see Section 3.0).

A ground water monitoring plan will also be implemented to ensure that OU-II ground water does not pose an unacceptable risk to human health and the environment (see Section 4.0). This is the other non-ROD RAO. The two ground water monitoring wells installed on the downgradient side of the OU-II site will be incorporated into the site-wide perimeter ground water monitoring plan. Ground water samples will be collected annually. The results will be evaluated to confirm that ground water does not pose any unacceptable risks to human health and the environment.

The ultimate performance of the remedy will be evaluated against closure criteria. The shutdown evaluation for the VENR remedial system is comprised of an initial, temporary shutdown followed by pre-closure monitoring and an eventual permanent shutdown of the system. The permanent shutdown phase will be followed by a period of post-shutdown monitoring.

This EMP outlines criteria which will likely be employed to optimize the timing of temporary shutdown. Additionally, this EMP outlines criteria that will be used to decide that the VENR system has, to the extent practical, achieved the remedial goals such that the project can move into the post-shutdown monitoring phase (see Section 5.0).

These objectives and criteria are discussed in greater detail in the following sections.

2.0 *VENR EFFECTIVENESS MONITORING*

2.1 *PURPOSE*

The purpose of this section is to establish the criteria that will be used to evaluate the overall effectiveness of the OU-II remedy. As discussed in Section 1.2, the effectiveness of the remedy will be gauged against the main remedial action objective identified in the OU-II ROD, the removal of free-phase NAPL. As a first step in establishing the criteria against which removal of free-phase NAPL would be measured, the distribution of NAPL in the formation was first evaluated.

The OU-II NAPL is distributed between three general locations:

- free-phase NAPL located at or near the current water table surface;
- residual NAPL above and below the water table; and
- residual NAPL within the historical water table fluctuation zone (i.e., the smear zone).

A schematic representation of these NAPL locations is provided in Figure 2-1.

NAPL found at or near the current water table surface may exist as either residual or free-phase NAPL. Free-phase NAPL refers to a contiguous horizon of NAPL that has the potential for mobility in the subsurface. Residual NAPL consists of isolated, disconnected droplets of NAPL that are immobile in the subsurface. The NAPL smear zone includes both the lowermost portion of the unsaturated zone and the uppermost portion of the saturated zone. Boring log data indicates that the smear zone is generally found between 4.0 and 8.0 feet below grade in NAPL Area L1 and between 2.5 and 8.0 feet below grade in NAPL Area L4.

To evaluate the effectiveness of this remedy, the NAPL volumes at these three locations were estimated. The following section presents the modeling and calculations conducted to determine the volume of:

- free-phase NAPL located at or near the current water table surface;
- residual NAPL above and below the water table; and
- residual NAPL within the smear zone.

As discussed above, the effectiveness of the remedy will be gauged against the main remedial action objective identified in the OU-II ROD, the removal of free phase NAPL. Using the free phase NAPL volume estimates (see Section 2.2), the effectiveness criteria for the remedy was established (see Section 2.3).

Although the main remedial action objective for the site is removal of free phase NAPL, the other locations of NAPL will also be addressed by the VENR systems. Residual NAPL located above and below the water table and within the smear zone will be addressed by the biodegradation and volatilization components of the remedy. The effectiveness of the remedy to remove the NAPL located in residual saturation through biodegradation and volatilization will be accomplished by the performance monitoring discussed in the following section.

2.2 *NAPL VOLUME ESTIMATE*

NAPL Areas L1 and L4 contain the vast majority of the OU-II NAPL. Consequently, the NAPL estimates were performed for these two areas.

Section 2.2.1 presents the estimation of the volume of free and residual NAPL in the vicinity of the water table in these two NAPL Areas. Section 2.2.2 presents the estimation of residual NAPL located within the smear zone in these two NAPL Areas.

2.2.1 *Estimate of Free and Residual NAPL Volume at the Water Table*

It has long been recognized that the apparent NAPL thickness detected in a monitoring well is much larger than the actual height of free NAPL in the subsurface. In the past, NAPL bail-down tests were commonly utilized to estimate the free NAPL thickness. The free NAPL thickness was then used along with soil porosity to simplistically estimate the volume of free phase NAPL. This method is now known to be extremely inaccurate and the current state-of-the-science utilizes numerical models based on soil physics theory in conjunction with apparent NAPL thickness measurements to determine free and residual NAPL volumes at the water table.

The landmark papers that established the solution to this problem were published concurrently in the Journal of Ground Water (Farr, et. al, 1990; Lenhard and Parker, 1990). The numerical theory developed in these papers provided the basis for the development of applied computer models to calculate free NAPL volume from apparent NAPL thickness data. This type of model was therefore utilized to estimate the volume of free and residual NAPL at the water table. The model that was selected is entitled OILVOL (Draper-Aden Environmental Modeling, 1995).

As per the theory developed by Farr, et. al. (1990) and Lenhard and Parker (1990), OILVOL is based on the assumption of "vertical equilibrium phase pressure distribution" (Draper-Aden Environmental Modeling, 1995). The OILVOL program works by dividing the problem domain into an evenly spaced grid. The apparent NAPL thickness measured in site monitoring wells is then interpolated onto the grid in a krigging process to establish values of apparent NAPL thickness throughout the domain. "Using the three-phase constitutive relation between phase saturation and pressure, the vertical distribution of water and oil saturation is computed. Integration of the oil saturation with depth gives the specific oil volume

(volume of free oil per unit surface area). The specific oil volume at each grid node is multiplied by the respective nodal surface to compute volume of free hydrocarbon at the node and these are summed to obtain the total free product in the soil." (Draper-Aden Environmental Modeling, 1995). Further description of the application of OILVOL at OU-II is presented below.

2.2.1.1 *OILVOL Input Parameters*

OILVOL initially requires that a two-dimensional grid be set-up to locate the apparent NAPL thickness data points. Grids were established for NAPL Areas L1 and L4 and are shown in Figures 2-2 and 2-3. Separate simulations were performed for these two areas. NAPL Areas L2 and L3 were not modeled due to their small size. The most extensive set of apparent NAPL thickness data was collected during the time period of 1995 to 1996 when the temporary OU-II NAPL delineation wells were installed. These wells no longer are present.

For most wells, multiple measurements were recorded during this period and the largest apparent NAPL thickness in each well was utilized for input to the model. A summary of the apparent NAPL thickness data used in the model is provided as Tables 2-1 and 2-2. In order to clearly define the extent of NAPL for the model, a number of additional "dummy" data points were placed around the perimeter of the NAPL plume areas and set at a value of zero to ensure that the model did not overestimate the NAPL plume areas.

OILVOL also requires input data to define the critical characteristics of the subsurface soil and NAPL. A list of the required parameters, input values and sources of data is presented below for NAPL Area L1:

OILVOL Input Parameters - NAPL Area L1

Parameter	*Input Value (units)*	*Data Source*
Porosity	0.35 (dimensionless)	Assumed
S_{or} - Maximum residual NAPL content in the saturated zone	0.25 (dimensionless)	Within typical range of 0.10 to 0.35 (1)
S_{og} - Maximum residual NAPL content in unsaturated zone	0.06 (dimensionless)	Within typical range of 0.01 to 0.10 (1)
S_m - Minimum water saturation	0.57 (dimensionless)	SOILPARA (see below)
van Genuchten α-parameter (inverse bubbling pressure)	3.557 ($feet^{-1}$)	SOILPARA (see below)
van Genuchten n-parameter (pore size distribution)	1.592 (dimensionless)	SOILPARA (see below)
NAPL Density	0.913 (dimensionless)	Average of three samples
B_{ao} - Air/NAPL phase scaling parameter	2.211 (dimensionless)	$1/B_{ao} + 1/B_{ow} = 1$ (2)
B_{ow} - NAPL/Water phase scaling parameter	1.826 (dimensionless)	B_{ow} = NAPL Density x 2 (1)

As indicated above, several parameters were determined using a separate computer program entitled SOILPARA (Draper-Aden Environmental Modeling, 1995). For this application, SOILPARA was used with grain size data from the site (three samples) to identify the soil type on a tri-linear texture diagram (sand/silt/clay). Through this process, the site soil type was identified as "sand". Soil bulk density is also a required input, which was determined via analysis of three samples (0.75 g/cc). The SOILPARA model was then used to estimate the parameters needed by OILVOL. The van Genuchten α and n parameters are determined directly by SOILPARA. The program also calculates the minimum residual water

(1) Kaytal, A., 1999
(2) Leonard & Parker, 1990

content (θ_r), through which the S_m parameter is determined using the following relationship:

$S_m = \theta_r$/porosity (Katyal, A., 1999).

The OILVOL input parameters for NAPL Area L4 are given as follows:

OILVOL Input Parameters - NAPL Area L4

Parameter	Input Value (units)	Data Source
Porosity	0.35 (dimensionless)	Assumed
S_{or} - Maximum residual NAPL content in the saturated zone	0.25 (dimensionless)	Within typical range of 0.10 to 0.35 (1)
S_{og} - Maximum residual NAPL content in unsaturated zone	0.06 (dimensionless)	Within typical range of 0.01 to 0.10 (1)
S_m - Minimum water saturation	0.117 (dimensionless)	SOILPARA (see below)
van Genuchten α-parameter (inverse bubbling pressure)	2.073 ($feet^{-1}$)	SOILPARA (see below)
van Genuchten n-parameter (pore size distribution)	1.322 (dimensionless)	SOILPARA (see below)
NAPL Density	0.877 (dimensionless)	Average of four samples
B_{ao} - Air/NAPL phase scaling parameter	3.326 (dimensionless)	$1/B_{ao} + 1/B_{ow} = 1$ (2)
B_{ow} - NAPL/Water phase scaling parameter	1.754 (dimensionless)	B_{ow} = NAPL Density x 2 (1)

In NAPL Area L4, the sieve analysis of four soil samples indicated the site soil type to be "sandy loam". Soil bulk density was determined via analysis of four samples (1.0 g/cc). The SOILPARA model was then used to estimate the parameters needed by OILVOL as previously described.

2.2.1.2 *Model Results*

The apparent NAPL thickness data (see Tables 2-1 and 2-2) are initially taken by OILVOL and interpolated (by krigging) to estimate a value for each node in the grid. The krigged datasets of apparent NAPL thickness have been contoured and presented as isopach maps in Figures 2-4 and 2-5. The apparent NAPL thickness isopach map for Area L1 matches well with the known historical extent of NAPL at this location. That is, the interpolated data predicted that a small, relatively thin apparent NAPL accumulation extends beyond the delineated extent of historical NAPL occurrence. This is an artifact of the krigging algorithm and will cause a small overestimation of the NAPL volume in L4.

OILVOL outputs spatially variable values of NAPL volume per unit area for three separate NAPL types: (1) free NAPL at the water table; (2) residual NAPL in the saturated zone at the water table; and (3) residual NAPL in the unsaturated zone at the water table. The model also calculates a total volume for each NAPL location.

The model results for NAPL Area L1 is presented in Figure 2-6. This figure is an isocontour map of free NAPL volume per unit surface area, as calculated by the model. The maximum value of this parameter in the L1 area is 0.028 ft^3/ft^2. The average value within the plume is 0.004 ft^3/ft^2. The volume of free and residual NAPL at the water table in Area L1 that was estimated using this model is 1,192 gallons. The distribution of NAPL volume in the vicinity of the water table in Area L1 is distributed as follows:

- The total volume of free phase NAPL at the water table in Area L1 is approximately 534 gallons.
- The total volume of residual NAPL in the saturated zone at the water table in Area L1 is approximately 506 gallons.
- The total volume of residual NAPL in the unsaturated zone at the water table in Area L1 is approximately 152 gallons.

The model results for NAPL Area L4 is presented in Figure 2-7. As previously done for L1, this figure is an isocontour map of free NAPL volume per unit surface area. The maximum value of this parameter in the L4 area is 0.121 ft^3/ft^2. The average value within the plume is 0.014 ft^3/ft^2. The volume of free and residual NAPL at the water table in Area L4 that was estimated using this model is 8,549 gallons. The distribution of NAPL volume in the vicinity of the water table in Area L4 is distributed as follows:

- The total volume of free NAPL at the water table in Area L4 is approximately 4,298 gallons.
- The total volume of residual NAPL in the saturated zone at the water table in Area L4 is approximately 3,541 gallons.
- The total volume of residual NAPL in the unsaturated zone at the water table in Area L4 is approximately 710 gallons.

2.2.2 *Estimate of Residual NAPL Volume in the Smear Zone*

The residual NAPL volume in the smear zone can be roughly approximated using the methods of CONCAWE (CONCAWE, 1979) or the American Petroleum Institute (API, 1972). CONCAWE gives typical NAPL retention capacities for kerosene in various types of unsaturated soils. Since the viscosity of kerosene is similar to diesel comprising OU-II NAPL, this approximation is valid. CONCAWE has estimated a retention capacity for medium to fine sand of 5.0 gallons per cubic yard of sand. Smear zone volumes for NAPL Areas L1 and L4 were determined based on the plume areas shown in Figures 2-2 and 2-3, and the smear zone thicknesses given above. Accordingly, the estimated volumes of residual NAPL in the smear zone for Areas L1 and L4 using the CONCAWE method are:

- L1: 2,742 yd^3 x 5.0 gal/yd^3 = 13,709 gallons
- L4: 8,150 yd^3 x 5.0 gal/yd^3 = 40,749 gallons
- Total L1 and L4 NAPL volume in the smear zone: 54,458 gallons

In contrast, API (1980) provides residual saturation values for different petroleum product types as a percentage of the total porosity. For diesel, API (1980) estimates that 15% of the porosity is filled by NAPL and the total porosity is 35% of the bulk soil volume. The estimated volumes of residual NAPL in the smear zone are then determined using the API guidance as indicated below:

- L1: 74,028 ft^3 x 0.35 x 0.15 x 7.481 gal/ft^3 = 29,075 gallons
- L4: 220,042 ft^3 x 0.35 x 0.15 x 7.481 gal/ft^3 = 86,422 gallons
- Total L1 and L4 NAPL volume in the smear zone: 115,497 gallons

Because these two methods are considered rough approximations, the variation between the methods is considered acceptable. The use of two methods serves to provide an estimated range of NAPL volumes in the smear zone for each of the two NAPL areas.

2.2.3 *Summary of the NAPL Volume Estimates*

The results of the OILVOL modeling can be used in combination with the estimates of NAPL volume in the smear zone to determine the overall NAPL volume present in Areas L1 and L4. The specific gravity can then be used to convert the volume estimates to mass as shown below.

