Final Remedial Investigation Report
Clifton Former MGP Site
Operable Unit 1 (OU-1)
Staten Island, New York
Site No. 2-43-023

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Executive Summary

On behalf of KeySpan Corporation (KeySpan), GEI Consultants, Inc. (GEI) conducted a remedial investigation (RI) and, in conjunction with Vanasse Hangen Brustlin, Inc. (VHB), prepared this RI report which addresses environmental conditions at and adjacent to the former manufactured gas plant (MGP) located at 25 and 40 Willow Avenue in the neighborhood of Clifton, Staten Island, New York. Qualitative Human Exposure Assessment (QHEA) and Fish and Wildlife Impacts Analysis (FWIA) aspects of the RI were conducted and the corresponding report sections prepared by VHB. The RI was performed in accordance with an Administrative Order on Consent (Index No. D2-0001-98-04) (AOC), the November 9, 1998 approved RI work plan, and the July 26, 1999, November 28, 1999, October 9, 2001, and the May 15, 2002 approved RI work plan addenda.

Five rounds of RI field work were completed between February 1999 and June 2002. The scope of the RI included the completion of exploratory test pits, soil borings, groundwater monitoring wells, piezometers, and surface-soil collection points at the 25 and 40 Willow Street parcels. The parcels have been separated into two operable units as the site progresses towards remedial action. Operable Unit 1 (OU-1) is the focus of this report and includes the following parcels: 40 Willow Avenue and adjacent parcels located at 66 Willow Avenue, the Lynhurst Avenue residential parcels (49 through 67 Lynhurst Avenue).

The parcel located at 25 Willow Avenue will be referenced as Operable Unit 2 (OU-2) and findings will be summarized under a separate RI report. The scope of the RI completed at OU-1 included 5 exploratory test pits, drilling of 43 subsurface-soil borings, drilling and installation of 3 groundwater monitoring wells, installation of 12 piezometers, and the sampling of 60 surface-soil locations. Eighty-eight subsurface-soil samples, 94 surface-soil samples, and 15 groundwater samples were chemically analyzed to evaluate the environmental conditions.

The 40 Willow Avenue parcel is set in an urban residential and commercial area of Staten Island, and encompasses approximately 0.98 acre. KeySpan currently owns the parcel. The 40 Willow Avenue parcel includes a natural gas regulating gate station, a paved parking area, and an unpaved, partially vegetated area. The 40 Willow Avenue parcel was the site of former Relief Gas Holder No. 2 and other structures associated with the former MGP. Residential homes abut the parcel to the south, and a commercial property borders the parcel on the west. The northern side of the parcel is bordered by Willow Avenue and the eastern side is bordered by Bay Street.

Construction of the former MGP began circa 1850 and the plant began production in April of 1857. Throughout the operating life of the plant, most of the operations were located on the 25 Willow Avenue parcel (Staten Island Gas Light/Richmond County Gas Light Company). Sometime prior to 1917, the plant expanded to the 40 Willow Avenue parcel with the addition of Relief Holder No. 2. Between 1937 and 1950, minor expansions occurred on both parcels. The MGP was demolished in 1959.

The geological setting has OU-1 located atop glacial deposits, including ground moraine, terminal moraine, and glacial outwash materials. The Manhattan Schist (bedrock) underlies these glacial deposits. Alluvial materials are also present at shallow depths at the 40 Willow Avenue parcel. Fill is present at shallow depths across the majority of OU-1. Topographically, the 40 Willow Avenue parcel is located in a gently sloping bowl-like depression that appears related to a historic stream channel. The nearest surface water body to the 40 Willow Avenue parcel is New York Harbor, approximately 500 to 600 feet to the northeast. Public water supply is currently provided to the parcels included in OU-1 and all surrounding residents and businesses. The source of the public water supply is reservoirs in the Catskill Mountains north of New York City.

Groundwater beneath OU-1 resides in two aquifers, shallow (water table) and deep. Dense, silty ground moraine and terminal moraine deposits create a hydrogeologic confining unit between the aquifers. The confining unit appears discontinuous beneath the 40 Willow Avenue parcel. Groundwater in the water table aquifer at OU-1 exhibits a radial flow pattern with flow ranging from west to north towards the adjacent 25 Willow Avenue parcel and northeasterly towards New York Harbor.

The most extensive observations of tar, staining, sheen, odors, and soil and groundwater containing chemical constituents related to the former MGP are limited to the 40 Willow Avenue parcel in close proximity to the former MGP-related structures. Tar, tar-staining, sheen, and/or tar-like odors were only present in soils beneath the Lynhurst residential parcels at depths greater than approximately 25 feet. Only naphthalene odors were observed beneath the 66 Willow Avenue parcel. Most of the chemical constituents encountered on the 40 Willow Avenue parcel were related to the presence of tar found within and adjacent to former MGP-related structures that handled tar as part of the gas production and storage process.

Similarly, within OU-1, dissolved chemical constituents in groundwater within the water table aquifer are predominantly limited to the 40 Willow Avenue parcel. Dissolved phase benzene, toluene, ethylbenzene, and xylene (BTEX) and polycyclic aromatic hydrocarbons (PAHs) were present in groundwater within the deep aquifer at well RW-7 and RW-14, adjacent to Relief Holder No. 2 (40 Willow Avenue parcel).

Shallow soils containing lead were identified on the residential parcels on Lynhurst Avenue during the course of investigation. In September 2002 through July 2003, an interim remedial measure (IRM) was conducted in accordance with the approved March 2002 IRM work plan to remove lead-containing soils to a target depth of 3 feet below ground surface on the residential parcels. The implementation of this IRM eliminated any potential contact by the residents with the soil containing lead.

The findings from VHB's qualitative exposure assessment indicate that chemicals present in soils and groundwater at Lynhurst Avenue Residential Parcels (off site) have an exposure pathway through which individuals could potentially be exposed to chemicals, which is incomplete based upon current and anticipated land use of the parcels.

The assessment of composure pathways and chemical occurrence of the 40 Willow Avenue parcel revealed that chemicals were present in surface soils, subsurface soils, and groundwater above applicable regulatory standards or site background conditions. Based upon the current site conditions and site access, potential for exposure scenarios were incomplete or determined to be minimal. The future site use scenario at the 40 Willow Avenue parcel could have potential pathways of concern if subsurface soils and groundwater are exposed. A feasibility study report has been prepared to assess the appropriate means to mitigate conditions related to the former relief holder on the 40 Willow Avenue parcel. The draft feasibility study was issued in December 2002.

The fish and wildlife impact analysis (FWIA) indicated that the site and surrounding area represent poor environmental resources due to the lack of vegetation in the urban environment. Wildlife species present are adapted to an urban setting and due to the limited size of vegetated areas only a few individuals would be present. Concentrations of several chemicals of potential ecological concern (COPECs) in soils pose a potential risk to wildlife, however this potential risk has minimal ecological significance. Only transient species and a few individual animals would use this area, therefore the frequency and duration of exposure to COPECs is limited. Therefore, the on-site COPECs do not pose a current risk nor an anticipated future risk to wildlife.

The body of this RI report presents the environmental observations and findings. The reader is referred to Sections 6 and 7 for a summary of the conceptual site model and a summary of the environmental and risk findings, respectively.

1. Introduction

GEI Consultants, Inc. (GEI) was retained by KeySpan Corporation (KeySpan) to conduct a remedial investigation (RI) and, in conjunction with Vanasse Hangen Brustlin, Inc. (VHB), to prepare this RI report which addresses environmental conditions related to the former manufactured gas plant (MGP) operation at the parcels located at 25 and 40 Willow Avenue in the neighborhood of Clifton in Staten Island, New York (Figure 1-1). VHB was responsible for conducting and preparing and updating the Qualitative Human Exposure Assessment (QHEA) and Fish and Wildlife Impacts Analysis (FWIA) aspects of the RI. As such, Section 7 of this report, including all associated tables and figures, have been prepared by VHB. All other report sections were prepared by GEI. The site has been separated into two operable units (OUs). Operable Unit 1 (OU-1) is the focus of this report and includes the 40 Willow Avenue parcel, the adjacent Lynhurst Avenue residential parcels (49 through 67 Lynhurst Avenue), and the adjacent 66 Willow Avenue commercial parcel. The remainder of the site (including 25 Willow Avenue) constitutes OU-2. Plate 1 presents the extent of investigations at each operable unit through 2002. The findings for OU-2 will be summarized under a separate RI report cover once additional field investigation is completed.

The RI was performed in accordance with the Administrative Order on Consent (AOC) (Index No. D2-0001-98-04) between Brooklyn Union Gas Company (Brooklyn Union) (KeySpan's predecessor) and the New York State Department of Environmental Conservation (NYSDEC) for the former Richmond County Gas Light Company MGP located at the 25 and 40 Willow Avenue parcels.

KeySpan currently owns the 40 Willow Avenue parcel. Plate 1 presents the current layout and former MGP plant configuration for both operable units. The scope of the RI included the completion of exploratory test pits, subsurface borings, groundwater monitoring wells, piezometers (temporary and permanent), and surface-soil collection points.

Subsection 1.2.1 presents a detailed description of the OU-1 parcels.

The remainder of Section 1 discusses the RI Objectives and Scope (subsection 1.1), background (subsection 1.2), the physical and environmental setting (subsection 1.3), and a summary of previous investigations (subsection 1.4).

Section 2 discusses the RI Scope of Work and methods used during the RI. Section 3 discusses the geology and hydrogeology underlying OU-1. Section 4 discusses the nature and extent of physical observations and chemical constituents. Section 5 discusses the fate and transport of chemical constituents. Section 6 presents a conceptual site model for OU-1, Section 7 presents an QHEA and an FWIA. The findings of the OU-1 RI are summarized in Section 8.