Summation of NAPL Present in Area L1

Free NAPL	534 gallons
Residual NAPL at the Water Table in the Saturated Zone	506 gallons
Residual NAPL at the Water Table in the Unsaturated Zone	152 gallons
Smear Zone Residual NAPL	13,709 - 29,075 gallons
Total L1 NAPL	13,901 - 30,267 gallons

Summation of NAPL Present in Area L4

Free NAPL	4,298 gallons
Residual NAPL at the Water Table in the Saturated Zone	3,541 gallons
Residual NAPL at the Water Table in the Unsaturated Zone	710 gallons
Smear Zone Residual NAPL	40,749 - 86,422 gallons
Total L4 NAPL	45,673 - 94,971 gallons

These results confirm pilot study findings that the majority of OU-II NAPL is located in residual saturation within the smear zone. Through the use of numerical models based on soil physics theory in conjunction with NAPL thickness measurements, realistic NAPL volumes around the water table have been estimated.

Since the free-phase NAPL volumes are a function of apparent NAPL thickness, the change in the apparent NAPL thickness can be used to determine the percentage of free-phase NAPL removed through VENR. To relate the free-phase NAPL volumes with apparent NAPL thickness, additional model runs were conducted wherein all monitoring wells that contained an accumulation of NAPL were assigned a constant value for apparent NAPL thickness. Monitoring wells that had a measured apparent NAPL thickness of zero were not changed. In NAPL Area L1, model runs were performed using constant apparent NAPL thicknesses ranging from 0.0 feet to 2.0 feet. In NAPL Area L4, model runs were performed using constant apparent NAPL thicknesses ranging from 0.5 feet to 2.0 feet. The results of this work were then used to prepare graphs of apparent NAPL thickness versus NAPL volume. These graphs are presented as Figure 2-8 (NAPL Area L1) and Figure 2-9 (NAPL Area L4). This information will be used in the following sections to relate the amount of free-phase NAPL removed to average apparent NAPL thicknesses.

2.3 *NAPL MONITORING*

To evaluate the effectiveness of the VENR technology, NAPL thickness measurements will be collected from all the extraction wells and a number of the air inlet wells on a monthly basis. NAPL monitoring activities are discussed in detail in Section 3.2.2.3. At the end of each quarter, the average NAPL thicknesses observed in each NAPL area over the previous three month period will be calculated. This information will then be used in the above-referenced model and graphs, to determine the percentage of NAPL removed during that quarter and since system start-up. As discussed further in Section 5.0, this information will then be used to evaluate the effectiveness of the VENR system.

2.4 *RECORDKEEPING AND REPORTING*

The monthly NAPL thickness measurements, the calculated three month average NAPL thickness, and the percentage of NAPL removed will be included in the quarterly progress reports to NYSDEC. Additional discussion regarding the quarterly monitoring report requirements are provided in Section 6.0.

2.5 *OPERATIONAL MODIFICATIONS*

Throughout the remedial action, process modifications will be conducted to optimize VENR system effectiveness. Performance measurements that will be routinely collected and evaluated to determine what, if any, operating modifications are required to maintain VENR system effectiveness at an optimum. These performance measurements and operational adjustments are discussed in Section 3.0.

3.0 VENR PERFORMANCE MONITORING

Performance monitoring is different from the effectiveness monitoring defined in Section 2.0, which is primarily designed to measure whether the VENR system as a whole is removing NAPL. System performance is defined as the ability of the each of the basic components of the VENR system to meet their specific design objectives. The basic components of the VENR system are: soil gas extraction and air inlet systems, free-phase NAPL removal, and vapor treatment. VENR performance is evaluated by monitoring each component of the remedial system to determine whether it is operating in a satisfactory manner. Through fulfillment of the VENR performance objectives identified below, NAPL-related remedial action objectives will be fulfilled.

3.1 PURPOSE

The performance objectives of the VENR systems are as follows:

- draw sufficient air through the formation to ensure that adequate oxygen is distributed throughout the OU-II NAPL Areas to facilitate biodegradation;
- promote volatilization into the soil gas of the remaining volatile organic components contained in the OU-II NAPL and extraction of the soil gas through the vapor recovery system;
- draw free-phase NAPL through the subsurface soil to the recovery wells from where it can then be removed using the NAPL-only recovery systems; and
- remove VOCs from the extracted soil gas and thus ensure that vapor emissions from the VENR system do not pose any unacceptable risks to the surrounding community and the on-site workers.

This section presents a basis for monitoring the performance of the individual components of the VENR system (e.g., blower, vapor controls, NAPL-only recovery pumps), and the system as a whole, to ensure that the technology is operating at its optimum and meeting its objectives. This section also identifies the parameters to be monitored to ensure that the individual VENR components are operating properly, and the operational adjustments to be made to optimize system performance.

3.2 *SYSTEM COMPONENTS*

Each VENR system is comprised of the following major systems: soil gas extraction and air inlet systems, NAPL-only recovery systems and vapor treatment systems.

3.2.1 *Soil Gas Extraction/Air Inlet Systems*

The soil gas extraction system includes the following components:

- air inlet wells in the high air permeability NAPL Areas (i.e. NAPL Area L1, L2 and L3);
- forced air injection wells and a forced air injection blower in the low air permeability NAPL Area (i.e. NAPL Area L4);
- soil gas withdrawal blowers;
- soil gas extraction/NAPL recovery wells in all four NAPL Areas; and
- recovery well vaults and pull boxes, piping and buildings.

A process and instrumentation diagram of the VENR system is shown on Remedial Design Drawings Numbers PID-2, 3 and 4 (See Appendix A).

The locations of the wells and other major components of the system in each area are shown on Drawing C-2 presented in Appendix A. This figure presents the estimated aerial extent of NAPL in the four (4) OU-II NAPL Areas. The well layouts for each of the NAPL Areas was determined using the pneumatic effective radius of influence (EROI) for each area observed during the VENR pilot testing. As discussed in the collective pilot testing results documentation, the well spacing for each of the NAPL Areas has been conservatively based upon the pneumatic EROI observed in each NAPL Area. A summary of the pneumatic EROIs for each of the NAPL Areas along with the number of soil gas extraction and air inlet/injection wells is provided in Table 3-1. Use of the pneumatic

EROI is conservative since the oxygen EROIs, the true spacing parameter of a VENR system, are greater than the pneumatic EROI at this site.

The soil gas extraction/NAPL recovery wells will be constructed of PVC pipe with a slotted screen at a minimum depth of 2 feet below the water table and 3.5 feet above the water table to ensure that the entire NAPL smear zone is addressed. Construction details of the wells are shown in Appendix A, Drawing C-6.

Blowers will be utilized in all four NAPL Areas to extract the soil gas from the formation through the soil gas extraction wells. In NAPL Area L4, a blower will also be used to inject air under pressure through air injection wells. This will provide additional air to the formation to address the low permeability of the soil in this NAPL area. External pressure will not be applied to the air inlet wells that are to be used to provide atmospheric air to the remaining three NAPL areas. The specific blower requirements for the extraction and injection wells in each of the four (4) NAPL Areas are shown in Table 3-1. These requirements were determined during the VENR pilot testing.

Soil gas extraction lines will be installed between all the soil gas extraction wells and the blowers serving these wells. Air inlet or air injection wells will be installed between extraction wells and at the outer limits of the pneumatic EROI to provide sufficient oxygen around each of the extraction wells. Further discussion regarding the system components and operation in each of the four NAPL Areas follows below.

NAPL Areas L1 and L2

At an operating vacuum of 8-inches w.c., and a resulting soil gas withdrawal rate of 120 cfm per well, the pneumatic EROI observed in NAPL Area L1 during the pilot testing was approximately 21 feet. This corresponds to a conservative well spacing of 34 feet for the soil gas extraction wells. Therefore, to provide adequate oxygen coverage for the area, eleven (11) soil gas extraction wells will be installed, spaced at 34 feet. These wells will be designated VE1-1 to VE1-11.

Pilot testing in NAPL Area L2 indicated that a vacuum of 22-inches w.c. would provide an adequate pneumatic EROI and would withdraw approximately 16 cfm of soil gas from the formation. This soil gas extraction rate would be sufficient to provide more than adequate oxygen to NAPL Area L2. Based on these pilot test results a pneumatic EROI of 25 feet was estimated for this NAPL Area. At this pneumatic EROI, only one soil gas extraction well (VE2-1) would be needed for NAPL Area L2. This EROI will be confirmed during installation.

Air inlet wells will be installed between extraction wells and at the outer limits of the pneumatic EROI in NAPL Area L1 to provide sufficient oxygen around each of the extraction wells. Because of its limited size, air inlet wells will only be installed at the outer limits of the pneumatic EROI in NAPL Area L2 to provide sufficient oxygen around the single extraction well to be installed in NAPL Area L2. These wells will be constructed of 2-inch diameter PVC with a screen slot size of 0.01-inch. The locations of these wells are presented on Drawing C-2 of Appendix A.

If all eleven soil gas extraction wells in NAPL Area L1 are operated concurrently, the total soil gas extraction rate would be approximately 1,320 cfm. Due to this high soil gas extraction rate, NAPL Area L1 will be divided into two operating zones, which will be operated alternately.

Two blowers will run concurrently to aerate half of the area at a time. After four hours the electronically-controlled valves will open and close to redirect the vacuum to the other operating zone. Since the NAPL content in this NAPL Area is low and the formation is so highly permeable, alternate aeration of the two areas is not expected to significantly increase the overall remediation timeframe.

Due to the close proximity of NAPL Area L2 to NAPL Area L1 and the fact that only one extraction well is required in NAPL Area L2, these two areas will be operated as one. The combined area will be split up into two zones as stated above. These zones will be as follows:

- Zone 1: soil gas extraction wells VE 1-1 through VE 1-6 in NAPL Area L1; and
- Zone 2: soil gas extraction wells VE 1-7 through VE 1-11 in NAPL Area L1 and VE 2-1 in NAPL Area L2.

The vacuum blower assembly for the combined NAPL Area L1/L2 is shown schematically on Design Drawing PID-2, presented in Appendix A. The blower assembly consists of: a liquid vapor separator; 4-inch dilution valve; an in-line air filter; two (2) electrically actuated butterfly valves; two (2) regenerative blowers; two (2) pressure transmitters; one (1) temperature transmitter; and one (1) flow transmitter.

Under normal operating conditions the system will withdraw 720 cfm from one of the two NAPL Area L1/L2 operational zones at a time. The blower assembly is oversized and is capable of a maximum withdrawal of 1100 cfm. The assembly will draw in soil gas from the subsurface, through the soil gas extraction/NAPL recovery wells and a liquid/vapor separator. The soil gas will then be processed through vapor control equipment (See Section 3.2.3) and ultimately exhausted through an emissions stack.

All NAPL Area L1/L2 VENR equipment will be housed in the NAPL Area L1/L2 building. The building will be of concrete block construction and be divided into two rooms, the equipment room and control room. The equipment room will contain the vacuum blower assembly, liquid-vapor separator, vapor control equipment (GAC drums), the storage drums for the condensate from the vapor/liquid separators (which will be placed on secondary containment pallets). The control room will contain all soil gas recovery system instrumentation and controls, motor starters and power panels.

NAPL Area L3

At an operating vacuum of 19-inches w.c., and a resulting soil gas withdrawal rate of 14 cfm per well, the pneumatic EROI observed in NAPL Area L3 during the pilot testing was approximately 23 feet. This corresponds to a conservative well spacing of 37 feet for the soil gas extraction wells. Therefore, to provide adequate oxygen coverage for NAPL Area L3, three (3) soil gas extraction wells will be installed, spaced at 37 feet. These wells will be designated VE 3-1 to VE 3-3. This configuration results in a total soil gas extraction rate of 42 cfm for NAPL Area L3. Air inlet wells will be installed at the outer limits of the pneumatic EROI in NAPL Area L3 to provide sufficient oxygen around each of the extraction wells. The locations of these wells are presented on Drawing C-2 presented in Appendix A.

The vacuum blower assembly for Area L3 is shown schematically on Drawing PID-3 of Appendix A. The blower assembly will consist of: a liquid vapor separator; 2-inch dilution valve; in-line air filter; a check valve; one (1) regenerative blower; one (1) pressure transmitter; one (1) temperature transmitter; and one (1) flow transmitter.

The blower assembly will be capable of withdrawing 42 cfm at 19-inches w.c. The assembly will draw in air from the subsurface, through the soil gas extraction/NAPL recovery wells and the liquid vapor separator. The soil gas will then be processed through vapor control equipment (See Section 3.2.3) and ultimately exhausted through an emissions stack.

The blower for NAPL Area L3 will be placed in an enclosure mounted on a skid base. The enclosure walls will consist of 16 gauge galvanized carbon steel sheet metal with 2-inch thick polyether foam with mylar facing for noise reduction. The enclosure will also be fitted with a ventilation fan to prevent the blower motor from overheating. The remaining equipment, consisting of the vapor/liquid separator, vapor control units (GAC drums) and the storage drums for the condensate from the vapor/liquid separators, will be heat traced and located on the ground next to the equipment skid. All drums will be placed on secondary containment pallets.

NAPL Area L4

Pilot testing in NAPL Area L4 indicated that a vacuum of 10 to 20-inches w.c. would withdraw approximately 3 to 4 cfm of soil gas from the formation and would provide an pneumatic EROI in this area of 25 feet. This corresponds to a conservative well spacing of 35 feet for the soil gas extraction wells. In order to provide adequate oxygen to the NAPL Area L4 formation under these operating conditions, 13 soil gas extraction wells will be installed at 35-foot well spacing. The designations for these wells is VE4-1 through VE4-13.

During pilot testing in NAPL Area L4, the formation was observed to exhibit extremely heterogeneous conditions. As a result, in-field pneumatic testing will be conducted during the Remedial Construction to confirm that the well spacing is adequate in this area. The Oversight

Engineer will determine the need for additional soil gas extraction wells in this area and the construction contract will include an allowance item for the installation of additional soil gas extraction wells.

Based on the installation of thirteen soil gas extraction wells and conservatively assuming a soil gas extraction rate of 10 cfm per well, the total soil gas extraction rate for this NAPL Area will be 130 cfm.

Due to the low air permeability of the subsurface soil in NAPL Area L4, forced air injection wells will be used to provide oxygen to the formation. The forced air injection wells will be installed between the soil gas extraction wells and at the outer limits of this NAPL area. Approximately 21 new air injection wells will be installed and four (4) of the existing observation wells from the pilot testing activities (wells OW-1, OW-3, OW-5 and OW-6) will be converted to air injection wells. These wells will supply air at a flow rate of approximately 1.5 cfm per well. Consequently, the blower will be required to supply a minimum total air flow for injection of 37.5 cfm.

The proposed locations of these 25 forced air injection wells, designated as FA 4-1 through FA 4-25, are provided in Design Drawing C-3 of Appendix A. The final locations may be revised slightly during construction, depending on physical constraints. If needed, additional forced air injection wells will be installed in the future to provide an adequate supply of air to subsurface soil.

The vacuum blower assembly for NAPL Area L4 is shown schematically on Design Drawing PID-4 of Appendix A. The blower assembly will consist of: a liquid vapor separator; 2-inch dilution valve; in-line air filter; a check valve; one (1) regenerative blower; one (1) pressure transmitter; one (1) temperature transmitter; and one (1) flow transmitter.

The blower assembly will be capable of withdrawing 130 cfm at 60 inches w.c.. The assembly will draw air through the subsurface to the soil gas extraction/NAPL recovery wells and through a liquid vapor separator. The soil gas will then be processed through vapor control equipment (See Section 3.2.3) and ultimately exhausted through an emissions stack.

As discussed above, due to the low air permeability in NAPL Area L4, forced air injection is needed for this NAPL Area. The air injection blower assembly for NAPL Area L4 is shown schematically on Design Drawing PID-4 of Appendix A. The blower assembly will consist of: an inlet air filter with silencer, one (1) regenerative blower, one (1) pressure transmitter, one (1) temperature transmitter, one (1) flow transmitter, and one (1) aftercooler. The blower assembly will be capable of providing a total of 37.5 cfm of air at 40 inches w.c.. The blower will force air through each of the 25 air injection wells into the subsurface.

All NAPL Area L4 equipment will be housed in the NAPL Area L4 building. The building will be of concrete block construction and be divided into two rooms, an equipment room and a control room. The equipment room will contain the vacuum blower assembly, air injection assembly, liquid-vapor moisture separator, air compressor, vapor control equipment (GAC drums), the storage drums for the condensate from the vapor/liquid separators (which will be placed on secondary containment pallets), and continuously operating ceiling fan. The control room will contain all soil gas recovery system and NAPL recovery system instrumentation and controls.

3.2.1.1 *Performance Objective*

The objective of the soil gas extraction systems is to draw sufficient air through the formation in order to: ensure adequate oxygen is distributed throughout the NAPL Areas to facilitate biodegredation; promote volatilization into the soil gas of the remaining volatile organic components of the NAPL, which are then extracted through the vapor recovery system; and draw free-phase NAPL through the subsurface soil to the recovery wells from where it can then be removed using the NAPL-only recovery systems.

3.2.1.2 *System Control Components*

The mechanical controls for each NAPL Area soil gas extraction system are as follows:

- manual flow control valve (butterfly type) for each extraction well;
- manual flow control valve (butterfly type) for dilution air;
- manual isolation valves (butterfly type) for inlet side of each blower;
- check valve for each inlet side of each blower (Area L1 only);
- automatic vacuum relief valves on inlet side of each blower;
- level controls on moisture separator;
- differential pressure switch across blower; and
- temperature switch on blower outlet.

The airflow and isolation of each of the soil gas extraction wells can be controlled by the butterfly valve on the header for each well. For Area L1 only, the check valve is placed in the vacuum line for each blower to prevent back siphoning of the air through the blowers should they be shut off.

A manual butterfly valve for each blower will allow for the isolation of a blower for either normal operation or during maintenance. The moisture separator level controls are used to automatically cycle the condensate pump to transfer condensate from the moisture separator to a storage vessel. The level controls include an alarm/shutdown feature should the condensate over-accumulate in the vessels. The vacuum relief valves along with the pressure differential switch prevent the blower from operating outside the safe operating range. The temperature switch triggers an alarm shutdown to prevent the blower from damage should a condition cause over-heating.

In addition, NAPL Area L1/L2 will have two (2) electric automatically actuated butterfly valves. As this area will be operated in two operational zones the actuator valves will be placed in the header assembly. The valves will either be opened or closed to direct the vacuum supplied by the blowers to the appropriate operational zone. This will be done electronically every four hours. Also, for the buildings in NAPL Areas L1 and L4, a lower explosive limit (LEL) monitor triggers an alarm shutdown should explosive vapors begin to accumulate to potentially dangerous levels.

3.2.1.3 *Monitoring*

The soil gas extraction system will be monitored to ensure safe and accurate operation. Operation and maintenance personnel will routinely visit the work area to monitor and record system operation. Routine O&M will be conducted at least monthly, although the frequency may be higher during start-up. Detail regarding actual activities to be conducted during the routine O&M will be provided in the OU-II O&M Plan.

During routine O&M, the following tasks shall be performed:

- inspection of soil gas extraction system;
- flow balance adjustments;
- open/close wells as required;
- lubricate equipment and facilitate repairs as necessary; and
- work valves, as necessary to ensure they are operable.

In addition, the following measurements will be taken and recorded:

- soil gas flow rate from each extraction well;
- air flow rate into each forced air injection well;
- vacuum at each extraction well;

- pneumatic response at the air inlet wells;
- pressure at each forced air injection well;
- Volatile organic compound concentrations (VOCs) at each extraction well and at the combined inlet and outlet of each carbon vessel;
- % LEL and % oxygen at each extraction well and the combined inlet and outlet of each carbon vessel;
- water table elevations; and
- NAPL thickness.

For each extraction well, the flow rate will be measured by the use of permanently installed flow averaging annubars and differential pressure gauges and the vacuum measured by permanently installed gauges. For each forced air injection well, the flow rate will be measured by the use of a portable air velocity meter and the pressure will be measured by permanently installed gauges.

To measure the pneumatic response at the air inlet wells, the wells will be sealed with a well cap with a petcock valve attached. The wells will be allowed to sit for a few minutes with the cap on while the pressure in the well comes to equilibrium. A differential pressure gauge will then be attached to the petcock valve, the valve will be opened and the vacuum measured.

In NAPL Area L4, where the air is introduced to the subsurface through pressurized air injection, the air injection system will need to be switched off before the vacuum response at these wells can be evaluated. Once the air injection system is shut-off, the wells will need to be capped and allowed to come to equilibrium (approximately 1 hour). After this time the vacuum response can be measured as discussed above.

The concentration of VOCs in the extracted soil gas will be measured at each extraction well using a PID. PID readings will also be taken at the combined inlet and outlet of each carbon vessel. The % LEL and % oxygen will also be measured at each extraction well and the combined inlet and outlet of each carbon vessel, using a LEL/O_2 meter. These measurements are discussed further in Section 3.2.3.2. On a monthly basis, water table elevations and NAPL thicknesses will be measured in all the extraction wells and in a number of the air inlet wells. These measurements are discussed further in Section 3.2.2.3.

The system operation will be monitored through the use of programmable logic controllers (PLC) in each of the three (3) NAPL operational areas (i.e., L1/L2, L3 and L4). The following parameters will be datalogged through the PLC and downloaded daily through a software package using an autodialer with an RS-232 adapter:

- discharge flow rate (i.e. soil gas extraction rate);
- blower differential pressure;
- blower discharge temperature; and
- diagnostic information, including alarm conditions.

The data generated by these automated PLC-based controls, along with the data collected manually during routine O&M, will be used to perform trend analyses. This information will be utilized in optimizing the soil gas extraction system operation.

On a quarterly basis, an operations report will be prepared. This report will include VENR system performance data, discussion of results with interpretation of data, and recommendations of operating modifications to optimize system performance.

3.2.1.4 *Operational Adjustments*

As the system operation progresses, it is expected that several operational adjustments will be needed to ensure the system's ability to induce an adequate flow of air/soil gas through the formation. Decisions about making adjustments will be based on the data obtained from the system monitoring, as discussed in Section 3.2.1.3, and per the discussion presented below.

When starting up the soil gas extraction system all of the valves to the soil gas recovery wells and the dilution air valve will be 100% open. The dilution air valve will then be gradually closed which will cause the soil gas flow from the extraction wells to gradually increase.

Once the dilution air valve has been set and the total flow of soil gas is established, the data shown in Tables 3-2 and 3-3 will be collected. The vacuum response will indicate whether there are sufficient pneumatic EROIs around the extraction wells such that adequate oxygen is reaching the NAPL Area. The criteria vacuum required to provide a sufficient pneumatic EROI will be at least 0.1 inches w.c. at each passive air inlet well, after the air inlet wells have been capped.

In NAPL Area L4, where the air is introduced to the subsurface through pressurized air injection, the air injection system will need to be switched off before the vacuum response at these wells can be evaluated. Once the air injection system is shut-off, the wells will need to be capped and allowed to come to equilibrium (approximately 1 hour). After this time the vacuum response can be measured as discussed above. Although the process of air injection means that additional air is being forced into the subsurface, by measuring the pneumatic response at these wells in this manner, it is possible to determine whether the injection well and the extraction well are pneumatically connected and as such approximately how much of the injected air is being drawn towards the extraction well and how much is only affecting the specific area surrounding the injection well.

If the vacuum in all air inlet wells is at least 0.1 inches w.c., all valves can remain as they are set. If the vacuum is less than 0.1 inches w.c. in some wells but greater in others, adjustments to the extraction flow rates from the wells will need to be made. Extraction wells in areas with vacuum response significantly greater than 0.1 w.c. may need a reduction in flow to allow more flow from wells in an area where the vacuum is less than 0.1 inches w.c. After the adjustments, the air inlet wells will then be rechecked to confirm that a 0.1 inch w.c vacuum has been achieved.

If a 0.1 inch w.c vacuum is still not achieved, evaluation of the oxygen EROI at that particular point may be considered. The oxygen EROI is the distance from a soil gas extraction well that an increase in the oxygen concentration, which is due to soil gas withdrawal from the extraction well, is observed. During the pilot testing, the observed oxygen EROI was generally greater than the pneumatic EROI at a particular applied vacuum. Therefore, even if the required pneumatic EROI has not been achieved at a particular inlet well, it is possible that the required oxygen EROI has been achieved. The pneumatic EROI was selected as the primary evaluation criteria since it is a more conservative determination that sufficient oxygen is reaching the outer regions of the NAPL area.

If the criteria vacuum, or oxygen concentration, has still not been reached, further adjustments may be needed. It may be necessary to develop a well rotating program where certain wells are operated for a given period of time and then, at some point in time, the operating wells are shut-down and the extraction wells not in operation are started up. The need for such a program will be evaluated during O&M.

3.2.1.5 *Recordkeeping*

Tables 3-2 and 3-3 present sample data recording forms for the soil gas extraction system which will be completed by the operator. The files are available in Excel format. Data to be recorded by the operator includes:

- the vacuum applied to each well;

- the pneumatic response at the air inlet wells;
- the soil gas flow rates from each well and from dilution air;
- valve status (open/closed/% open);
- %LEL and % oxygen values;
- PID readings from each well and from the vapor controls exhaust; and
- the date and time at which the measurements were taken.

Table 3-2 will be used to record the vacuum applied to each well and the corresponding pneumatic response at the air inlet wells. The methods to be used to collect this data are defined in Section 3.2.1.3. Table 3-3 will be used to record the data pertaining to the operation of the soil gas extraction blower and the vapor controls, such as total flow rates of soil gas and dilution air and readings from field meters including VOC concentrations and percent LEL/oxygen. The methods to be used to collect this data are defined in Section 3.2.1.3. This table will also be used to record the results of the laboratory analysis of the soil gas sample, taken at system start-up, from the inlet and outlet of the emission control systems for each NAPL area (see Section 3.2.3)

3.2.2 *NAPL-Only Recovery Systems*

NAPL-only recovery systems will be installed in the soil gas extraction /NAPL recovery wells in all four NAPL Areas. Further discussion regarding the system components and operation in each of the four NAPL Areas follows below.

NAPL Areas L1/L2 and L3

Due to the low volume of free-phase NAPL observed in NAPL Areas L1/L2 and L3 and the slow recharge rates observed during the pilot tests, non-automated NAPL-only recovery systems will be installed in the soil gas extraction/NAPL recovery wells in these areas. In NAPL Area L3, non-automated NAPL-only recovery systems will be installed in all three of the soil gas extraction/NAPL recovery wells. In NAPL Are L1/L2, the non-automated NAPL-only recovery systems will first be installed in the six Zone 2 soil gas extraction/NAPL recovery wells (see Drawing C-3 in Appendix A). Following VENR operation, these recovery systems will be rotated to the six soil gas extraction/NAPL recovery wells in Zone 1. The rotation schedule will be discussed in the OU-II O&M Plan.

Based on an evaluation of a number of NAPL-only recovery systems, the Specific Gravity Skimmer (SPG-4) manufactured by Clean Environment Equipment of Oakland, CA, or equivalent, has been chosen for NAPL Areas L1/L2 and L3. Each of the SPG-4 skimmer assemblies includes: a skimmer hanging strap, floating intake head with canister, flexible discharge tubing, NAPL reservoir, and a drain valve.

The skimmer operates using density differences. The floating intake of the skimmer has a specific gravity of 0.94. The specific gravity of diesel fuel ranges from 0.85 to 0.92 while the specific gravity of the ground water is 1. These specific gravity differences enable the skimmer to sink into the lower specific gravity NAPL layer and to float on top of the higher specific gravity ground water table. Due to its configuration, the skimmer leaves approximately 1.5 to 2 inches of NAPL in the well at all times.

NAPL recovered from the non-automated units in NAPL Areas L1/L2 and L3 will be manually collected in a hand held 5-gallon pail and transferred to the 500-gallon above ground storage tank located outside the NAPL Area L4 equipment building. This will initially be done on a weekly basis, but the frequency will be re-evaluated depending on recharge rates. Although non-automated NAPL-only recovery has been identified for NAPL Area L1, NAPL transfer conduits will be installed in the event that automated NAPL-only recovery becomes feasible in the future. However, NAPL transfer tubing will not be installed in the NAPL Area L1 conduits until this need has been confirmed. Further information about the construction of these NAPL transfer conduits is provided in the NAPL Area L4 section below.

NAPL Area L4

Automated NAPL-only recovery systems will be installed in NAPL Area L4. Based on the evaluation of NAPL-only recovery units, the Genie-200 Controllerless System, or equivalent, combined with the Specific Gravity Skimmer (SPG-4) manufactured by Clean Environment Equipment of Oakland, CA, or equivalent, has been selected for installation in the NAPL Area L4 soil gas extraction/NAPL recovery wells. Each of the Controllerless-type systems consists of the following: a double stage filter/regulator, a Genie controllerless pump, or equivalent; SPG-type skimmer; NAPL transfer line; control panel; and compressor.

These automated NAPL-only recovery pumps will be installed in three (3) of the thirteen (13) soil gas/NAPL recovery wells located in NAPL Area L4. The pumps will then be rotated to the remaining ten (10) NAPL recovery wells, as needed. The rotation schedule for these recovery systems will be discussed in the OU-II O&M Plan.

The floating skimmer allows NAPL to pass into and accumulate in the pump chamber/canister at the rate at which it recharges into the well. Using the introduction and release of compressed air, the pump draws NAPL from the skimmer and pushes it up to a NAPL storage tank located at the surface.