1.1 RI Objectives and Scope

The RI was conducted in accordance with the AOC and as outlined in the approved RI Work Plan, dated November 9, 1998, and its approved addenda listed below. The addenda work plans are included in Appendix A.

- *Remedial Investigation Clifton Former MGP Site, Amendment to the Work Plan, Staten Island, New York* (July 26, 1999)
- *Clifton Former MGP Site, Additional Scope of Work for Residential Lots Adjacent to the 40 Willow Avenue Parcel, Staten Island, New York* (November 28, 1999)
- *Former Clifton MGP Site, Revised Supplemental Investigation (RI) Work Plan, 25 and 40 Willow Avenue Parcels, Staten Island, New York (October 9, 2001)*
- *Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) Revised Work Plan (May 15, 2002)*

The RI was intended to characterize soil and groundwater conditions at the 40 Willow Avenue parcel and adjacent parcels included in OU-1. The information gathered during the RI was intended to supplement information available from previous investigations of the 40 Willow Avenue parcel. Two previous investigations were completed at the 40 Willow Avenue parcel by Brooklyn Union, and Fanning, Phillips, and Molnar (FP&M) between 1993 and 1998. These previous investigations are discussed in subsection 1.4.

1.2 Background

This subsection provides a description of the setting of OU-1 and discusses the surrounding demographics and the history of the former MGP.

1.2.1 Description of Parcels

The 40 Willow Avenue parcel encompasses approximately 0.98 acre. The 40 Willow Avenue parcel is located at the southwestern corner of Bay Street and Willow Avenue and is bounded on the northwest by Willow Avenue, on the northeast by Bay Street, on the west by a two-story commercial building and a paved parking lot (66 Willow Avenue), and by residential dwellings (49 through 67 Lynhurst Avenue) on the south. The residential parcels encompass approximately 0.66 acre and front on Lynhurst Avenue (Plate 1).

The 40 Willow Avenue parcel includes:

- A paved parking lot on the northern and eastern portions of the parcel
- Two, one-story brick buildings utilized as a natural gas regulating gate station on the northern portion of the parcel
- An undeveloped, partially grassed lot on the southern portion of the parcel, periodically used for vehicle parking (Plate 1)

The regulating station and unpaved lot on the 40 Willow Avenue parcel were previously the location of a former gas holder (Relief Holder No. 2). A chain-link fence surrounds the entire perimeter of the 40 Willow Avenue parcel.

The 66 Willow Avenue parcel consists of a two-story, commercial office building with loading docks and a paved parking lot that surrounds the building (Plate 1).

The Lynhurst Avenue residential parcels (49 through 67) consist of occupied residential dwellings (Plate 1). Each residential parcel contains a grassed and landscaped back yard with the only exception being a paved parking area on the 51 Lynhurst Avenue parcel. A chain-link fence surrounds the perimeter of each parcel.

The OU-1 parcels are located in an area of mixed commercial and residential land use. Population data was obtained from the United States Environmental Protection Agency (EPA) Internet web site based upon 1990 census data. Census data from 1990 indicate that the average population density per square mile within 1 mile of the two parcels is 8,266 (Figure 1-2). There are 10,255 household units and a population totaling about 26,000 within this 1-mile radius. Updated population data obtained from the 2000 Census Internet web site indicates that the population density for Richmond County (Staten Island) ranges between 4,655 and 7,588 persons per square mile.

1.2.2 History

The Clifton former MGP was operated by Richmond County Gas Light from 1856 to 1901 and the Staten Island Gas Light Company circa 1884. Plate 1 shows the historic layout of the former plant. From 1901 until 1957, the plant was operated by the New York and Richmond Gas Company. Brooklyn Union acquired that company in 1957, at which point MGP operations ceased. Brooklyn Union (KeySpan) never operated the gas works.

The following discussion regarding the MGP history pertains to both OU-1 and OU-2.

Only a partial history of the former plant is available based on public records; however, through review of documentation at the Staten Island Institute of Arts and Sciences, *Brown's Directory of American Gas Companies*, and available Sanborn Fire Insurance (Sanborn) maps, a general depiction of the former plant development is possible.

The earliest available map of the general vicinity is a Revolutionary War period map of Staten Island for the years 1775 through 1783 (Figure 1-3). Here the location of the future plant is shown as undeveloped with a small (unnamed) stream flowing from the uplands to the south toward the northeast into New York Harbor. Bay Street (a.k.a. Shore Road) is essentially a shoreline travel way near the future plant location. Anchorages are also noted just offshore of where the MGP would be built 70 years later. In 1853, a James Butler map of the vicinity depicts substantial changes in the vicinity of the future plant (Figure 1-4). A street grid has been established, the shoreline appears to have bulkheads, and a number of dwellings dot the landscape. The unnamed stream that flows through the former MGP site is illustrated in more detail. This drawing probably represents the community layout at the time the MGP was constructed in 1850. It is documented in the Richmond County Gazette that the construction of the MGP began in 1850. At that time, the plant consisted of the following.

- A 30- x 50-foot brick retort house
- A 25- x 30-foot purifying house which contained purifiers, condensers, and a scrubber
- An office and meter house, 20 x 30 feet in dimension
- A single 75-foot diameter holder having a brick tank 21 feet deep (subsequently referred to as Relief Holder No. 1)
- Lime and coal sheds

The plant was owned by the Richmond County Gas Light Company, which started production in April 1857.

An *1874 F.W. Beers Map of Staten Island* shows what is considered the earliest plant layout. Referring to Plate 1, the first gas holder is the same as Relief Holder No. 1. The main production facilities were located just to the southwest of the holder. Plate 1 indicates three of the original buildings as "purifying," "retort house," and "coal shed."

According to an article written by F. Rider in 1961, titled *Looking Back to Gas Light Era*, a second gas company, the Staten Island Gas Light Company, had previously existed only on paper with no plant or infrastructure improvements on the island. The Staten Island Gas Light Company was indicated to have built a plant adjacent to the Richmond County Gas

Light Company (also referred to as the Richmond Gas Works). In 1884, the Staten Island Gas Light Company merged with the Richmond County Gas Light Company and a new carbureted water gas plant was built at the current 25 and 40 Willow Avenue parcels. The Staten Island Company was responsible for production and the Richmond County Gas Light Company distributed the gas.

The 1885 Sanborn map depicts a gas works with a gasometer as “not completed” on the western portion of the 25 Willow Avenue parcel that are believed to be the Staten Island Gas Light Company operations. The 1885 Sanborn map also shows various operational features of the unlabeled gas works, including a gasometer (referred to in later years and in Plate 1 as Relief Holder No. 1), a fuel oil tank, several coal sheds, a purifying house, a lime house, and a retort house. In the 1898 Sanborn map, a second generating house, gasometer, and associated structures in the western portion of the 25 Willow Avenue parcel (likely the former Staten Island Gas Light Company operations) and a gasometer (referred to in later years as Relief Holder No. 2) are depicted on the 40 Willow Avenue parcel. The 25 Willow Avenue plant is referred to as the Richmond Gas Works in this Sanborn map.

A *1907 Atlas of the Borough of Staten Island, Richmond, City of New York*, indicates that the MGP is referred to as the Richmond County Gas Light Company. The atlas depicts the configuration of the plant to be relatively unchanged from the 1898 Sanborn map.

A 1917 Sanborn map shows that much expansion had occurred at the plant between the late 1800s and 1917, including the addition/conversion of the original coal carbonization plant to a water gas plant, and construction of a large-capacity (1 million cubic feet) gas holder (Holder No. 2) at the northern corner of the 25 Willow Avenue parcel near Bay Street. In addition, in the northeastern portion of the site, a tar separator was located east of Relief Holder No. 1 and tanks (later referred to as tar tanks) and two oil tanks are depicted. The MGP is listed as the New York and Richmond Gas Company. This expansion in the plant was accompanied by increased gas production at the site from 38 million cubic feet (MMCF) to 372 MMCF in 1920 *Brown's Directory* listings (*Brown's*, 1890 and 1920). The former gas works (Staten Island Gas Light Company) and associated structures have been incorporated into the New York and Richmond Gas Company MGP (also referred as the Richmond County Gas Light Company) and were used for site operations.

A 1937 Sanborn map shows the expansion of the water gas plant and purifying facilities, the addition of another tar separator, and three fuel oil tanks at the southwestern corner of the 25 Willow Avenue parcel, and the addition of support equipment on the 40 Willow Avenue parcel around Relief Holder No. 2. Gas production continued to increase at the site to 910 MMCF by 1935 (*Brown's*). Between 1937 and 1950, minor expansions occurred on both sides of Willow Avenue. Gas production at the site continued to increase to 1,230 MMCF by 1945 and reached a peak of 1,400 MMCF in 1955. The gas plant was demolished in the spring of 1959 according to a newspaper article in the “Advance.” The 1977 Sanborn map shows the Brooklyn Union Service Center on the southeastern corner of the 25 Willow Avenue parcel, and a Brooklyn Union natural gas regulator station on the southern side of Willow Avenue (40 Willow Avenue parcel). The natural gas regulator station is the building associated with the gas plant that is depicted on the 1977 Sanborn map.

1.2.3 Water Use

Public water supply is currently provided to the OU-1 parcels and the surrounding area by the New York City Water Department. Mr. Joseph McGuire, a representative from the New York City Water Department, was contacted regarding historic water use on Staten Island (McGuire, 2000). According to Mr. McGuire, all of Staten Island's water supply currently comes from the Catskill Region of New York and is stored in the Clove Lakes area of Staten Island in underground storage tanks (USTs). Staten Island was connected to the New York City water system in 1970, when the Richmond Tunnel was completed across The Verrazano Narrows.