A compressor is required to operate the recovery pumps for the automated NAPL-only recovery systems. The compressor will be a Quincy QTH 3 Hp compressor, or equivalent, complete with the following accessories: 80-gallon horizontal receiver tank; low oil and pressure switch; and desiccant dryer. This compressor will be located in the equipment room of the NAPL Area L4 building, and will supply the air required to operate the automated NAPL-only recovery units.

NAPL transfer conduits with inner tubing will be installed in NAPL Area L4 so that the material recovered using the automated NAPL-only recovery pumps can be transferred to the 500-gallon above ground NAPL storage tank, located outside the NAPL Area L4 equipment building. As PVC is chemically compatible with diesel type NAPL, PVC piping will serve as secondary containment for the NAPL transfer lines below grade. In the event that the high pressure hose has to be replaced in the future, the hose will be accessed through the containment access port located in the vaults. The NAPL transfer lines above grade will be galvanized steel and end at the containment dike of the NAPL storage tank.

High pressure hose (normal operating pressure 80 psi) will be used to transfer the recovered Area L4 NAPL to the storage tank. The selected hose material will be compatible with the NAPL that will be removed. Each recovery well will be connected to the NAPL storage tank area through one main header. Thus, only one line will end and discharge into the NAPL storage tank.

High pressure hose will also be used to transfer the air to the NAPL Area L4 NAPL-only recovery pumps. The tubing will extend from the Tank Full Shut Off (TFSO) control panel in the building and consist of a continuous main line that is connected by a tee to each of the three (3) NAPL-only recovery pumps.

All NAPL Area L4 equipment will be housed in the NAPL Area L4 building, which will be divided into two rooms, an equipment room and a control room. The equipment room will contain the vacuum blower assembly, air injection assembly, liquid-vapor moisture separator, air compressor, vapor control equipment (GAC drums), the condensate storage drums, and continuously operating ceiling fan. The control room will contain all soil gas recovery system and NAPL-only recovery system instrumentation and controls.

3.2.2.1 *Objective*

The objective of the NAPL-only recovery systems is to recover the free phase NAPL, which accumulates in the NAPL recovery wells.

3.2.2.2 *Controls*

The control panel supplied with the NAPL-only recovery pumps will be supplemented by additional instrumentation and controls to ensure smooth, consistent and safe recovery system operation. These controls are described in the following subsection and shown in the process flow diagram provided as Design Drawing PID-5, presented in Appendix A. Since the NAPL recovery systems in NAPL Areas L1/L2 and L3 are not automated, no controls will be installed in these areas. These systems will be monitored during routine O&M. However, should automation of NAPL Area L1 be required in the future, controls will be installed at the same time as the automation equipment (i.e., pumps, air compressor, and piping) is installed.

The mechanical controls for the NAPL Area L4 NAPL recovery and storage system are:

- a check valve for each recovery pump, provided as part of the pump assembly;
- an isolation quick connect with built in shut off valve for each recovery line;
- an atmospheric tank vent;
- an emergency relief tank vent; and
- secondary containment systems.

The check valve will be used to prevent the recovered NAPL from flowing back down the NAPL tubing into the recovery well. This valve is provided as part of the pump assembly and is an integral component of the NAPL-only recovery pump. The quick connect shut off valve will act as an isolation valve and will be used to temporarily "isolate" a recovery well from the tubing manifold and storage tank.

The atmospheric tank vent will be used to maintain atmospheric pressure within the tank. The emergency relief tank vent will be used as a backup to the atmospheric tank vent. In the event that the atmospheric tank vent fails, the emergency relief vent will open when the pressure within the tank reaches approximately ten (10) inches w.c..

The secondary containment systems (i.e., the above ground storage tank dike and the outer PVC piping for the tubing running between the tank area and recovery well vaults) will contain NAPL in the event of a tank or NAPL transfer tubing failure. The secondary containment for the NAPL transfer tubing is graded upwards from the well to the tank. As such, if a leak occurs in the transfer piping, the NAPL will flow back along the piping and into the well vault.

In addition to the mechanical controls, there are several electronic controls designed to protect the safety of personnel and equipment. These controls are:

- LEL monitor (Area L1 and Area L4 buildings);
- NAPL-only recovery pump controls;
- a low level oil switch in the air compressor; and
- Tank Full Shut Off level control in the NAPL storage tank (TFSO401)

In the event that the LEL level reaches 5% or greater, all equipment in the equipment room will be shut off (i.e. soil gas extraction blower, air injection blower, and air compressor) to protect against explosion.

A number of the controls control the supply of compressed air and thus affect the NAPL-only recovery pump operation. If the oil in the compressor reservoir reaches the low-level switch set point, the air compressor will be shut off, which will result in the shut off of all the NAPL-only recovery pumps. In the event that the bubbler sensor on the TFSO indicates a high level, the system closes down the valve supplying compressed air to the NAPL-only recovery pumps and exhausts the air, effectively shutting down all pumping systems. In addition, if the float level sensor rises to come in contact with the button located on the TFSO Tank Unit, the button will be depressed releasing the air pressure behind it and prevent the compressed air from reaching the NAPL-only recovery pumps.

3.2.2.3 *Monitoring*

The NAPL-only recovery system will be monitored to ensure safe and optimum operation. Operation and maintenance personnel will routinely visit the work area to monitor and record system operation as outlined in the O&M Plan. In addition, instrumentation and controls will be used as discussed in Section 3.2.2.2.

As it recharges into the well, NAPL is drawn into and accumulates in the automatic NAPL-only recovery pump. On a preset time cycle, compressed air is forced into the pump, which causes the NAPL in the pump to be discharged from the pump and forced through the transfer tubing to the collection tank. The time period between pulses of compressed air (i.e. the pump cycle time) is the length of time that the NAPL has to accumulate in the pump before it is discharged. The Genie pumps are preset at the factory to operate at a cycle time of 30 seconds at an air pressure of 80 psi.

A pumping cycle is apportioned approximately 30% to NAPL ejection (air pulse) and 70% to NAPL recharge. Changing the pump cycle time will affect the rate at which NAPL is recovered from the well. The following table shows the effect different cycle rates have on the daily NAPL recovery rates.

NAPL Recovery Rates

Cycle Time	Gallons per day (GPD) 12-inch Pump
7 seconds	145
15 seconds	68
30 seconds	34
60 seconds	17
90 seconds	11
30 minutes	0.5
60 minutes	0.25

The quantity of NAPL removed by each of the automatic NAPL pumps will be determined during the routine O&M visits. A NAPL pump test for each individual pump will be performed at the system start-up. The volume of NAPL removed by each pump will be measured with a graduated container and compared to the recovery rates provided in the above table. If the amount of NAPL measured corresponds to a rate that is less than 20% of the rate listed in the table for the cycle time that is set, the cycle time will be increased. Conversely, if the NAPL recovery rate is greater than 75% of that listed in the table, the cycle time will be decreased. The ways in which the cycle time can be adjusted are discussed in Section 3.2.3.4.

On a monthly basis, water table elevations and NAPL thicknesses will be measured in all the extraction wells and in a number of the air inlet wells. The air inlet wells to be monitored will be selected based on the NAPL thicknesses observed in these wells during initial system operation (e.g. wells in which at least six inches of NAPL have been observed on a regular basis). Since steady-state system operation will be disrupted while these measurements are being taken due to the uncapping of the wells, the measurements will be taken at the end of the O&M visit, once all other system monitoring has been completed. The extraction wells and the selected air inlet wells will be unsealed and the interface probe inserted into the well. The system may be either temporarily shutdown, or the wells may be uncapped and monitored while the system continues to operate. Uncapping the wells will disrupt the air flow through the subsurface for the duration of the monitoring, but will not adversely affect the overall remedial system operation. Once the measurements have been taken the wells will be resealed and the system re-started.

In addition, the total volume of recovered NAPL will be monitored through volumetric calculations during tank clean-out. On a quarterly basis, an operations report will be prepared. This report will include all NAPL-only recovery system performance data, discussion of results with interpretation of data and recommendations of operating modifications to optimize system performance.

3.2.2.4 *Operational Adjustments*

For the non-automated NAPL-only recovery systems, the NAPL recovery rates and NAPL thickness will be evaluated to determine the frequency that NAPL needs to be manually removed. For NAPL Area L1, if the removal frequency remains at weekly and NAPL thickness remains high, it may warrant the automation of the NAPL-only recovery systems. This would involve installation of a Genie-200 Controllerless System, or equivalent, as installed in NAPL Area L4, to automate the recovery of the NAPL from the specific gravity skimmers, and installation NAPL transfer hose to transfer the recovered NAPL to the NAPL storage tank.

For NAPL Area L4, where automated NAPL-only recovery pumps will be used, NAPL recovery rates and NAPL thicknesses will be evaluated to determine if the recovery pumps are operating at their optimum and to determine which wells should be on-line.

Optimum performance of the NAPL-only recovery pumps is such that the NAPL is recovered from the well at the same rate that it recharges into the well. As discussed in Section 3.2.3.3, changing the pump cycle time will affect the rate at which NAPL is recovered from the well. During routine O&M, the NAPL recovery from each of the pumps will be assessed. If the per cycle NAPL recovery rate for any pump is less than 20% of the theoretical rate for the cycle time that is set, the cycle time will be increased. Conversely, if the per cycle NAPL recovery rate is greater than 75% of the theoretical rate, the cycle time will be decreased.

There are three main ways in which the cycle time can be adjusted: (1) adjust the time adjustment screw on the pump; (2) vary the pressure from the air compressor; and (3) change the volume of the cycle extender hose. These adjustments or system modifications are discussed further below.

When the pump's time adjustment screw is fully opened, the cycle time is at its minimum and, thus, the NAPL recovery rate is at its maximum. The cycle time is decrease by turning the screw in the clockwise direction. It is important to note that this action causes the size of the exhaust air hole to be reduced, which can increase the potential for particles to get trapped in the opening. Trapped particles can significantly increase the pump cycle time, and result in a reduction in the NAPL recovery rates. Therefore, if cycle times greater than 570 seconds are required, other combination of two or three of the cycle time adjustment methods should be used.

Adjusting the pressure of the air supplied by the air compressor will also result in changes to the cycle rate without the need to change the adjustment screw. The air pressure can be adjusted at the air regulator located on the pump control panel. Increasing the air pressure will cause a decrease in the cycle time and conversely, decreasing the air pressure will increase the cycle time. The final adjustment that will result in a change in the cycle time, is to change the length and/or diameter of the cycle extender. The addition of extra lengths of the cycle extender hose will result in reduced cycle times.

At some point in the future, NAPL thickness may begin to recover more slowly and no longer warrant operation of an automated system. When this occurs, a determination will be made, based on the NAPL thicknesses present, to either convert the automated NAPL-only recovery pumps to passive recovery systems or to cease all NAPL-only recovery either temporarily or permanently. The criteria upon which a decision to take such an action will be based are discussed further in Section 5.0.

3.2.2.5 *Recordkeeping*

The operator will record the NAPL recovery rates, the total volume of recovered NAPL, and the NAPL thickness measurements during routine O&M. This data will be periodically transferred to Table 3-4 and used to evaluate the performance of the NAPL-only recovery system.

3.2.3 *Vapor Treatment*

The extracted soil gas from the combined NAPL Area L1/L2 VENR system and the NAPL Area L3 and Area L4 VENR systems will be passed through an emission control system. Each of the three systems consist of two (2) in-line granular activated carbon (GAC) canisters installed in series. These units will be used to remove the residual VOCs in the extracted soil gas stream prior to final discharge through an emission stack.

For the combined NAPL Area L1/L2, each canister contains 500 pounds of GAC and is rated for a maximum air flow of 1,500 CFM at a maximum pressure drop of 8.5 inches w.c. For NAPL Area L3, each canister contains 200 pounds of GAC and is rated for a maximum air flow of 100 CFM at a maximum pressure drop of 3.75 inches w.c.. For NAPL Area L4, each canister contains 170 pounds of GAC and is rated for a maximum air flow of 300 CFM at a maximum pressure drop of 4.25 inches w.c..

3.2.3.1 *Objective*

The objective of the VENR vapor control systems is to remove VOCs from the extracted soil gas and thus ensure that vapor emissions from the VENR system do not pose any unacceptable risks to the surrounding community and on-site workers.

3.2.3.2 *Monitoring*

The VENR vapor control system will be monitored to ensure adequate VOC removal. The air exiting the VENR vapor control system will be periodically monitored to determine when breakthrough of the carbon filters occurs. VOC measurements will be collected using a PID at the primary vapor control unit inlet and outlet and the secondary outlet. Initially, vapor control monitoring will be conducted weekly. However, as discussed in Section 3.2.3.3, the frequency will be evaluated based on mass loading and breakthrough times. The vapor stream at the inlet and outlet of the primary and secondary vapor control units are under slight pressure and therefore, the PID can be inserted into the sample valves to obtain a reading.

3.2.3.3 *Operational Adjustments*

Breakthrough of the primary vapor control unit will be defined as a PID reading at the primary outlet greater than 5 ppmv. When breakthrough is detected, arrangements will be made to replace the spent primary carbon unit. The unit with the freshest carbon will always serve as the last in-series unit. Therefore, when the new unit is installed, it will be installed in the secondary position and the secondary unit will become the primary unit. The spent carbon units will be sent off-site for disposal.

During system startup, air samples will be collected from the inlet and outlet of the primary vapor control unit and outlet of secondary unit. The samples will be analyzed for VOCs, SVOCs, and PCBs. Sampling and analytical methodologies are provided in Table 3-5. The air sampling results along with the air flow rate will be used to estimate mass loading onto the carbon and the carbon life expectancy. The frequency of PID monitoring will be determined based on the estimated carbon bed life. During the first month of operation, PID monitoring will be conducted at least weekly. Should the initial mass loading rates indicate that breakthrough may occur in less than one month, the PID monitoring schedule will be adjusted to ensure adequate vapor control.

Once an operating history for the vapor control systems has been established using the mass loading rates and actual breakthrough periods, the monitoring frequency may be refined. If it is determined that bed life is greater than one month, the bed size will remain the same and the VOC monitoring frequency may be reduced. If the bed life is less than one month, the monitoring frequency will remain at weekly. If the breakthrough time is less than two weeks, the VOC concentration will be monitored more frequently than weekly. It this condition persists, consideration will be given to increasing the bed capacity.

3.2.3.4 *Recordkeeping*

As discussed above, air sampling will be conducted during startup of each of three vapor control units. The sampling results will be compiled and compared to the projected air emissions rates provided in the air permit application provided to NYSDEC. If air sampling results indicate higher emission rates than the air permit, the data will be evaluated to ensure no unacceptable impacts to the community and on-site workers.

Routine PID and LEL/O_2 measurements will initially be recorded in the operator's log book along with the date and time of the measurements. These will be periodically transferred to Table 3-3. The PID readings, along with the flow rates recorded as discussed in Section 3.2.1.3, will be used to estimate the mass of VOCs adsorbed. Records will also be kept of the dates that carbon vessels are taken off-line for disposal and replaced with new carbon vessels.

4.0 *GROUND WATER PERIMETER MONITORING*

4.1 *PURPOSE*

The purpose of the perimeter ground water monitoring is to continue to ensure that OU-II ground water does not pose an unacceptable risk to human health and the environment.

4.2 *MONITORING*

Two ground water monitoring wells will be installed on the downgradient side of the OU-II site. One well will be installed downgradient of NAPL Area L1 and the other well will be installed downgradient of NAPL Area L4. The location of these wells is provided in Drawing C-2.

Ground water samples will be collected annually and analyzed for the ground water chemicals of concern listed in Table 4-1. Ground water monitoring will be continued until such time as the NAPL source is deemed removed to the extent practicable, i.e. until permanent shutdown of the VENR system has been fully established.

4.3 *REPORTING*

The annual ground water monitoring results will be evaluated using the risk assessment procedure contained in the NYSDEC-approved Feasibility Study Report to confirm that ground water continues not to pose unacceptable risks to human health and the environment. The results will be reported annually to NYSDEC.

5.0 *SHUTDOWN EVALUATION FOR THE OU-II REMEDIAL ACTION*

As discussed in Section 2.0, NAPL is present in three locations:

- prevent further migration of on-site OU-II NAPL;
- remove free-phase NAPL to the extent practicable; and
- continue to prevent direct contact with subsurface OU-II NAPL in the vicinity of the former lagoon.

The primary remedial action objective, as documented in the OU-II ROD, is to remove free phase NAPL to the extent practicable. As such, the decision to shutdown the VENR system in each of the NAPL Areas will be determined based upon the amount of free-phase NAPL removed from that NAPL Area. The amount of free-phase NAPL removed from NAPL Areas L1 and L4 will be estimated based on the apparent NAPL thickness in each area. The correlation between the average NAPL thickness in NAPL Areas L1 and L4 and the amount of NAPL removed was discussed in Section 2.2.

As determined in Section 2.2, the free-phase NAPL volumes in NAPL Areas L1 and L4 are approximately 534 gallons and 4,298 gallons, respectively. Using Figures 2-8 and 2-9, these volumes correspond to average NAPL thicknesses of 0.95 and 1.75 feet respectively. For NAPL Area L1, the goal of the remedial action, and the criteria for shutdown, will be 90% removal of free-phase NAPL or an average NAPL thickness of 0.25 feet (see Figure 2-8). For NAPL Area L4, the goal of the remedial action, and the criteria for shutdown, will be approximately 98% removal of free-phase NAPL or an average NAPL thickness of 0.25 feet.

Shutdown of the VENR systems in the four NAPL Areas will be determined in a phased manner as discussed below and as shown in Figure 5-1.

As previously discussed, a secondary remedial action objective for the VENR systems will be to remove NAPL present in residual saturation to the extent that it contributes to free-phase NAPL. As discussed in Section 3.0, this secondary remedial action objective will be achieved through optimum operation of the VENR systems.

5.1 *TEMPORARY SHUTDOWN*

The VENR system will be operated in each NAPL Area until the target average NAPL thickness has been achieved. Once the three-month average NAPL thickness in a NAPL Area meets its target NAPL thickness, the VENR system will be temporarily shutdown and the NAPL Area will enter a pre-closure NAPL monitoring period.

If the three-month average NAPL thickness in other NAPL Areas has not yet met its target NAPL thickness, VENR systems will continue to operate in those areas until such time as the target thickness is reached. However, in the event that the average NAPL thickness does not decrease significantly within a 3-year period or the average NAPL thickness becomes asymptotic for a prolonged (i.e., 6-month) period, alternate NAPL removal technologies will be evaluated. Additional discussion regarding alternate NAPL removal technologies is presented in Section 5.3.

5.2 *PRE-CLOSURE MONITORING AND PERMANENT SHUTDOWN*

Pre-closure monitoring will be conducted for one year after temporary shutdown of the VENR system in a particular NAPL Area. During pre-closure monitoring, monthly NAPL thickness measurements will continue to be collected and the three-month average NAPL thickness calculated. If, at any stage during this pre-closure monitoring period, the three-month average NAPL thickness increases above the target level, the VENR system will be restarted until the target level has been achieved once more. However, as discussed above, if the system has been operated for at least three years, or the average NAPL thickness has become asymptotic for a prolonged (i.e., 6-month) period, alternate NAPL removal technologies will need to be evaluated (See Section 5.3). Once a three-month average NAPL thickness below the target NAPL thickness has been observed for four consecutive quarters of pre-closure NAPL measurements, the VENR system will be shut down permanently.

5.3 *EVALUATION OF ALTERNATE NAPL REMOVAL TECHNOLOGIES*

In the event that the average NAPL thickness does not decrease significantly within a 3-year period or the average NAPL thickness becomes asymptotic for a prolonged (i.e., 6-month) period, alternate NAPL removal technologies will be evaluated. These alternative technologies may include: continued VENR, nutrient injection, heat addition, or biosparging. The latter three alternatives are described in greater detail below. Other technologies may also be considered, as appropriate.

Nutrient Addition

The data collected during the pilot testing demonstrates that there is sufficient nitrogen and phosphorus in soil in Area L1 and sufficient phosphorus in Area L4. Although pilot data was inconclusive regarding nitrogen levels in Area L4, it is not likely that nitrogen levels are limiting biological growth in this area. In the event that VENR does not meet its target levels and insufficient nutrient levels are determined to be a cause, a system to introduce nitrogen into subsurface soil will be considered. These are relatively simple systems to install and operate.

Heat Addition

Heat may enable NAPL at the Site, which is primarily a severely degraded diesel fuel, to flow more easily. If the data indicates that NAPL flow is a limiting factor for OU-II NAPL removal, this technology will be evaluated. Although heat can be introduced into subsurface soil as heated water or hot air, these systems are expensive to operate given the heat sink capacity of the formation (i.e., a lot of energy is needed to raise the subsurface temperature). Given the fact that free-phase NAPL removal rates reported during the pilot tests were generally equal to or greater than those used in the FS to evaluate this technology, heat addition may not improve system performance sufficiently to warrant its installation. If necessary, implementation would not be difficult since these are typically not complex systems, although additional pipes or equipment might need to be installed.

Biosparging

Biosparging consists of injecting air into saturated soil below the layer of free-phase NAPL or NAPL in residual saturation. This technology was described and evaluated in Section 7.3.1.11 of the FS as an optional task for a NAPL-only removal alternative (i.e., Alternative II). These are typically not complex systems, but may require installation of additional pipes or equipment.

6.0 *PROGRESS REPORTS*

Progress reports for the VENR system will be prepared on quarterly basis and submitted to the NYSDEC for review and approval. The quarterly progress reports will include the following information:

- Summary of the VENR operations during the quarter;
- Copies of completed O&M tables (i.e., Tables 3-2, 3-3 and 3-4) for that quarter;
- Monthly NAPL thickness measurements;
- Average monthly NAPL thicknesses for each NAPL Area;
- Average 3-month NAPL thickness measurements for each NAPL Area;
- NAPL volume tracking for the four NAPL Areas with total volumes of NAPL recovered from each area;
- Evaluation of VENR performance and effectiveness monitoring;
- Summary of operational adjustments made to the VENR systems;
- Analytical results for the VENR emissions sampling conducted during system start-up and evaluation of the data collected;
- Results from the breakthrough monitoring of the vapor control systems and any modifications to the vapor control systems (e.g., unit replacement);
- Ground water monitoring results following annual perimeter ground water monitoring;
- Problems and resolutions.

The quarterly progress report will contain an evaluation of the effectiveness and performance of the VENR systems for that quarter. While O&M modifications to the system operation will be on-going during system operation, other system modifications may be recommended upon review of the quarterly monitoring results.

Due to variations in subsurface conditions, coalescence of NAPL in residual saturation, and ground water table elevations, etc., increases in the NAPL thickness measurements may be observed in some wells at certain times during system operation. Operational modifications and system performance evaluations will take these factors into consideration.

ERM will provide technical assistance to the party conducting VENR start-up and O&M activities and will review the quarterly progress reports prior to their submittal to NYSDEC.

7.0 REFERENCES

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Table 2-1
NAPL Area L1 Apparent Thickness Input Data
Metro North Harmon Yard
Croton-on-Hudson, NY

Well ID	Apparent NAPL Thickness (feet)	Well ID	Apparent NAPL Thickness (feet)
RW-2	1.39	TB-1-2d2	0.82
WB-9	1.23	TB-1-2d2a	0.54
OW-7	0	TB-1-3a	0
OW-8	0.95	TB-1-4a	0
OW-9	0.19	MW-A	1.00
OW-10	0	FC-1	0.83
OW-11	0.43	WB-9-1a	1.33
OW-12	0.69	WB-9-3a	1.17
WB-9-4a	1.38	WB-9-2a	0
P1-A	0	WB-9-1c	0
P2-A	0	WB-9-3b	0.51
OS-N	0	WB-9-1b	0
MW-B	0	WB-9-3c	1.15
MW-C	0	WB-9-3c1	0.31
WB-6	0	WB-9-3c2	0.88
WB-6e	0.69	WB-9-3c2a	0.92
TB-1	0.70	Dummy1	0
TB-1a	0.95	Dummy2	0
TB-1a1	1.00	Dummy3	0
TB-1a1b	1.99	Dummy4	0
TB-1-2a	1.73	Dummy5	0
TB-1-2b	0.56	Dummy6	0
TB-1-2c	0	Dummy7	0
TB-1-2d	0.13	Dummy8	0
TB-1-2d1	0.84	Dummy9	0

Table 2-2
NAPL Area L4 Apparent Thickness Input Data
Metro North Harmon Yard OU-II
Croton-on-Hudson, NY

Well ID	Apparent NAPL Thickness (feet)	Well ID	Apparent NAPL Thickness (feet)
OW-1	0	WB-3	0
OW-2	0	WB-5	1.23
OW-3	3.46	WB5-1a	1.16
OW-4	2.93	WB5-1a1	1.36
OW-5	2.47	WB5-2a	1.63
OW-6	0	WB5-2b	0
MW-1s	2.99	WB5-3a	1.53
P4A	0	WB5-3b	1.30
P5A	0	WB5-3c	2.22
OS-A	0.29	WB5-3c1	1.29
OS-C	1.11	WB5-3b1	2.34
OS-D	0.27	WB5-3b2	0.28
OS-F	1.84	WB5-3b3	0
OS-I	0	WB5-3a'	0
OS-J	0.38	WB5-4a	1.93
RW-1	2.76	Dummy1	0
TB-4	0	Dummy2	0
OS-H	0	Dummy3	0
WB-7	3.68	Dummy4	0
OS-G	0	Dummy5	0
OS-M	0	Dummy6	0
OS-FS	0	Dummy7	0
OS-L	0	Dummy8	0
OS-K	0	Dummy9	0
OS-E	0.68	Dummy10	0
OS-B	0.62	Dummy11	0
TB-6	0.72	Dummy12	0
TB6-1a	2.33	Dummy13	0
TB6-2a	0	Dummy14	0
TB6-1b	2.05	Dummy15	0
TB6-1b1b	2.74	Dummy16	0
TB6-1c	0	Dummy17	0
TB6-1b1b1	0	Dummy18	0

Table 3-1
Components of Soil Vapor Extraction System,
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY

Component	NAPL Area L1	NAPL Area L2	NAPL Area L3	NAPL Area L4
Extraction Wells:				
Design well head vacuum, inches w.c.	8	22	19	20
Conservative pnuematic EROI, ft.	21	25	23	25
Well Spacing, ft.	34	NA	37	35
Number of extraction wells	11	1	3	13
Flow rate per well, cfm	120	16	14	10
Number of operating zones	2	1	1	1
Total system flow rate, cfm	720	16	42	130
Vacuum Blowers:				
Number of vacuum blowers	2	0	1	1
Required flow per blower, cfm	360	NA	42	130
Max blower diff pressure, inches w.c.	70	NA	45	70
Emission Controls:				
Vapor GAC press. drop, inches w.c.	8	NA	6	4
Vapor GAC carbon mass, lbs.	500	NA	200	140
Inlet Wells:				
Number of air inlet wells	16	3	6	25
Type of inlet well	Passive	Passive	Passive	Forced
Pressure of inlet well, inches w.c.	0	0	0	40
Flow per inlet well, cfm	NA	NA	NA	1.5
Total inlet flow, cfm	NA	NA	NA	37.5
Inlet Blowers:				
Number of inlet blowers	0	0	0	1
Required flow per blower, cfm	NA	NA	NA	37.5
Max blower pressure, inches w.c.	NA	NA	NA	60

Table 3-2
Pneumatic Responses
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY

Date & Time	Extraction Well (______)					Air Inlet Wells							
	Valve (% open)	Flowrate (cfm)		Vacuum (" w.c.)	PID Reading (ppm VOCs)	Vacuum (" w.c.)							
		From Well	Dilution Air			Well ID	Well ID	Well ID	Well ID	Well ID	Well ID	Well ID	Well ID

Table 3-3a
Soil Gas Extraction Blower and Vapor Controls Operating Parameters
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY
NAPL Area L ___

Blower Operation
Total Soil Gas Extraction Rate, cfm: ____________________
Total Dilution Air Flowrate, cfm: ____________________

Field Meter Readings

Parameter	Primary Carbon Inlet	Primary Carbon Exit	Secondary Carbon Exit
Date & Time:			
PID (ppm)			
% LEL			
% O_2			
Date & Time:			
PID (ppm)			
% LEL			
% O_2			
Date & Time:			
PID (ppm)			
% LEL			
% O_2			
Date & Time:			
PID (ppm)			
% LEL			
% O_2			

Table 3-3b
Soil Gas Extraction Blower and Vapor Controls Operating Parameters
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY

NAPL Area L ___
Date & Time of Sampling Event:

Blower Operation
Total Soil Gas Extraction Rate, cfm: ____________
Total Dilution Air Flowrate, cfm: ____________

Air Sampling Results

	Vapor Controls			Ambient Air	
Parameter	Primary Carbon Inlet	Primary Carbon Exit	Secondary Carbon Exit	Site Perimeter Location 1	Site Perimeter Location 2

Table 3-4a
NAPL Thickness and Volume Measurements
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY

NAPL Area L ___
Date & Time: ____________________

Blower Operation
Total Soil Gas Extraction Rate, cfm: ________
Total Dilution Air Flowrate, cfm: ________

NAPL Thickness Measurements, feet.