No wells are known to be currently in use. The nearest former well to OU-1 was an industrial/private water supply well operated by Louis Dejone and Company located at 330 Tompkins Avenue (McGuire, 2000). The well is not active and was located approximately 0.2 mile southwest and upgradient of the OU-1 parcels. Soren (1988) identified another former well approximately 0.2 mile south of the parcel. The former use of this well is unknown.

In previous investigations at the site, an 8-inch steel well that was likely associated with the former MGP was encountered on the site. The discovery and the decommissioning of this well are described within subsection 1.4.1.

1.3 Physical and Environmental Setting

The OU-1 parcels are in a locally topographic high area that gently slopes to the north towards the 25 Willow Avenue parcel and east-northeast towards New York Harbor (Plate 1). The parcels reside on the edge of a topographic bowl-like depression that appears to be associated with the historic stream that flowed on the northwestern portion of the adjacent 25 Willow Avenue parcel. Historic maps reveal that an unnamed stream was present beneath the existing railroad bed on the northwestern portion of the 25 Willow Avenue parcel (Figures 1-3 and 1-4). This stream appears to have been filled at one point and replaced with the current stormwater drainage system. New York Harbor is the closest surface water body to OU-1 and is located approximately 500 to 600 feet northeast (Figure 1-1).

1.3.1 Regional Geology

The 40 Willow Avenue parcel is located in the Manhattan Prong Geologic Province, which contains bedrock associated with the New York City group (Bennimoff and Ohan, no date). Two other geologic provinces on Staten Island include the Staten Island Serpentinite that makes up the central highlands or spine of Staten Island, and the Newark Basin, which is located on the western portion of Staten Island (Bennimoff and Ohan, no date). OU-1 is believed to be underlain by the Manhattan Schist, which is described as a metamorphosed dark gray micaceous rock unit of Late Proterozoic to Cambrian Age that was folded, faulted and eroded with younger deposits overlying (Soren, 1988). Surficial, unconsolidated Pleistocene age (Wisconsin) glacial deposits lie unconformably on the Manhattan Schist in the northeastern portion of Staten Island (Soren, 1988). Holocene (recent) aged deposits are inferred to be associated with streams, rivers and marsh deposits.

The OU-1 parcels are indicated as underlain by Harbor Hill Terminal Moraine deposits which consist of unsorted sand, gravel, cobbles, and boulders within a clayey and silty matrix with some occurrences of locally stratified sand and gravel beds (Soren, 1988). A nearby geologic contact indicates that Pleistocene Age (Wisconsin) Ground Moraine deposits are located just to the west of the parcels and are described as a mainly reddish-brown, clayey-till from the surface to approximately 150 feet below ground surface (bgs). The unit is described as having local bodies of stratified sands and gravel bodies within the unit (Soren, 1988).

1.3.2 Regional Hydrogeology

The regional hydrogeology of the northern portion of Staten Island is characterized by groundwater flow from the central highlands easterly towards New York Harbor. Groundwater elevations range from as much as 350 feet above sea level in the central spine of Staten Island to sea level at the shore. The water table is less than 10 feet above sea level in the vicinity of the OU-1 parcels. Water table conditions are encountered on Staten Island where sandy till is present and confined conditions are encountered where silty-till and clayey-till over water-bearing units are present (Soren, 1988).

The terminal moraine that underlies OU-1 is estimated to have an average hydraulic conductivity of 0.001 feet per day for a clayey till and 0.008 feet per day for a silty till. Horizontal hydraulic conductivities are approximately 10 to 20 times greater than the vertical hydraulic conductivities (Morris and Johnson, 1967, and Soren, 1988). Higher hydraulic gradients were noted within the stratified sand and gravel layers contained within the ground moraine unit.

1.3.3 Climatology

Climatologic records were reviewed for the Newark International Airport in Newark, New Jersey for the time period 1970 through 1997. The Newark International Airport is located approximately 8 miles to the northwest of the 40 Willow Avenue parcel and its weather records are considered representative of weather conditions at the parcels. Based upon a review of this data, the normal maximum and minimum daily temperature, normal monthly and annual precipitation, and mean wind speed and prevailing direction were obtained. Table 1-1 summarizes the climatologic data for the airport. The average daily maximum temperature was 63.4°F and the average daily minimum temperature was 46.1°F. The lowest normal daily maximum temperature was 37°F recorded for January and the highest normal daily maximum was 87.0°F recorded for July. The annual precipitation (rainfall) for the area is 43.97 inches with the largest northerly amount of precipitation of 4.5 inches, which occurs in July. The annual snowfall in the vicinity is 27.0 inches with the largest amount (9.2 inches) falling in February. The average annual wind speed is 10.2 miles per hour from the south/southwest (230ºE).

1.4 Previous Investigations

Subsurface investigations were conducted by others in and around the 40 Willow Avenue parcel since 1993. These investigations are summarized below.

1.4.1 40 Willow Avenue Investigation

1.4.1.1 Brooklyn Union Previous Activities (February 1993)

A summary of previous Brooklyn Union activities for the 40 Willow Avenue parcel is presented in the August 29, 1994 report by FP&M. A summary of observations and activities reported in FP&M's report are as follows.

- Discovery of an oil-like substance on the unpaved lot at the 40 Willow Avenue parcel
- Discovery of an 8-inch steel well casing on the 40 Willow Avenue parcel
- Removal of a water/hydrocarbon mixture from the 8-inch well and sealing of the well with cement grout
- Excavation of 20 cubic yards (cy) of soil down slope of the 8-inch pipe

The following paragraphs provide a detailed summary of these events as obtained from the FP&M report, dated August 29, 1994.

Brooklyn Union personnel had previously discovered a puddle of an oil-like substance on unpaved soil located approximately 20 feet southeast of the Gate Station on the 40 Willow

Avenue parcel. The oil-like substance was originally assumed to be related to site use by Brooklyn Union contractors that had previously used the area as a temporary soil and pavement storage area. Stained soils and soils containing the oil-like substance were drummed and sampled. Analysis by the Brooklyn Union laboratory revealed that the oil-like substance closely resembled coal tar [sic]. In February 1993, an additional soil cleanup by Brooklyn Union personnel revealed an 8-inch diameter steel pipe located just below the ground surface (Plates 1 and 3). The well was observed to be vertical with a welded steel cap that was leaking small amounts of water and an oil-like material. The well was measured to a depth of approximately 90 feet bgs. Miller Environmental Group (the environmental contractor) was contacted and subsequently removed water and a hydrocarbon free-product mixture from the well into a vacuum tanker. Brooklyn Union subsequently sealed the 8-inch pipe with a mixture of cement grout and removed approximately 20 cy of soil downgradient of the casing (Plates 1 and 3). Brooklyn Union notified NYSDEC and the incident was assigned Spill #92-12952.

1.4.1.2 Fanning Phillips & Molnar, 1993-1994 Subsurface Investigation and Soil Removal (40 Willow Avenue Parcel)

A subsurface investigation conducted between April 1993 and June 1994 is summarized as follows.

- Installation of three monitoring wells (MW-1 through MW-3)
- Completion of eight soil borings (SB-1 through SB-8)
- Sampling of subsurface soil and groundwater
- Removal of groundwater and free product (coal tar) [sic] from the deep well and abandonment of the deep well
- One excavation resulting in the removal of approximately 43 cy of soil

The following paragraphs present these activities in chronological order and provide more detail regarding the 40 Willow Avenue parcel.

Between April 1 and 5, 1993, three shallow monitoring wells (MW-1, MW-2, and MW-3) were installed within 10 feet of the former puddle in topographically uphill and downhill directions (FP&M, 1993) (Plates 1 and 3). The wells were installed to a maximum depth of 24 feet below grade. No free product was observed in soil samples or within wells MW-1 or MW-2 after 48 hours. The soil at MW-3 contained coal tar [sic]-saturated material in the 0- to 2-foot sample interval. Volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene, and xylenes (BTEX), and polycyclic aromatic hydrocarbons (PAHs) were detected in the soil. At a depth of 22 feet below grade, soil concentrations of VOCs and PAHs were two to three orders of magnitude less than those encountered at the 0- to 2-foot depth. The groundwater samples detected xylenes in MW-2 and acenaphthylene (PAH) in MW-3.

On December 7, 1993, eight additional soil borings (SB-1 through SB-8; see Plate 1) were installed topographically downhill of the steel well to further characterize shallow soil in the area of the former 8-inch steel well (FP&M, August 29, 1994) (Plate 2). The majority of the chemical constituents and observed staining, etc. in soils down slope of the steel well were found to be localized in the vicinity of MW-3.

Between December 9 and 17, 1993, the concrete grout slurry in the 8-inch steel well was drilled out by air rotary drilling and tar and groundwater within the steel well was removed by pumping (FP&M, August 29, 1994). The 8-inch well was drilled out to a total depth of 79 feet and connection with the aquifer was determined by the reddish-brown silt present in the water flowing from the well. It was concluded by FP&M engineers that tar [sic] present in the well did not migrate into the formation because no discoloration or staining was noted in the groundwater flowing from the well. The well was gauged for light nonaqueous phase liquids (LNAPL) and dense nonaqueous phase liquids (DNAPL) and none were detected. The well was subsequently sealed by pressure grouting with cement slurry in accordance with NYSDEC well abandonment guidelines and with NYSDEC approval.

On June 15, 1994, 43 tons of soil in the vicinity of MW-3 and SB-4 was excavated and disposed of in accordance with NYSDEC regulations (FP&M, 1994). Sidewall and bottom confirmation samples were taken from the excavation prior to backfilling. These sidewall samples had detections of VOCs and PAHs. Following the removal of source materials, sampling results indicated that minimal groundwater impacts existed.

On January 19, 1996, NYSDEC issued a letter to Brooklyn Union, stating that the results of the investigations and remediation show little or no signs of contamination in the soil, and that the work was done satisfactorily and meets all Departmental requirements. This letter closed Spill Number 92-12952.