Well ID	Depth to NAPL	Depth to Water	NAPL Thickness

NAPL Volume Measurements, gallons
Volume of NAPL in NAPL storage tank: ________
Volume of NAPL in NAPL storage tank during previous monitoring round: ________
Volume of NAPL removed from tank since previous monitoring round: ________
Total volume of NAPL recovered since last monitoring round: ________
Total volume of NAPL recovered since initial system start-up: ________

Table 3-4b
NAPL Recovery Rates
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY
NAPL Area L ___
Date & Time: ____________

Actual NAPL Recovery Rates

Well ID & Pump #	Cycle Time, sec	NAPL Recovery Rate, gal		Increase/Decrease Cycle Time? (1)
		Per Pump Cycle	Per Day (calculated)	

Theoretical NAPL Recovery Rates (2)

Cycle Time	Recovery Rate, gpd
7 seconds	145
15 seconds	68
30 seconds	34
60 seconds	17
90 seconds	11
30 minutes	0.5
60 minutes	0.25

Notes:
(1) If the per cycle NAPL recovery rate is less than 20% of the theoretical rate for the cycle time that is set, the cycle time should be increased. Conversely, if the per cycle NAPL recovery rate is greater than 75% of the theoretical rate, the cycle time will be decreased.
(2) Theoretical NAPL recovery rates provided by pump manufacturer.

Table 3-5
Summary of Analytical Methods, Sample Preservation, Holding Times and Containers
Metro-North Harmon Yard OU-II
Croton-on-Hudson, NY

Parameter	Number of Samples	Sample Matrix	Analytical Method Reference	Sample Preservation	Holding Times Extraction/Analysis (days)	Containers
Air Samples						
VOCs	3	Air	EPA Method TO-14	NA	14	Summa Canister
PAHs	3	Air	EPA Method TO-13	Cool, 4°C	7 (extraction)	XAD/PUFF Cartridge
PCBs	3	Air	EPA Method TO-10	Cool, 4°C	7 (extraction)	PUFF Cartridge

Table 4-1
Ground Water Monitoring Parameters (1)
Harmon Railroad Yard Wastewater Treatment Area Operable Unit II
Croton-on-Hudson, New York

Parameter (1)	*Basis for Listing*	
	Potential Risk to Human Health (2)	*Potential Impact to Aquatic Life (3)*
Volatile Organic Compounds		
chloromethane	✓	
1,2-dichloroethane (total)		✓
benzene	✓	✓
chlorobenzene	✓	✓
ethylbenzene		✓
xylene (total)		✓
Semi-volatile Organic Compounds		
1,3-dichlorobenzene		✓
1,4-dichlorobenzene		✓
1,2-dichlorobenzene		✓
naphthalene		✓
2-methylnaphthalene		✓
acenaphthalene		✓
fluorene		✓
phenanthrene		✓
anthracene		✓
fluoranthene		✓
pyrene		✓
bis(2-ethyl)phthalate	✓	✓
Inorganic Constituents		
aluminum	✓	✓
arsenic	✓	✓
barium	✓	✓
beryllium	✓	✓
chromium	✓	✓
cobalt		✓
copper	✓	✓
iron	✓	✓
lead	✓	✓
manganese	✓	✓
mercury		✓
nickel		✓
silver		✓
vanadium	✓	✓
zinc		✓
cyanide		✓

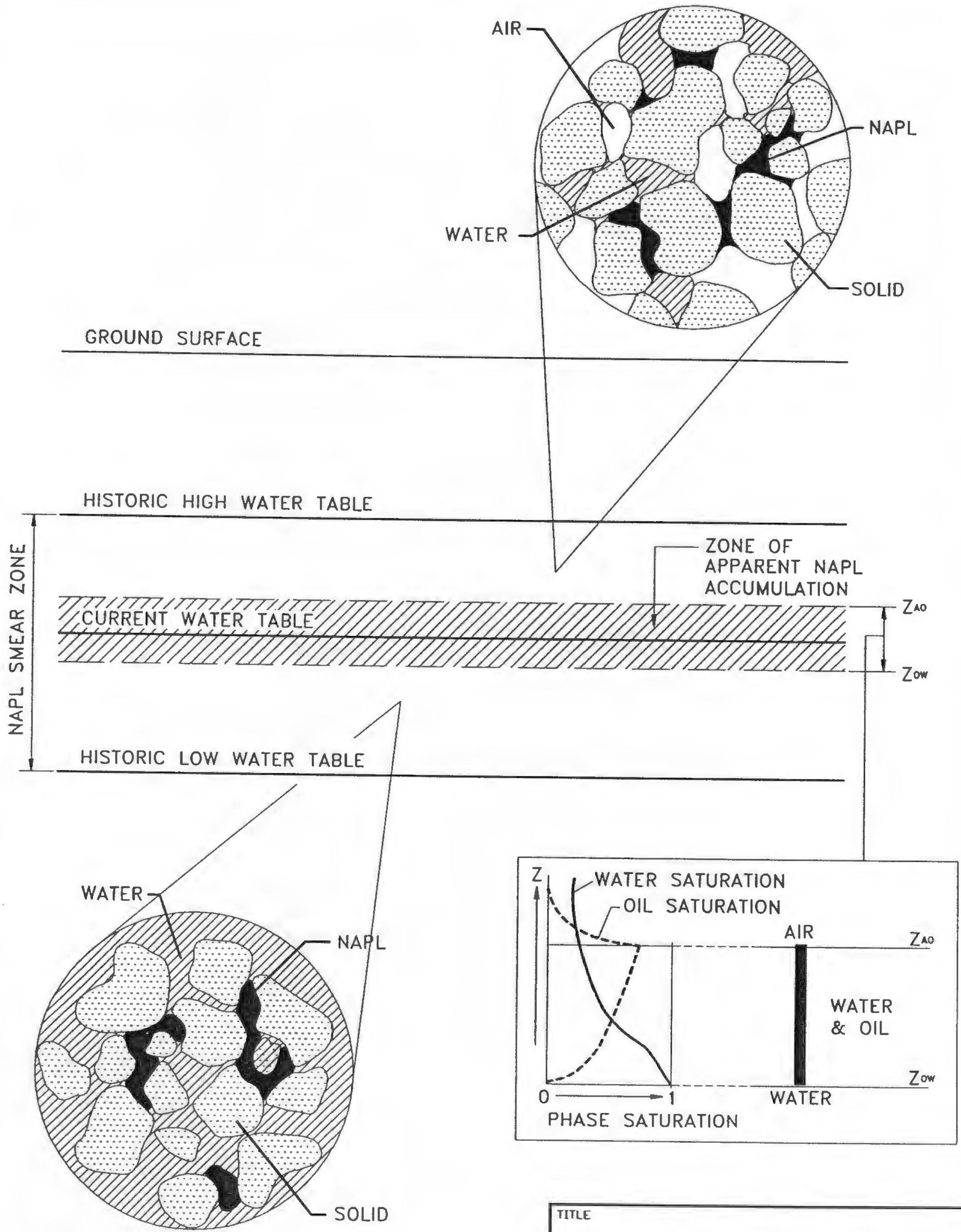
Table 4-1
Ground Water Monitoring Parameters (1)
Harmon Railroad Yard Wastewater Treatment Area Operable Unit II
Croton-on-Hudson, New York

Notes:

1. Ground water samples to be collected from the OU-II ground water perimeter monitoring well shown on Figure 7-1 will be analyzed for these parameters.

2. Chemicals of concern in OU-II ground water identified in Section 4.4.2.1 for the evaluation of human health risks related to OU-II ground water. This selection was based on a concentration and toxicity screening for the chemicals detected in OU-II ground water. See also Table 4-7.

3. Chemicals of concern in OU-II ground water identified in Section 4.4.2.2 for the evaluation of potential impacts to aquatic life. As discussed in Section 4.4.2.2, this list includes all chemicals detected in OU-II ground water for which related criteria, i.e., the NYSDEC Surface Water Quality Standards (NYSDEC, 1993b), were available. See also Table 4-11.



TITLE

SCHEMATIC MODEL OF NAPL DISTRIBUTION

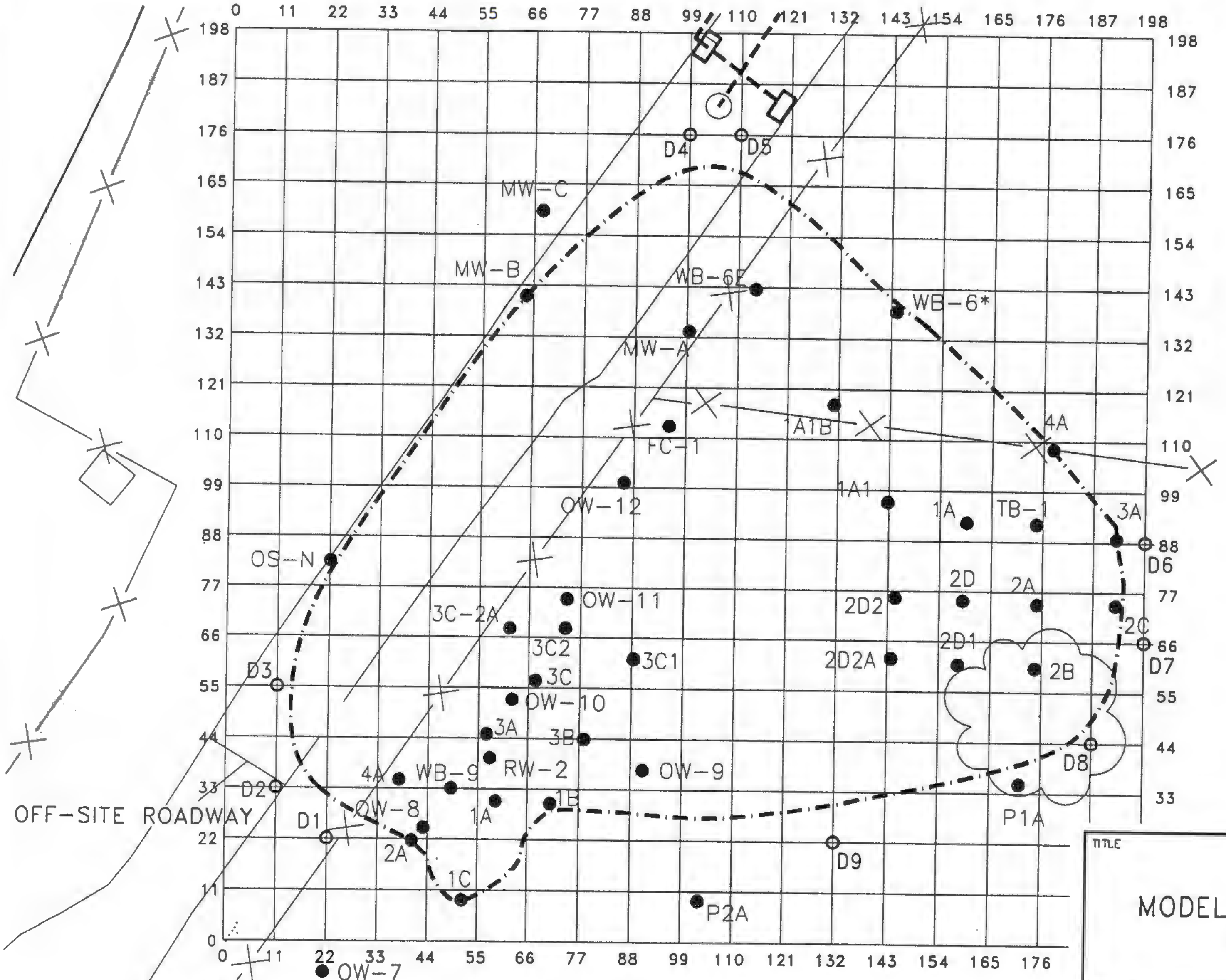
PREPARED FOR

METRO–NORTH COMMUTER RAILROAD

ERM Environmental Resources Management

SCALE	FIGURE
NONE	2–1
DATE 8/23/00	

DRAWN	JOB NO.	FILE NAME
Y.S.	X7603.01	X7603012



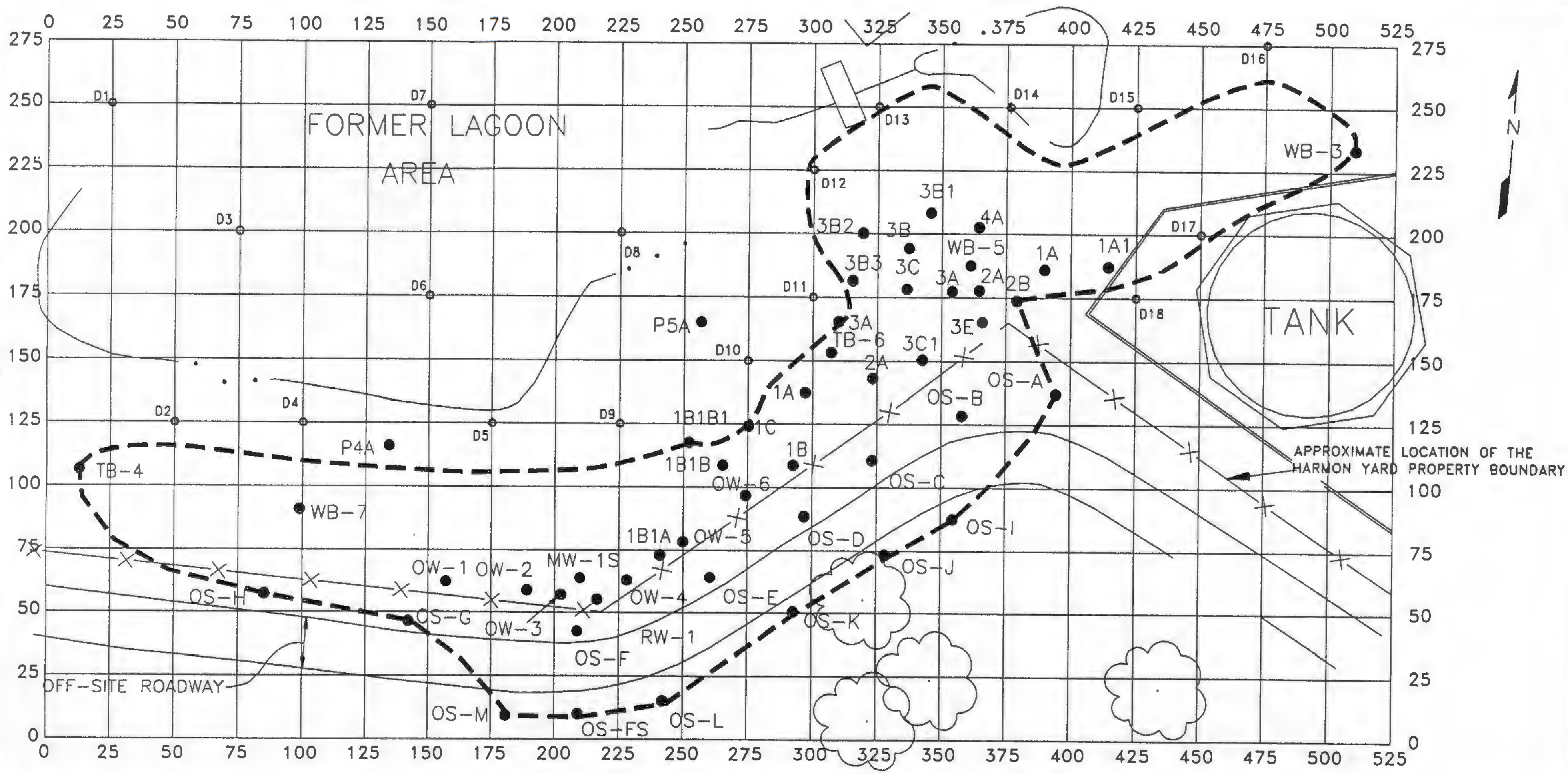
LEGEND

- = 0.0' FEET NAPL APPARENT THICKNESS CONTOUR (1995)
- =PIEZOMETER OR MONITORING WELL
- ="DUMMY" DATA POINTS

0 30' 60'

GRAPHIC SCALE

TITLE	NAPL AREA L1 MODEL GRID AND MONITORING WELL LOCATIONS
PREPARED FOR	METRO-NORTH COMMUTER RAILROAD
ERM	Environmental Resources Management
SCALE	GRAPHIC
FIGURE	2-2
DATE	8/22/00
DRAWN:	Y.S.
JOB NO.:	X7603.01
FILE NAME:	X7603009



LEGEND

● = PIEZOMETER OR MONITORING WELL

— — — = 0.0' FEET NAPL APPARENT THICKNESS CONTOUR (1995)

⊕ = "DUMMY " DATA POINT

0 25' 50'
GRAPHIC SCALE

TITLE

NAPL AREA L4 MODEL GRID AND MONITORING WELL LOCATIONS

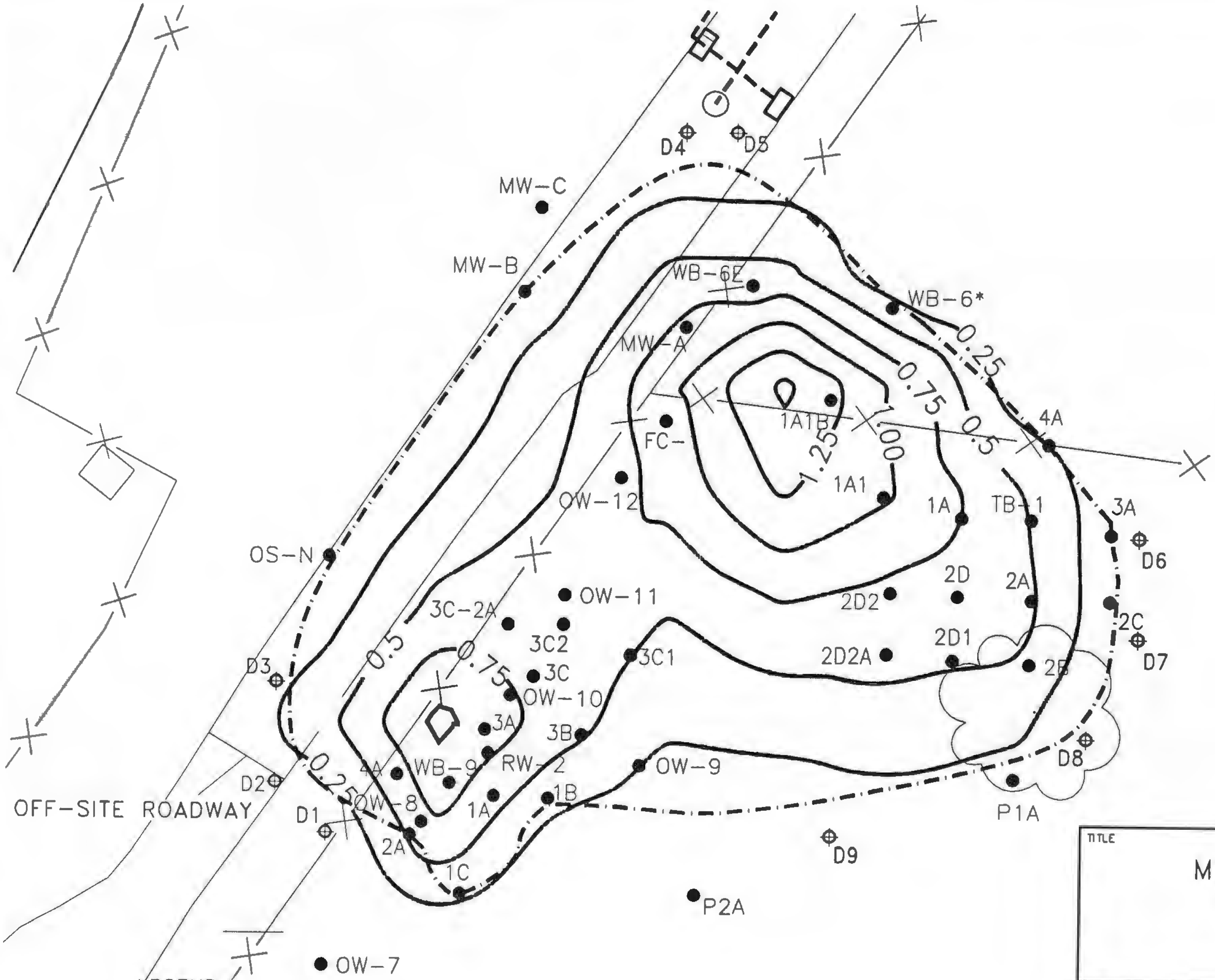
PREPARED FOR

METRO-NORTH COMMUTER RAILROAD

ERM Environmental Resources Management

SCALE	FIGURE
GRAPHIC	2-3
DATE: 8/22/00	

DRAWN:	JOB NO.:	FILE NAME:
Y.S.	X7603.01	X7603006



LEGEND

= 0.0' FEET NAPL APPARENT THICKNESS CONTOUR (1995)

● =PIEZOMETER OR MONITORING WELL

⊕ ="DUMMY" DATA POINTS

CONTOUR INTERVAL = 0.25 FEET

0 30' 60'

GRAPHIC SCALE

TITLE

MEASURED APPARENT NAPL THICKNESS IN AREA L1

PREPARED FOR

METRO-NORTH COMMUTER RAILROAD

ERM Environmental Resources Management

SCALE	FIGURE
GRAPHIC	2-4

DRAWN:	JOB NO.:	FILE NAME:	DATE
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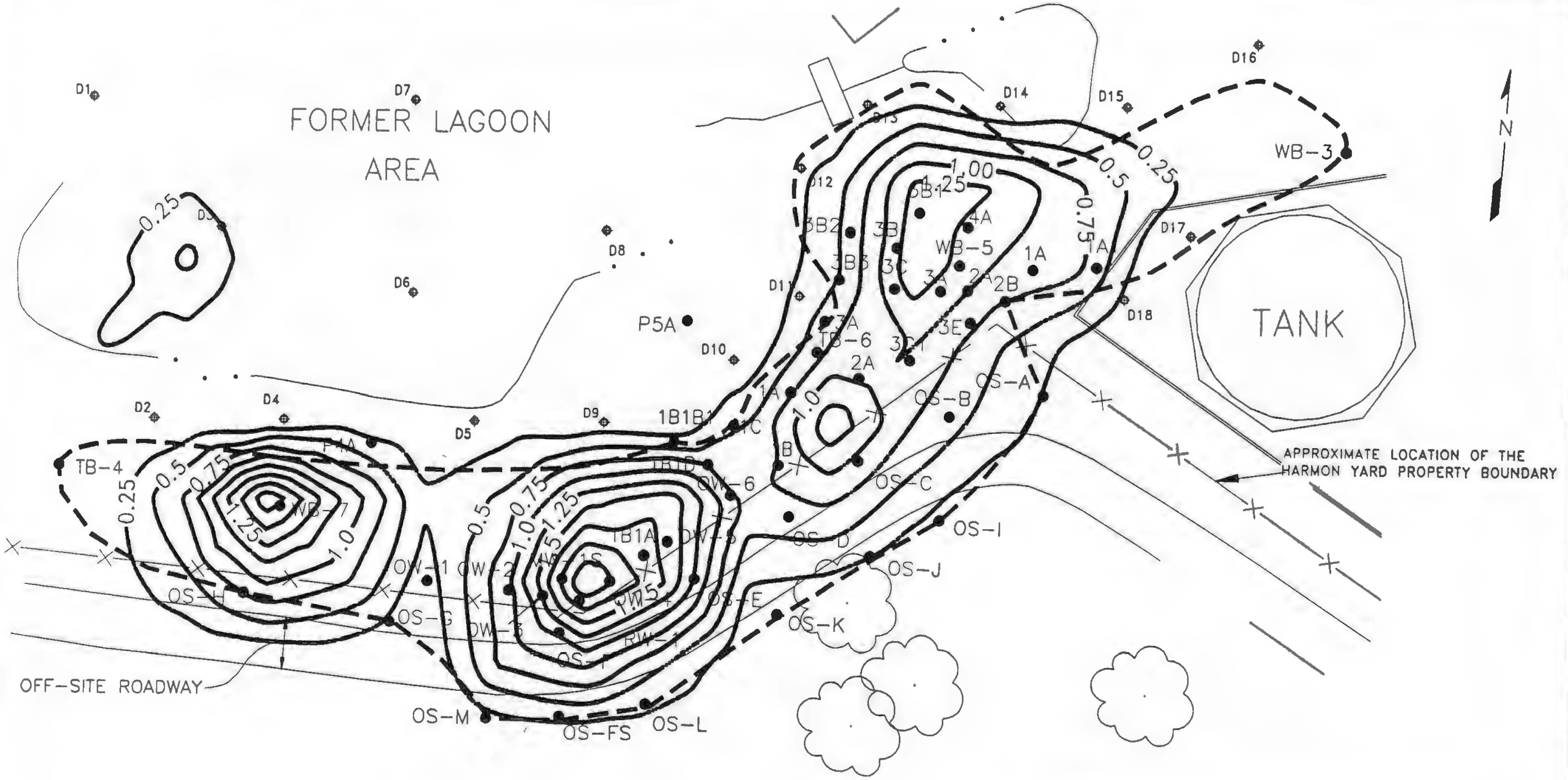


LEGEND

● = PIEZOMETER OR MONITORING WELL

– – – = 0.0' FEET NAPL APPARENT THICKNESS CONTOUR (1995)