2. Remedial Investigation Scope of Work

The RI was primarily completed on the parcels located at 25 and 40 Willow Avenue, which contained the primary operations of the former MGP. Some work was completed on adjacent parcels contained within OU-1 and OU-2. The scope of work for OU-1 included the completion of soil borings, test pits, installation of groundwater monitoring wells, soil sampling, hydraulic conductivity testing, and groundwater sampling to characterize the soil and groundwater conditions. Figure 2-1 depicts the RI sampling locations at OU-1.

The RI was completed in five rounds of field work: Round 1 (February through April 1999); Round 2 (July through October 1999); Round 3 (November through December 1999); Round 4 (November 2001 through January 2002); and Round 5 (May through June 2002). Sampling locations were selected to address/identify former MGP structures; to obtain information regarding the soil and groundwater conditions at the 40 Willow Avenue parcels; and to characterize the soil and groundwater at adjacent parcels.

The OU-1 portion of the RI included completion of 5 exploratory test pits, drilling of 43 subsurface-soil borings, drilling and installation of 3 groundwater monitoring wells, installation of 12 piezometers, and the sampling of 60 surface-soil locations. Eighty-eight subsurface-soil samples, 94 surface-soil samples, and 15 groundwater samples were chemically analyzed to evaluate the environmental conditions within OU-1.

This section generally describes the methods used for the sampling in accordance with the NYSDEC-approved work plan and the NYSDEC-approved work plan addenda. Detailed field procedures are located in the work plan and work plan addenda. Sample analyses were completed by Severn-Trent Laboratories (STL), located in Shelton, Connecticut (a NYSDEC-approved laboratory).

2.1 Field Work

2.1.1 Round 1 - Investigation of 40 Willow Avenue Parcel (February through April 1999)

The general objective of this phase of the RI was to identify the presence/absence of the former MGP structures and to characterize the subsurface conditions at the 25 and 40 Willow Avenue parcels.

In accordance with the RI work plan, two test pits (TP-10 and TP-10A) and seven borings (SB-17/RW-7, SB-18, SB-21, SB-22, SB-23, SB-36, and RW-4) were completed at the 40 Willow Avenue parcel [OU-1] (Figure 2-1). Of the seven soil borings, two (RW-4 and RW-7/SB-17) were installed as monitoring wells.

Surface- and subsurface-soil sampling, groundwater sampling, hydraulic conductivity testing, and groundwater level measurements (at high and low tides) were completed during the first round of the RI.

Within OU-1, groundwater samples were collected from monitoring wells RW-4 and RW-7 as part of the Round 1 scope of work. A single-well pump test was conducted on RW-4 to assess the hydraulic conductivities of the deep groundwater aquifer beneath the 40 Willow Avenue parcel. Each monitoring well was gauged for the potential presence of non-aqueous phase liquid (NAPL) during the groundwater sampling event. In addition, temporary hand-dug piezometers (PZ-2 and PZ-3) were installed to provide additional groundwater elevation data, and five surface-soil samples (SS-1 to SS-5) were collected from the unpaved portion of the 40 Willow Avenue parcel (Figure 2-1).

Nine air quality stations (AQS-1 to AQS-9) were established to monitor the air quality on the perimeter of the 25 and 40 Willow Avenue parcels during the test pit excavations (Plate 1 and Figure 2-1). Air quality monitoring was also conducted immediately adjacent to test pits (work zone) to document the air quality during exposure of soils during shallow excavations. The air-monitoring program included the collection of real-time air quality data, time-averaged air quality data, and meteorological data to document potential migration routes of airborne VOCs and particulates.

2.1.2 Round 2 Investigation of 25 and 40 Willow Avenue Parcels and Adjacent Parcels (July through October 1999)

This portion of the RI was completed to characterize subsurface soils to a confining layer (bedrock), characterize shallow subsurface soils, determine the presence of additional former MGP structures, characterize groundwater conditions within the upper and lower aquifers, evaluate the lateral and vertical extent of subsurface conditions, and evaluate surface-soil conditions on adjacent residential and other abutting parcels.

Within OU-1, five soil borings were drilled and sampled (SB-40, SB-41, SB-42/RW-14, SB-43, SB-44) with one of these borings completed as a monitoring well (RW-14/SB-42). Six residential parcel surface soils (SS-6 to SS-11) were collected from 63, 61, 59, 55, 53, and 51 Lynhurst Avenue, respectively.

Surface- and subsurface-soil sampling, groundwater sampling, hydraulic conductivity testing, and groundwater level measurements (at high and low tide stages) were completed at boring and monitoring well locations on the 40 Willow Avenue parcel. Groundwater samples were collected from monitoring wells RW-4 and RW-14. Monitoring well (FPM-MW-1) and piezometers (PZ-2 and PZ-3) were used to determine water table groundwater flow directions. Monitoring wells RW-4 and RW-14 were used to determine the groundwater flow within the deep aquifer. Groundwater information from OU-2 was used to supplement groundwater information collected within OU-1.

In addition to the proposed work described in the work plan addenda, hand-dug piezometers (PZ-2, and PZ-3) were replaced with permanent GeoProbe®-installed piezometers with sand packs and protective well heads (Figure 2-1). PZ-2 and PZ-3 were permanently reinstalled in their approximate original locations.

2.1.3 Round 3 Investigation of Lynhurst Avenue Residential Lots and Commercial Lot at 66 Willow Avenue (November through December 1999)

This phase of the RI was conducted to characterize the soil conditions beneath the residential lots on Lynhurst Avenue. In addition, further characterization of surface soils at these lots was performed and background surface-soil samples were collected to establish the condition of background soils in the vicinity of the former MGP.

In accordance with the RI work plan addendum dated November 11, 1999, five soil borings (SB-58, SB-59, SB-60, SB-61, and SB-62) were drilled on the residential parcels with a GeoProbe® rig and 12 residential surface-soil samples (SS-12, SS-14, SS-15, SS-16, SS-19, SS-21, SS-22, SS-23, SS-26, SS-28, SS-29, and SS-30) were collected from the residential parcels located at 49 through 59 Lynhurst Avenue. An additional three soil borings (SB-65, SB-66, and SB-67) were drilled with a GeoProbe® in the paved parking lot on the commercial property located at 66 Willow Avenue (Figure 2-1). Proposed soil borings SB-63 and SB-64 and surface-soil samples SS-17, SS-18, SS-24, SS-25, SS-31, and SS-32 were not able to be completed at the time of the investigation because site access agreements to 61 and 63 Lynhurst Avenue could not be secured. Proposed surface-soil samples SS-13, SS-20, and SS-27 were not able to be completed because concrete covered the residential yard area.

Ten background surface-soil samples (SS-33 through SS-42) were collected at accessible locations in the vicinity of the 25 and 40 Willow Avenue parcels. These samples were collected to establish background conditions against which the residential parcel surface-soil samples could be compared (Plate 1).

2.1.4 Round 4 - Former Clifton MGP Site, Revised Supplemental Investigation (RI) Work Plan, 25 and 40 Willow Avenue Parcels, Staten Island, New York (October 9, 2001) (November 2001 through January 2002)

This phase of the RI was conducted to characterize the soil conditions between the Relief Holder No. 2 located at 40 Willow Avenue and the residential parcels on Lynhurst Avenue and within Lynhurst Avenue. In addition, further characterization of soils and groundwater directly adjacent to Relief Holder No. 2 and a construction and integrity assessment of Relief Holder No. 2 was completed to assist in the feasibility study being completed for the removal of the holder. Additional surface characterization was also completed on the Lynhurst Avenue residential parcels.

In accordance with the RI work plan addendum dated October 9, 2001, one soil boring (SB-77) was installed with a GeoProbe® within the backyard of the 59 Lynhurst Avenue parcel and one soil boring (SB-78) was installed with a Resonant Sonic drilling rig within the Lynhurst Avenue Right-of-Way (ROW). Twelve soil borings (GP-01A/B, GP-02, GP-03A/B, GP-04, GP-05, GP-06, GP-07, GP-08, GP-09, GP-10, GP-11, and GP-12) were installed with a GeoProbe® drill rig. Two test pits (TP-12 and 13) were completed with a rubber-tired backhoe. Nine residential surface soils (SSR-40 through SSR 48) were collected from the 63 and 67 Lynhurst Avenue parcels.

Ten air quality stations (AQS-1 to AQS-10) were established to monitor the air quality on the perimeter of the 25 and 40 Willow Avenue parcels during the test pit excavations (Plate 1 and Figure 2-1). The original nine air quality stations (AQS-1 through AQS-9) were monitored during Round 4 and an additional air quality station (AQS-10) was established adjacent to the 40 Willow Avenue and 66 Willow Avenue property line. Air quality monitoring was also conducted immediately adjacent to test pits (work zone) to document the air quality during exposure of soils during shallow excavations. The air-monitoring program included the collection of real-time air quality data, time-averaged air quality data, and meteorological data to document potential migration routes of airborne VOCs and particulates.

In addition to the proposed work described in the work plan addenda, an additional test pit (TP-14) was completed within Relief Holder No. 2 to better define the outer holder wall of former Relief Holder No. 2 (Plate 1, Figure 2-1).

2.1.5 Round 5 - Former Clifton, Staten Island MGP Site, Supplemental Remedial Investigation (RI) (May through June 2002)

This phase of the RI was conducted to further characterize the soil conditions between the Relief Holder No. 2 and the residential parcels on Lynhurst Avenue and within Lynhurst Avenue. Shallow groundwater quality adjacent to the residential dwellings was also evaluated. The floor profile of the former Relief Holder No. 2 was also investigated to determine the contents and construction to support the feasibility study.

In accordance with the RI work plan addendum dated March 14, 2002, four subsurface-soil borings were installed with a GeoProbe® drill rig within the back yards of three of the Lynhurst Avenue parcels, as follows: SB-79/79A on 63 Lynhurst Avenue; SB-80 on 51 Lynhurst Avenue; and SB-87 on 53 Lynhurst Avenue. Three borings (SB-84, SB-85, and SB-86) were installed on the southeastern side of Lynhurst Avenue. Eight temporary piezometers (PZ-5 through PZ-12) were installed on 49 through 67 Lynhurst Avenue residential parcels adjacent to the basements of the dwellings. Groundwater samples were collected from the groundwater piezometers to evaluate the shallow groundwater quality adjacent to the residential homes.

In addition to the proposed work described in the work plan addenda, additional surface-soil samples SSR-49 through SSR-63 were collected on 51, 63 and 67 Lynhurst Avenue to support the lead impacted surface soil interim remedial measure (IRM) that commenced in September 2002 and was completed in July 2003.

2.2 Field Methods

Several pieces of heavy equipment were mobilized and various sampling techniques were utilized to complete the RI. This subsection generally describes the sampling procedures utilized. For details refer to the approved RI work plan and addenda.

2.2.1 Air Monitoring

2.2.1.1 Perimeter Air Monitoring

Ambient air monitoring was completed during the excavation of test pits (Round 1 and Round 4). Nine perimeter air quality stations (AQS-1 to AQS-9) were sampled during Round 1 and ten air quality stations (AQS-1 to AQS-10) were sampled during Round 4 of the RI (Plate 1). The air quality monitoring program was designed to evaluate the potential migration of VOCs and particulates off the perimeter of the parcels where excavation occurred, and to document the levels of VOCs and particulates in air at the property boundaries. A photoionization detector (PID) organic vapor analyzer (OVA) and MiniRAM™ particle detector were used in the collection of the air quality data at each air quality station. Each instrument was calibrated prior to use. Measurements were taken hourly at each sampling station while test pit excavation occurred. The perimeter air quality monitoring program was supplemental to, and discrete from, the air monitoring program implemented for purposes of evaluating worker health and safety.

Meteorological data, including wind speed, wind direction, and temperature, were monitored throughout the air sampling program to evaluate potential migration pathways of VOCs and particulates. These data were collected from a weather station temporarily mounted on the roof of the building at the 25 Willow Avenue parcel during Round 1 of the RI. Meteorological information was collected from a temporary weather station mounted on the chain-link fence adjacent to the gate of the 40 Willow Avenue parcel during Round 4 of the RI.

2.2.1.2 Worker Health and Safety Air Quality Monitoring

As specified in the work plan and addenda, two particulate meters were used during the test pit activities (Round 1 and Round 4 of the RI) to monitor dust generation during excavation of test pits. One unit was placed upwind of the excavations and the remaining unit was placed downwind of the excavations. The particulate meters were placed approximately 10 to 20 feet away from the excavation activities. The units were moved as appropriate during the excavation activities, based on wind direction. Potential organic vapor emissions were also monitored using a PID-OVA approximately 10 to 20 feet downwind of excavation activities. In addition, personnel working on excavating and logging each test pit monitored total VOCs within their work space breathing zone with a PID-OVA.

Subsection 2.3 discusses the results of the air monitoring program.

2.2.2 Soils (Borings, Test Pits, and Surface)

This subsection describes the methodology used at OU-1 to collect soil samples during the RI. Table 2-1 identifies the rationale for conducting each boring, submittal of each sample for laboratory analysis, and the analyses completed for each sample. Generally, soils were logged and screened in accordance with the RI work plan. Selected soil samples were placed directly into certified pre-cleaned containers and placed directly into ice-filled coolers. The samples were then shipped to STL under chain-of-custody or were picked up by laboratory courier and delivered to the laboratory for analysis. Boring logs and monitoring well construction logs are presented in Appendix B. Test pit logs are presented in Appendix C.

2.2.2.1 Test Pit Excavations

A backhoe was used to perform excavation of test pits TP-10 and TP-10A, TP-12, TP-13, and TP-14 at the 40 Willow Avenue parcel to investigate the presence, integrity and contents of the former Relief Holder No. 2 (Plate 1, Figure 2-1). Test pits 12, 13, and 14 were completed in support of the feasibility study to be completed for the Relief Holder No. 2. Soil from the test pits was excavated, logged and screened with a PID-OVA according to the RI Work Plan. Test pit logs are provided in Appendix C. If historic structures were encountered in a test pit, the structure was described and the locations of the structures were noted in the field book.

Two soil samples were collected from the test pits for analytical testing (Table 2-1). Soils from TP-10 and TP-10A were analyzed for BTEX (EPA Method 8260); semivolatile organic compounds (SVOCs) and 20 tentatively identified compounds (TICs) (EPA Method 8270); Resource Conservation and Recovery Act (RCRA 8) metals (EPA Method 6010); and total cyanide (TCN) (EPA Method 9012). No analytical samples were collected from TP-12, TP-13, and TP-14 during the excavation of TP-12, TP-13, and TP-14. Once test pits were logged, the test pits were backfilled in the reverse sequence that they were excavated.

2.2.2.2 Soil Borings

Forty-six borings were completed as part of the RI for OU-1 (including three completed as monitoring wells). Table 2-1 provides the boring IDs as well as the rationale for sampling. Soil boring logs and monitoring well construction logs are provided in Appendix B. Soil boring samples were collected utilizing GeoProbe®, hollow-stem auger, drive casing (drive and wash and mud rotary), and Rotosonic™ drilling methods. The objective of these borings was to evaluate the shallow and deep geologic conditions, and to install monitoring wells to screen the groundwater quality at the OU-1 parcels.

Within each boring, soil samples were generally collected from intervals exhibiting the greatest observed occurrence of tar, staining, odors, sheen, and/or PID readings and from a deeper interval not exhibiting these physical observations. Soils with discrete intervals of observed tar, staining, sheen, odors, and/or PID detections, soils at the completion depth of selected borings, and soils from the water table interface were also submitted for analysis. Generally, soils were analyzed for VOCs (full scan and BTEX fraction only), SVOCs (full scan and PAH fraction only), RCRA 8 metals, and TCN as specified in the RI Work Plan and addenda. Selected samples were also analyzed for total organic carbon (TOC) and grain size (Table 2-1).

Soils were logged, screened with a PID-OVA, and visual and olfactory observations were noted according to the RI work plan and work plan addenda. At sampling locations that are overlain by pavement, sampling generally began immediately beneath the pavement and the underlying gravel base.

Hollow-stem auger, drive casing, GeoProbe®, and Rotosonic™ drilling methods used were described in the work plan and/or agreed to in the field by GEI representatives and the NYSDEC field representative.

2.2.2.3 Monitoring Well Installation and Well Development

Three monitoring wells (RW-4, RW-7, and RW-14) and 12 piezometers (PZ-2, PZ-3, PZ-4A, PZ-TP-13, and PZ-5 through 12) were completed at OU-1 as part of the RI. Table 2-2 provides a summary of all the OU-1 monitoring wells installed during and prior to the RI, and Appendix B presents the well construction logs. Monitoring wells RW-4 and RW-7 were installed utilizing the hollow-stem auger drilling method while RW-14 was installed utilizing Rotosonic™ drilling methods.

Each well (except RW-14) was completed as a 2-inch ID monitoring well with flush-threaded polyvinyl chloride (PVC) 0.0010-inch slotted screen, solid PVC riser, and a flush-mounted cover. The annular space between the well screen, the borehole wall, and approximately 2 feet above the screen was backfilled with a sand pack. A 1- to 2-foot bentonite clay seal was placed above the sand pack. The thickness of the bentonite seal in some monitoring wells was less than specified in the work plan because of shallow groundwater conditions. The remaining annular space was filled to grade with a cement-bentonite grout. A concrete pad surrounds each flush-mounted well cover. Each well was sealed with an expandable well cap that was secured with a padlock.

Monitoring well RW-14 was installed utilizing the Rotosonic™ drilling method. This well was completed at the top of the saprolite layer (weathered bedrock) to characterize and monitor the deep aquifer water conditions. This well was constructed with 4-inch ID, flush-threaded PVC 0.0010-inch slotted screen, solid PVC riser, and a flush-mounted cover. The annular space between the well screen and the borehole wall was backfilled with a sand pack to approximately 3 feet above the screen. An 11-foot bentonite seal was placed above the sand pack. The remaining annular space was tremie-grouted to grade with a cement-bentonite grout slurry. A concrete pad surrounds the flush-mounted well cover for well RW-14.

Following installation, each monitoring well was developed to remove silt and clays from the well and to stabilize the well filter pack. Development was done in accordance with the RI work plan.

2.2.2.4 Surface-Soil Sampling

Surface-soil sampling was completed at the 40 Willow Avenue parcel, at the adjacent residential parcels on Lynhurst Avenue, and at background locations surrounding OU-1 and OU-2 (Plate 2). Table 2-1 provides a summary of the rationale for surface-soil collection and analysis. The 40 Willow Avenue surface-soil samples (SS-1 through SS-5) were collected from 0 to 6 inches bgs. Residential surface-soil samples SS-6 to SS-11 were from 0 to 6 inches bgs on the residential lots at 63 to 51 Lynhurst Avenue. Residential surface-soil samples (SS-12 to SS-30) were collected from 0 to 2 inches of mineral soil immediately beneath the sod at the residential parcels at 49 to 59 Lynhurst Avenue. Background surface-soil samples (SS-33 to SS-42) were collected from 0 to 2 inches of mineral soil immediately beneath the sod in the vicinity of the 25 and 40 Willow Avenue parcels. Residential surface-soil samples (SSR-40 through SSR-49, SSR-51, SSR-52, SSR-53, SSR-55, SSR-57, SSR-59, SSR-60 through SSR-63) were collected from 0 to 2 inches of mineral soil beneath the sod at the residential parcels located at 51, 63, and 67 Lynhurst Avenue.