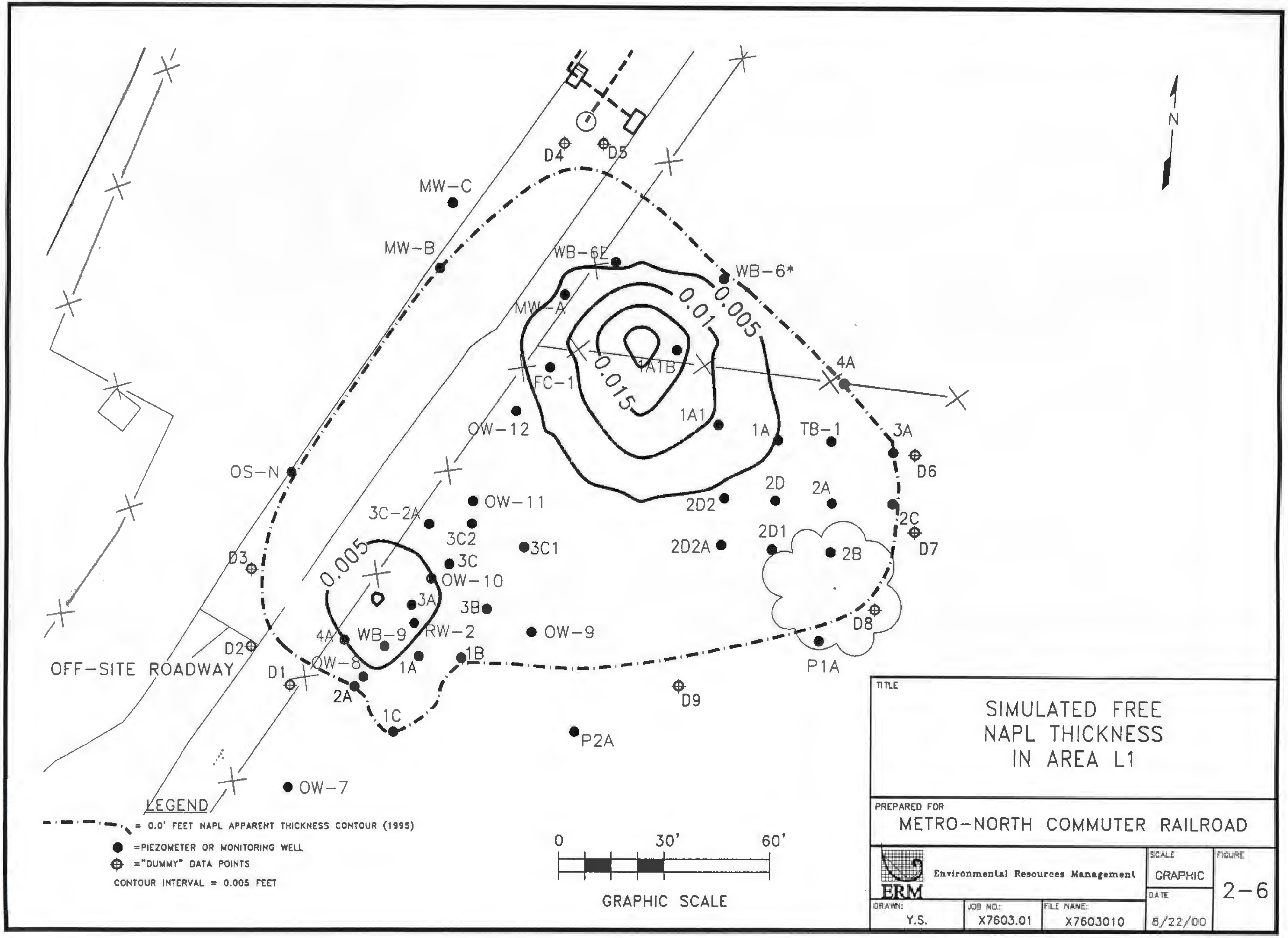
⊕ = "DUMMY " DATA POINT

CONTOUR INTERVAL = 0.25 FEET

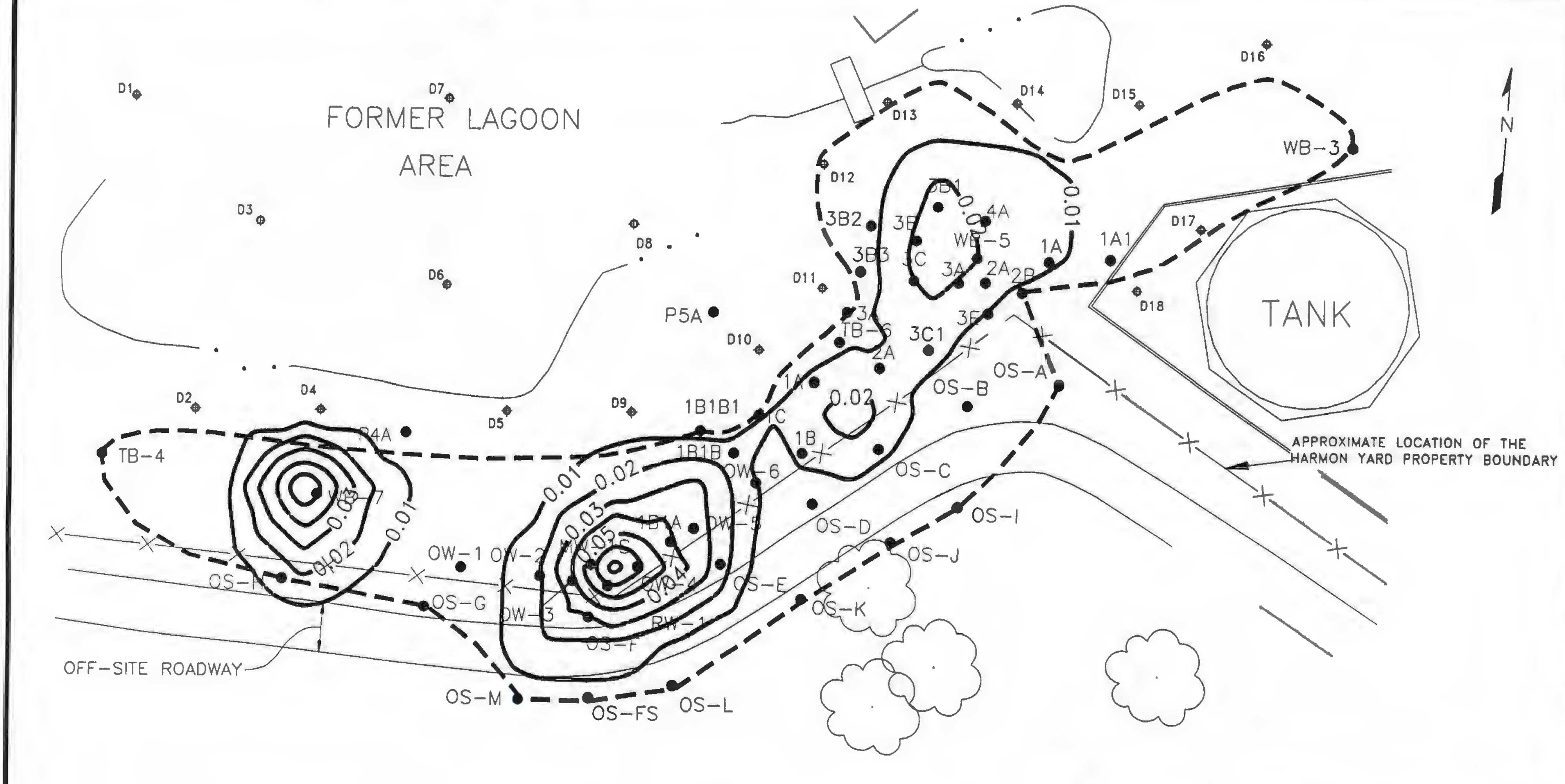
0 25' 50'

GRAPHIC SCALE

TITLE MEASURED APPARENT NAPL THICKNESS IN AREA L4				
PREPARED FOR METRO-NORTH COMMUTER RAILROAD				
ERM Environmental Resources Management			SCALE GRAPHIC	FIGURE 2-5
DRAWN Y.S.	JOB NO. X7603.01	FILE NAME: X7603008	DATE 8/22/00	



TITLE				
SIMULATED FREE NAPL THICKNESS IN AREA L1				
PREPARED FOR METRO-NORTH COMMUTER RAILROAD				
ERM Environmental Resources Management			SCALE GRAPHIC	FIGURE 2-6
DRAWN: Y.S.	JOB NO.: X7603.01	FILE NAME: X7603010	DATE 8/22/00	



LEGEND

- ● = PIEZOMETER OR MONITORING WELL
- – – – = 0.0' FEET NAPL APPARENT THICKNESS CONTOUR (1995)
- ⊕ = "DUMMY " DATA POINT

CONTOUR INTERVAL = 0.01 FEET

0 25' 50'
GRAPHIC SCALE

TITLE

SIMULATED FREE NAPL THICKNESS IN AREA L4

PREPARED FOR

METRO–NORTH COMMUTER RAILROAD

ERM Environmental Resources Management

SCALE	FIGURE
GRAPHIC	2–7
DATE 8/22/00	

DRAWN:	JOB NO.:	FILE NAME:
Y.S.	X7603.01	X7603007

FIGURE 2-8
Metro North Harmon Yard OU-II
L1 Apparent NAPL Thickness vs. Predicted NAPL Volume
at the Water Table

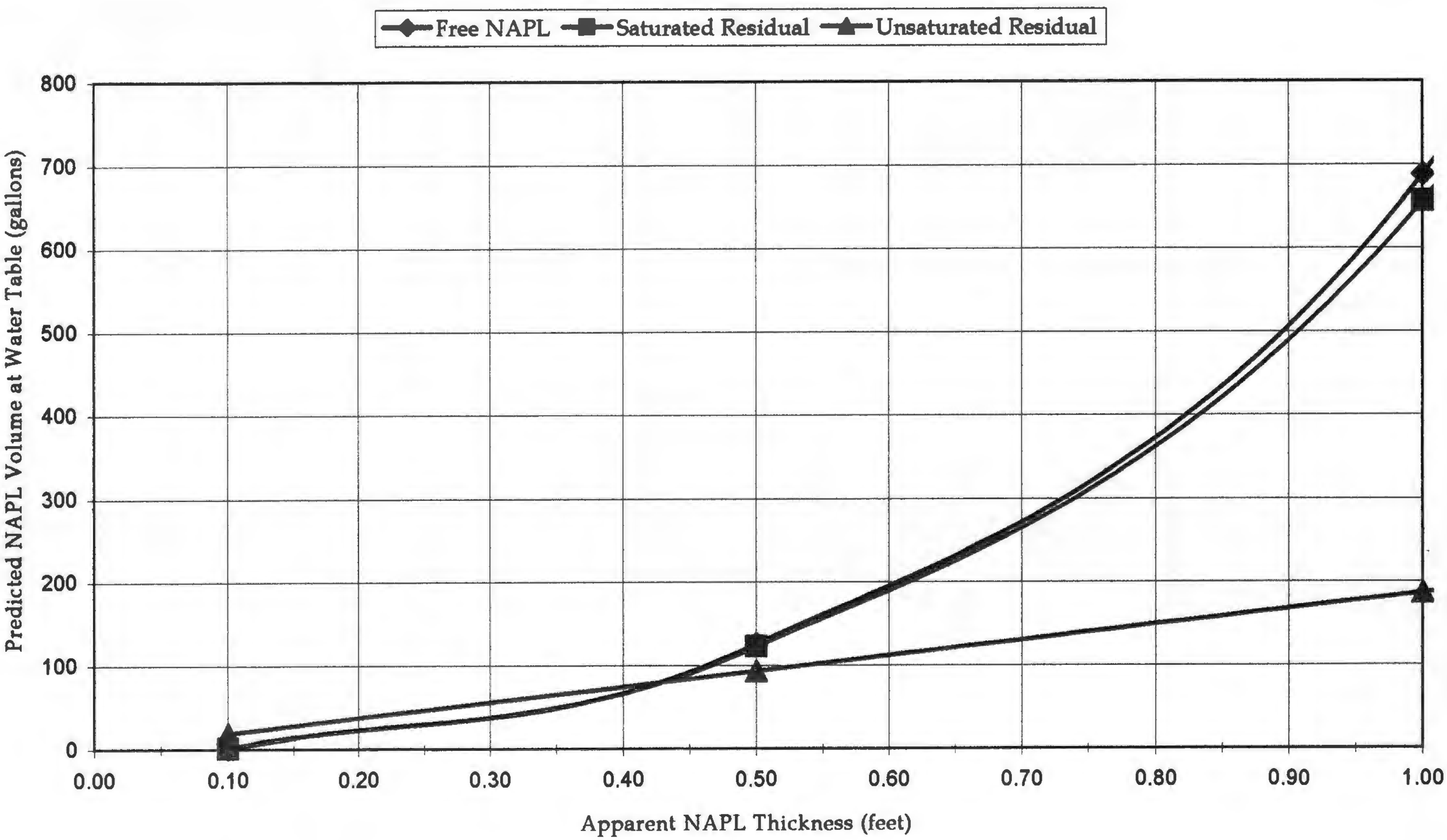
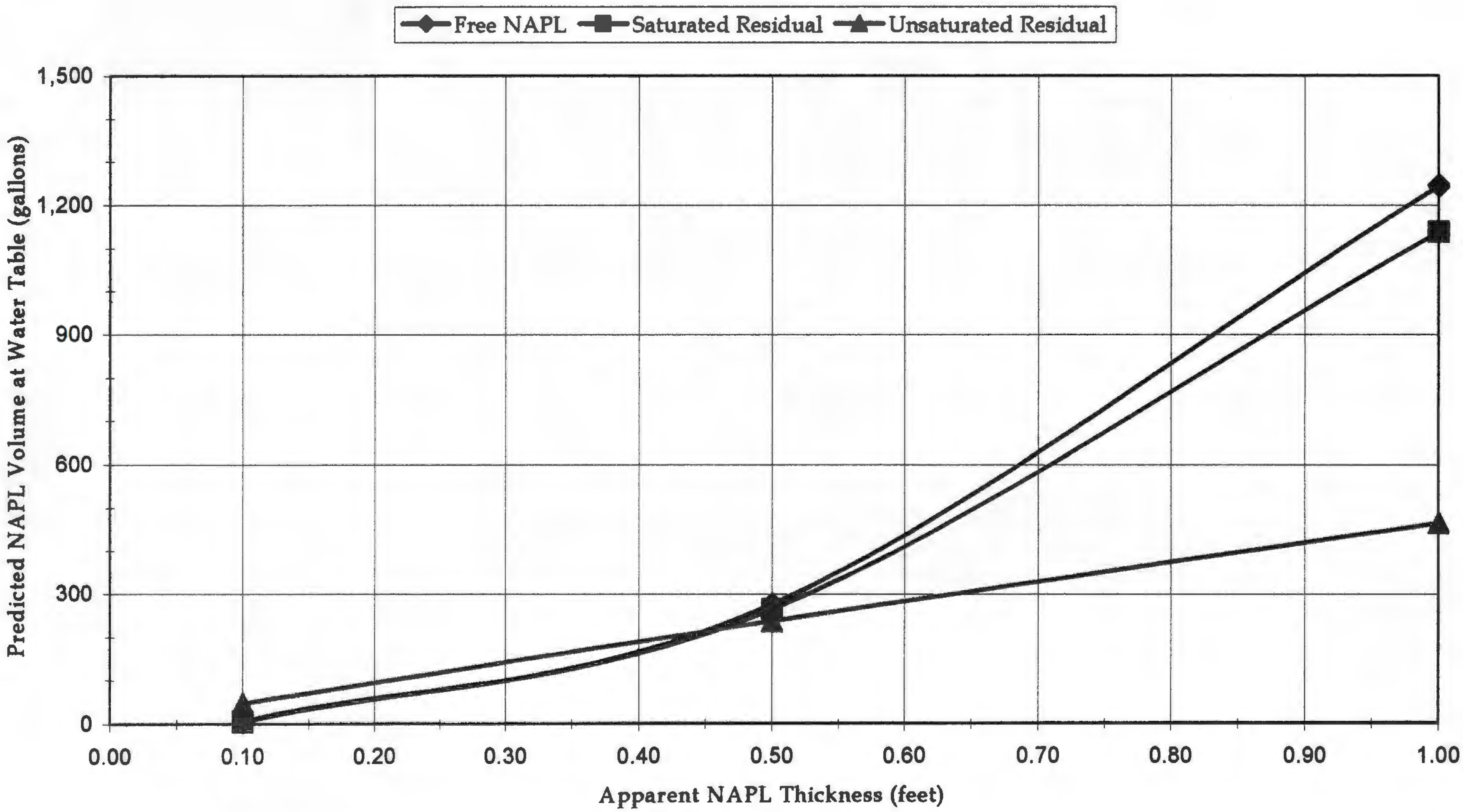
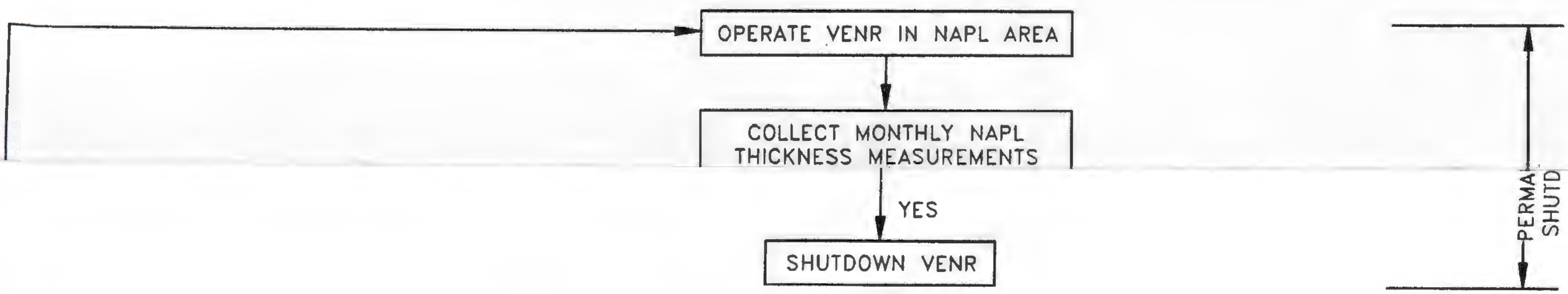


FIGURE 2-9
Metro North Harmon Yard OU-II
L4 Apparent NAPL Thickness vs. Predicted NAPL Volume
at the Water Table





TITLE

OU-II VENR SYSTEM SHUTDOWN EVALUATION

PREPARED FOR

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ERM Environmental Resources Management

DRAWN:	JOB NO:	FILE NAME:	SCALE	DATE	FIGURE
G.G./Y.S.	X7602.04.01	X7602044	NTS	9/25/00	5-1