Additionally, soil samples from 1-foot, 2-foot, and 3-foot intervals were collected at surface-soil sample locations (SSR-43, SSR-44, SSR-59, SSR-60, SSR-61, SSR-62, and SSR-63) on 51 and 63 Lynhurst Avenue. Soil samples were also collected from 0.5- to 0.75-foot, 1-foot, 2-foot, and/or 3-foot depth intervals at surface-soil sample locations SSR-50, SSR-52, SSR-54, SSR-56, and SSR-58 on 67 Lynhurst Avenue.

Each surface-soil sample was collected using decontaminated, stainless-steel sampling tools. Soils were placed into certified pre-cleaned sampling containers. Surface-soil samples SS-1 to SS-5 were analyzed for SVOCs, RCRA 8 metals, and TCN. Surface soil samples SS-6 through SS-42 were analyzed for VOCs (BTEX), SVOCs, RCRA 8 metals, TCN, and TOC. In addition, surface-soil samples SS-6 to SS-11 and SS-33 to SS-42 were analyzed for grain size distribution. Surface-soils SSR-44 through SSR-63 were analyzed for lead only (Table 2-1).

2.2.3 Groundwater

Groundwater sampling was conducted at OU-1 in April 1999, October 1999, January 2002, and June 2002. Groundwater sampling completed in April and October 1999 (Rounds 1 and 2) at OU-1 included monitoring wells RW-4, RW-7, and RW-14. No groundwater sampling was completed as part of Round 3 of the RI. In January 2002 (Round 4), groundwater sampling included piezometers PZ-TP-13, PZ-4A and PZ-3, and groundwater elevations were collected from PZ-2 and monitoring well FMP-MW-02. Groundwater monitoring sampling in June of 2002 included temporary piezometers (PZ-5 through PZ-12) located on the residential parcels 49 through 67 Lynhurst Avenue. In addition, a round of groundwater elevations was collected from piezometers PZ-2, PZ-3, and PZ-4A on 40 Willow Avenue and PZ-5, PZ-6, PZ-7, PZ-8, PZ-10, and PZ-12 on the Lynhurst Avenue residential parcels. Table 2-2 provides a summary of monitoring well information, including the screened interval and groundwater elevations.

At monitoring wells where groundwater was sampled, groundwater levels were measured prior to sampling, followed by purging and sampling of the monitoring wells. Groundwater depths were measured from the surveyed top of the PVC riser pipe for each well. Following sampling, the groundwater levels were again measured in each monitoring well. Sampling was completed in accordance with the RI work plan and work plan addenda.

2.2.3.1 Purging

Three well volumes were removed from each well prior to sampling to ensure that a representative sample from the aquifer was obtained. Sampling and purging wells in the shallow groundwater aquifer (PZ-3, PZ-4A, PZ-TP-13, and PZ-5 through PZ-12) was performed using low-flow methods employing a peristaltic pump with dedicated down hole tubing for groundwater piezometers. Purging rates varied because of the aquifer conditions; however, pumping rates generally ranged between 50 milliliters (mL) and 100 mL per minute in the shallow groundwater aquifer. Sampling and purging wells in the deep groundwater aquifer (RW-4 and RW-7) was performed using low flow methods employing a peristaltic pump with dedicated tubing. Purge rates varied because of aquifer conditions; however, pumping rates generally ranged between 575 ml to 700 ml. Regardless of the purge rate, draw down of the static water level was minimized as much as possible at all times.

A submersible Grundfos® pump with dedicated tubing was used to purge and sample groundwater in deep monitoring wells RW-4 and RW-14. These wells were screened in the deep groundwater aquifer, which displayed artesian conditions. These monitoring wells were purged at a rate of 0.600 mL per minute to 6 liters per minute. The monitoring wells were able to be pumped at higher rates with minimal draw down of the water column because of higher permeability materials and the flowing artesian conditions.

All wells were monitored for field parameters (temperature, pH, conductivity, dissolved oxygen, and oxygen reduction potential [ORP]) with flow-through cells during purging. In addition to these parameters, purge water from each well was monitored for turbidity in Round 1 and salinity in Round 2, turbidity and salinity in Round 4, and turbidity in Round 5. Measured flow rates and purge volumes were recorded coincidently with field parameter measurements. When at least three well volumes were purged and values of measured field parameters remained within a 10 percent difference over several consecutive readings, the well was sampled.

2.2.3.2 Sampling

After each well was purged, groundwater samples were collected and placed into preserved containers provided by STL. Groundwater samples were analyzed for VOCs, SVOCs, TCN, and RCRA 8 metals for both the Round 1 and Round 2 sampling events. In addition, analyses of polychlorinated biphenyls (PCBs), total dissolved solids, and salinity were completed for groundwater samples obtained from wells RW-4 and RW-7 during Round 1. Groundwater samples from piezometers PZ-3, PZ-4A, and PZ-TP-13 were analyzed for VOCs, SVOCs, pH, RCRA 8 metals, copper, nickel, zinc, hexavalent chromium, flashpoint, total dissolved solids, total suspended solids, total PCBs, total petroleum hydrocarbons (TPH), total cyanide, and amenable cyanide during the Round 4 sampling event. The only exception to this sampling schedule was that PZ-4A was unable to be sampled for TPH because of an extremely low recharge rate for the piezometer and short laboratory hold times for other analyses. VOCs were collected using a dedicated single check-ball bailer for the shallow aquifer groundwater samples and double check-ball bailers were used for the deep aquifer samples. The double check-ball bailers minimized the potential for mixing of the sample with water in the water column as the bailer was retrieved from the well screen interval. Sample aliquots for analysis of SVOCs, RCRA 8 metals, TCN, total dissolved solids (EPA Method 160.1), total suspended solids (EPA Method 160.2), pH (EPA Method 9040B), flashpoint (EPA Method 1010), amenable cyanide (EPA Method 335.1), hardness (EPA Method A2340B), TPH (EPA Method 418.1), PCBs (EPA Methods 8081 and 8082), and salinity (EPA Method 2520B) were collected through dedicated tubing utilizing a peristaltic pump or a Grundfos® pump. A peristaltic pump was used for sampling shallow monitoring wells and groundwater was sampled at approximately 50-80 mL/minute. A Grundfos® and a peristaltic pump were used for groundwater sample collection from deep wells RW-14 and RW-4. The pump rate for the Grundfos® pump was approximately 1,000 mL/minute while sampling because this was the lowest flow rate the Grundfos® pump could attain before it disengaged. Following collection, groundwater samples were placed into an ice-filled cooler and shipped under chain of custody to STL Laboratories in Shelton, Connecticut for analysis.

Additionally, a sample of tar product was obtained from the bottom of RW-7 during the Round 1 groundwater sampling event. This sample was analyzed for VOCs, SVOCs, RCRA 8 metals, and TCN.

2.2.4 Survey

At the conclusion of the RI field activities, each boring and well location was surveyed by a GEI-employed New York State licensed surveyor (New York License No. 050156) with reference to the state coordinate grid system. The lateral accuracy of the survey was 0.1 foot and the vertical accuracy was 0.01 foot. The data were tied into a United States Geological Survey (USGS) benchmark to ensure that all groundwater elevations are referenced to the National Geodetic Vertical Datum (NGVD) and the National Astronomic Vertical Datum (NAVD). A reference point on the bulkhead at the harbor was surveyed to facilitate monitoring of tidal fluctuations during Round 1 and Round 2. Surface-soil and test pit sampling locations were either surveyed or field measured relative to known features.

2.3 Air Monitoring Findings

2.3.1 Meteorological Observations

Throughout the test pit excavation program of Round 1, wind blew out of the north at speeds ranging from 1 to 20 miles per hour (mph), with an overall average of 8 mph. Wind gusts ranged from 3 to 29 mph and averaged 13 mph. The outside temperature ranged from 20°F to 47°F, with an average of 35°F. Wind chill ranged from -3.9°F to 46°F, with an overall average of 27°F.

During the Round 4 of the RI, meteorological observations were collected during the test pit excavations and are summarized as follows: wind blew from the east to northeast from 2 to 8 mph, with an overall average of approximately 5 mph. The outside temperature ranged from 47°F to 49°F, with an average of 48°F. The wind chill was approximately 45°F.

2.3.2 Perimeter Air Monitoring Findings

Air monitoring at the perimeter of the 40 Willow Avenue parcel was conducted in accordance with Section 5 of the Health and Safety Plan (HASP). At no time did total organic vapor levels exceed 5 parts per million (ppm) above background at the perimeter of the 40 Willow Avenue parcel during the excavation of test pits (TP-10, TP-10A, TP-12, TP-13, and TP-14) (RI Rounds 1 and 4).

During Round 1 of the RI, there were five occurrences where the upwind perimeter particulate levels exceeded the downwind particulate levels by at least 150 $\mu g/m^3$ (two-minute maximum readings). The upwind exceedances occurred at stations along Bay Street and automobile and truck traffic likely resulted in high upwind (background) dust levels. There were 11 occurrences where the downwind perimeter particulate levels exceeded the upwind particulate levels by at least 150 $\mu g/m^3$ (two-minute maximum readings). Only three of these 11 occurrences had downwind two-minute time-weighted averages greater than at least 150 $\mu g/m^3$ greater than the upwind particulate levels, indicating that 8 of the 11 occurrences were very brief. For the three occurrences where the downwind time-weighted averages exceeded the upwind time-weighted averages, it was noted that dust-generating activities other than excavation were occurring nearby and likely accounted for the occurrences.

During Round 4 of the RI, there were no occurrences at the upwind perimeter or the downwind perimeter where the particulate level exceeded the 150 $\mu g/m^3$ two-minute maximum or average.

2.3.3 Worker Health and Safety Air Monitoring Results

Approximately 500 PID-OVA data points were recorded during excavation and backfilling at test pits on the 25 and 40 Willow Avenue parcels during Round 1 of the RI. No PID readings displayed detections greater than 0.0 ppm. During Round 4 of the RI, monitoring during the excavation of test pits TP-12 and 13 revealed detections ranging from 0.0 to a maximum of 1.0 ppm, which coincided with the excavation of soils within TP-12 on the western portion of the 40 Willow Avenue parcel. At no time did the PID readings exceed 5.0 ppm.

There were no instances where the average downwind particulate levels exceeded 150 $\mu g/m^3$ during the test pit monitoring on the 40 Willow Avenue parcel during Round 1 or Round 4 test pit excavation.

3. Site Geology and Hydrogeology

This section documents the geology and hydrogeology beneath the 25 and 40 Willow Avenue parcels and the surrounding vicinity.

3.1 Geology

Four major stratigraphic units were identified during the RI drilling program: (1) fill, (2) alluvial/marsh deposits, (3) glacial deposits, and (4) weathered bedrock (saprolite). The general stratigraphy beneath OU-1 consists of the saprolite overlain by the glacial deposits, alluvial deposits, and fill in order of decreasing depth. Cross-sections A-A' through C-C′ (Plate 2) and cross-sections D-D′ through F-F′ were developed to illustrate the geology underlying OU-1 (Plate 3). Cross-sections G-G′, H-H′, I-I′, and J-J′ depict the geology outside former Relief Holder No. 2 and cross-sections K-K′ and L-L′ depict the nature of materials within former Relief Holder No. 2 (Plate 4). Figure 2-1 indicates the location of each cross section. These cross sections also depict the physical observations of tar, tar blebs, staining, sheen, and odors. Table 3-1 summarizes the geologic units encountered during the RI. The distribution of chemicals and environmental observations is described in Section 4. Detailed geologic descriptions and well construction details are provided in Appendices B and C.

A general description of the four stratigraphic units is provided below.

3.1.1 Fill

Fill is present at the ground surface or immediately beneath a thin layer of topsoil or asphalt (Plates 2, 3 and 4). Fill consists of silt, sand, and gravel mixed with slag, coal fragments, brick, concrete, wood, metal, and porcelain fragments, transite, ash and clinkers. Typically, the fill is loose and non-cohesive. Fill was encountered in each of the test pits, soil borings, and monitoring well locations completed at OU-1, with the exception of soil borings SB-65 and SB-66 (Plate 3). The fill unit on the 40 Willow Avenue parcel ranged from a few inches in the vicinity of monitoring well RW-7 to a maximum of 16 feet in boring GP-11. Fill was also present from the ground surface to the bottom of the following subsurface structures of the former Relief Holder No. 2 and former rectangular foundation (likely the former cooling tower) located adjacent to the former relief holder. Borings SB-21, SB-40, GP-04, GP-09, and GP-13 through GP-18 were completed within Relief Holder No. 2 (Plate 4). The floor of the relief holder was encountered at depths ranging from approximately 15 feet bgs to 20 feet bgs. GP-08 was completed just outside the former Relief Holder and confirmed that fill material extended to 23 feet bgs. Boring SB-22 was completed through the floor of the former rectangular foundation that was located at approximately 6 feet bgs. Fill was also present at parcels adjacent to the 40 Willow Avenue parcels as observed in borings SB-58 to SB-62, SB-79, SB-80, and SB-87 on the Lynhurst Avenue residential parcels (Cross-section B-B′, Plate 3), SB-84 through SB-86 along Lynhurst Avenue (Cross-section C-C′, Plate 3), and SB-67 on 66 Willow Avenue.

3.1.2 Alluvial Deposits

A mix of alluvial/marsh deposits was encountered, generally beneath a layer of fill, at the 40 Willow Avenue parcels and at the boring locations located on the Lynhurst Avenue residential parcels and at the 66 Willow Avenue parcel. The alluvial/marsh deposits consist of sub-units of sand, gravelly-sand, gravelly-silt, silt, silt-clay, and peat, and are present throughout the majority of the OU-1 parcels. Historical maps of the area indicate that an unnamed stream had previously flowed along the north-central portion of the adjacent 25 Willow Avenue parcel and into New York Harbor. The former stream and its tributaries likely deposited these alluvial/marsh deposits.

Deposits encountered during the RI drilling are consistent with a former active stream depositional environment and an associated lower energy (marsh) environment. For this discussion, the deposits are broken down into the alluvial deposits (sorted sands and gravelly-sands) associated with the former active stream environment, and marsh deposits (silts, silt-clay, and peat deposits) associated with a lower energy depositional environment. The sand and gravelly sand units are typically gray, brown, red-brown fine to coarse sand and gravelly-sand with trace silt, and were generally loose and non-cohesive. The alluvial deposits are illustrated in cross-sections E-E′ and F-F′ (Plate 3). As shown on these cross-sections, these alluvial deposits extend to approximately 21 feet bgs at borings SB-22, GP-06, and GP-07.

An inferred scour into the underlying glacial deposits extends from the north of GP-07 to the south of GP-06, as depicted in cross-sections E-E′ and F-F′ on Plate 3. This scour is interpreted as a former stream channel/inter-tidal marsh that was related to the former stream that crossed the adjacent 25 Willow Avenue parcel to the northwest of OU-1. Historical maps of the area discussed in subsection 1.2.2 show an unnamed historic stream flowing through the northern portion of the 25 Willow Avenue parcel. The stratified sand units encountered in borings in the northern portion of OU-1 are consistent with former alluvial deposits and are interpreted as related to the former stream. These deposits ranged between 13 and 21 feet bgs in borings GP-06, GP-07, GP-10, GP-11, SB-22, and SB-61 (Cross-sections E-E′ and F-F′ on Plate 3).

The sand units associated with alluvial deposits were encountered at the residential parcels on Lynhurst Avenue, on the Lynhurst Avenue ROW and on the commercial parcel at 66 Willow Avenue.

Silt, gravelly-silt and silt-clay were encountered on the northern, eastern and central portions of the 40 Willow Avenue parcel. These deposits are believed to be associated with a former marsh (possibly intertidal) that was located adjacent to the former inferred stream and its tributaries and New York Harbor. These units are described as black, olive, gray to brown, soft, and slightly cohesive to cohesive. The northern/central portion of the 40 Willow Avenue parcel was characterized by thicker silt and silt-clay units than in the remainder of the 40 Willow Avenue parcel, 66 Willow Avenue parcel, the adjacent Lynhurst Avenue residential parcel, and beneath Lynhurst Avenue. The thickness of these units ranged from 2 feet in SB-22 to approximately 10 feet in GP-07 and GP-08 on the north/central portion of the 40 Willow Avenue parcel. These units were encountered approximately 8 to 16 feet bgs. Silt and silt-clay units were also present on the Lynhurst Avenue residential parcels.

3.1.3 Glacial Deposits

Glacial deposits were encountered beneath the alluvial/marsh deposits and above the saprolite layer at 40 Willow Avenue, the Lynhurst Avenue residential parcels, and beneath Lynhurst Avenue. The glacial deposits can be classified into two sub-units based upon previous geologic investigations by Soren, 1988: the Harbor Hill Terminal Moraine and the Ground Moraine. According to Soren, 1988, a geologic contact between the Harbor Hill Terminal Moraine and the Ground Moraine is located within the vicinity of the 25 and 40 Willow Avenue parcels.

The Harbor Hill Terminal Moraine and the Ground Moraine underlie the alluvial deposits at OU-1. The Ground Moraine was encountered in a number of borings during the RI (Plates 2 and 3). The Ground Moraine, as observed during the RI, consists of a silt to silt-sand mixture, with little to some cobbles and gravels, is dense to very dense and is slightly moist; this is consistent with the descriptions by Soren (1988). The top of the Ground Moraine varies from just below the ground surface in GP-01 to approximately 23 feet bgs in GP-08 (Cross-section E-E′ Plate 3). The unit extends to the top of the weathered bedrock with stratified graded sand layers likely of glacial fluvial origin noted within the lower portions of this unit at RW-7, RW-14, RW-4 and SB-78 (Cross-sections A-A′, E-E′ and F-F′, Plates 2 and 3). The Ground Moraine is believed to act as a leaky confining unit between the water table aquifer and the deeper confined unit (see subsection 3.2).

The 40 Willow Avenue parcel is believed to be partially underlain by the Harbor Hill Terminal Moraine, which consists of a clayey-silt with varying amounts of gravel as observed in borings SB-23, SB-18, and SB-36. This unit is similar to a description provided by Soren, 1988. A red-brown sand-silt-clay unit that ranged from loose to dense was encountered in borings on the 40 Willow Avenue parcel. The unit was encountered at approximately 7 feet bgs in RW-4/SB-36 to a maximum depth of around 45 feet bgs in boring SB-18 (Cross-section A-A′, Plate 2). Borings SB-22, RW-7, and RW-14 contained stratified sand and gravel layers within the glacial deposits that were encountered from about 50 feet bgs to the top of the saprolite layer.

A cobble zone was encountered during drilling in borings SB-18, SB-22, and SB-23 (Plates 2 and 3). This zone is characterized by minimal recovery and difficult drilling conditions. A large block of displaced saprolite (weathered bedrock) was encountered during the drilling of RW-4. This block is believed to have been scoured from the bedrock surface by glacial action, was incorporated into the Ground Moraine material and was stranded at a higher elevation (-50.85' NGVD or 61 feet bgs) than the in-situ saprolite.

3.1.4 Saprolite

Saprolite, or weathered bedrock, was encountered beneath the glacial deposits (sand layers) at the 40 Willow Avenue parcel in boring RW-14/SB-42 and within Lynhurst Avenue in boring SB-78 (Cross-section E-E′, Plate 3). The top of the saprolite unit elevation ranged between -108.76’ NAVD within SB-78 to -116.00’ NAVD within RW-14/SB-42. Based on these data points and additional points at OU-2 where the saprolite was encountered (Boring RW-15/SB-55A, -105.05’ NAVD and within Boring RW-16/SB-56, -116.18’ NAVD), the saprolite unit appears to dip to the north. The saprolite was formed by in-place weathering of bedrock; likely the Manhattan Schist based on descriptions of the bedrock by Soren, 1988.

The encountered saprolite was a red to red-brown, gray to green-gray clay with some silts and relict schist-like rock layering present, included muscovite and biotite mica mineral layers, and was very dense and dry. At the RW-14 location, a dense, micaceous silt and micaceous sand were encountered on the surface of the saprolite (Cross-section E-E′, Plate 3). The saprolite is believed to be the lower confining layer of the deep aquifer beneath OU-1.

3.2 Hydrogeology

No surface water bodies are located at or immediately adjacent to the OU-1 parcels. However, a stream formerly traversed the 25 Willow Avenue parcel (Figures 1-3 and 1-4). A stormwater drain follows the approximate trace of the historic stream and extends along the northwestern border of the adjacent 25 Willow Avenue parcel within OU-2. The storm drain empties into New York Harbor approximately 500 to 600 feet to the northeast.

Two aquifers are present beneath OU-1: a shallow, unconfined (water table) aquifer and a deep confined aquifer. The shallow groundwater aquifer is located in fill, alluvium/marsh, and shallow glacial deposits. The water table elevations (shallow aquifer) ranged from 7.78 feet NAVD in PZ-4A to 11.18 feet in PZ-3 (Table 2-2). The deep aquifer is under confining pressure and the wells tapping it exhibited flowing artesian conditions (RW-4, RW-7, and RW-14). These wells are screened in stratified silty-sand and gravelly sand layers within the glacial deposits located above bedrock. Static head elevations in the deep aquifer ranged between 12.44 feet (NGVD) in RW-4 and 13.62 feet (NGVD) in RW-7 (Table 2-2). The dense silt ground moraine and Harbor Hill Terminal moraine form a confining to semi-confining layer separating the water table aquifer from the deep aquifer, also resulting in confining pressure within the deep aquifer.

Groundwater table elevations were measured in Round 1 (April 1999), Round 2 (October 1999), Round 4 (January 2002) and Round 5 (June 2002) (Table 2-2). A slight seasonal variation in the water table elevation was observed between Round 2 and Round 4 with the Round 4 elevations being generally lower than elevations measured in October between 0.18 and 0.35 foot. However, no change in the groundwater flow pattern was observed between these two events. This decrease in groundwater elevation is likely attributable to the severe drought experienced by the Northeast during 2002.

Groundwater elevations were measured in monitoring wells during Round 2, both at high tide and low tide, to evaluate possible tidal influences on the groundwater flow pattern. Tidal influence on the shallow groundwater aquifer is apparently minimal based upon groundwater elevations gathered from Round 2 of the RI. In the deep groundwater aquifer, a decrease in groundwater elevations (-0.1' to -0.59') was observed between high tide and subsequent low tide groundwater measurements (Table 2-2).

Groundwater contour maps were created for the shallow and deep aquifers using the measurements collected at high tide on October 13, 1999 (Plate 5 and Plate 6) during Round 2 and for the shallow groundwater aquifer for Round 4 and Round 5 (Plate 7 and Plate 3-1). Groundwater contour patterns were evaluated for both high tide and low tide during the Round 2 monitoring event.

3.2.1 Water Table Aquifer

Groundwater flow within the water table aquifer appears to be dominated by two features: groundwater moving toward the former stream trace in the northern portion on the 25 Willow Avenue parcel, and groundwater flowing directly toward New York Harbor near the eastern portion of the 40 Willow Avenue parcel. As shown by Plate 5, Plate 6 and Plate 7, groundwater flows toward the former stream trace (current stormwater sewer) from west of the 25 Willow Avenue parcel and from the majority of the 25 Willow Avenue parcel.

Groundwater moving along the actual trace of the former stream is expected to discharge to New York Harbor.

An apparent divide between the influence of the local former stream trace and the more regional influence of New York Harbor exists on the 40 Willow Avenue parcel. Groundwater on the western side of this divide is flowing toward the former stream trace, while groundwater on the eastern side of the divide is flowing directly toward New York Harbor.

The average horizontal hydraulic gradients of the shallow groundwater aquifer ranges from 0.015 to 0.026 ft/ft. The steepest hydraulic gradients occurred on the northwestern portion of the 40 Willow Avenue parcel near piezometer PZ-4A. Lower hydraulic gradients are evident in the southwestern portion of the parcel nearer to New York Harbor.

No hydraulic conductivity tests were performed on the shallow groundwater table wells at OU-1. The shallow groundwater aquifer at OU-1 consists of low permeability glacial deposits similar to those encountered at OU-2. Hydraulic conductivities were calculated for water table wells using data generated from single well permeability tests (slug tests) conducted on wells RW-3, RW-6, and RW-12 at OU-2. A summary of the hydraulic conductivities is presented in Table 3-2. Appendix D includes the slug test data files and the hydraulic conductivity calculations.

Based upon slug tests completed within OU-2, the hydraulic conductivities (K) ranged from 3.2×10^{-4} centimeters/second (cm/sec) [0.9 feet/day] at RW-12 to 5.0×10^{-4} (cm/sec) [1.4 feet/day] at RW-3. These values are consistent with those expected for the silty-sand (Freeze and Cherry, 1979).

Average linear flow velocities for the water table aquifer were calculated based on the measured hydraulic conductivities and the horizontal hydraulic gradients using the following equation:

$$V = ki/n$$

where:

k = hydraulic conductivity of the formation
i = hydraulic gradient
n = effective porosity of the formation

Assuming an effective porosity of 30%, hydraulic gradients between 0.015 foot/foot along the southeastern portion of the property near FPM-MW-1 and 0.026 foot/foot in the vicinity of PZ-4A (western portion of the 40 Willow Avenue parcel), and the calculated hydraulic conductivity from RW-3 (1.4 ft/day), the average linear flow velocity of the water table aquifer ranges from 27 feet/year on the eastern to southeastern portion of the 40 Willow Avenue parcel to 44 feet/year on the northeastern portion of the 40 Willow Avenue parcel.

3.2.2 Deep Aquifer

The groundwater contour pattern for the deep aquifer is depicted in Plate 6. An apparent groundwater divide is oriented roughly north-south through the middle of the 40 Willow Avenue parcel. Groundwater on the western side of the divide appears to be flowing westerly and groundwater on the eastern side of the divide appears to be flowing easterly. It is unclear whether this divide actually exists or if it is an artifact of tidal influence. This apparent groundwater flow pattern may be the result of tidal lag influences. In other words, one or more of the deep aquifer monitoring wells may be "feeling" the effects of a tidal cycle, while other well(s) may not have been influenced by the tidal effect at the time these measurements were collected.

In the deep aquifer, the average horizontal hydraulic gradient was determined to be 0.00294 foot/foot in the vicinity of RW-4 on the 40 Willow Avenue parcel.

The hydraulic conductivity was calculated for the deep aquifer wells using data generated from a single-well pump test completed in well RW-4. This monitoring well was screened in relatively low permeability silt to silty fine-to-coarse sands related to the glacial deposits. Table 3-2 presents a summary of the hydraulic conductivity values, and Appendix D presents the pump test data and hydraulic conductivity calculations. The hydraulic conductivity (K) for RW-4 was 8.7×10^{-4} (cm/sec) [2.4 feet/day] at RW-4.

A similar calculation of the average linear flow velocity for the deep groundwater aquifer was performed. The average linear flow velocity of the groundwater was calculated to be 8.58 feet/year near RW-4.

Vertical hydraulic head potentials between the shallow aquifer and the deep aquifer were calculated for the following well clusters or nearby shallow and deep aquifer pairs: RW-4/PZ-2, PZ-3/RW-7, PZ-3/RW-14. The upward vertical head potentials for these well pairs ranged between 0.022 and 0.079 foot/foot. Vertical head potentials were greater between well pairs PZ-2/RW-4 on the northeastern portion of the 40 Willow Avenue parcel, than between the well pairs PZ-3/RW-7 and PZ-3/RW-14 on the southeastern portions of the two parcels. The three-well cluster of RW-7, RW-14 and PZ-3 confirmed that once below the semi-confining layer, the deep groundwater aquifer on the 40 Willow Avenue parcel behaves as one hydrologic unit. There was virtually no vertical head potential between RW-7 and RW-14, while a vertical gradient existed between these wells and the water table piezometer PZ-3.

4. Nature and Extent

This section summarizes the physical observations made during the RI, presents the analytical findings of the investigation, and discusses the degree and extent of observed tar, staining, sheen, odors, and chemical constituents detected during the RI. The sample locations are shown on Plate 1 and Figure 2-1.

The following terminology and descriptions were used to describe the visual and olfactory observations made during the field investigation. These terms are also used in this report section to describe the nature of the observed materials.

- **Saturated:** the entirety of the pore space of the soil matrix for a given soil sample was filled with a NAPL. The characteristics of the observed NAPL were used in the description (i.e., tar-saturated or petroleum-saturated).
- **Blebs:** observed discrete sphericals or pockets of NAPL within a soil sample. The majority of the soil matrix did not exhibit the presence of NAPL beyond these discrete blebs. The characteristics of the observed NAPL were used in the description (i.e., tar blebs or petroleum blebs).
- **Stained:** the soil sample exhibited a discoloration not associated with natural processes. The color of the observed stain was used and if the characteristics of the staining material were discernible, they were also noted (i.e., tar-stained or petroleum-stained).
- **Sheen:** iridescence was observed within a soil sample. Sheens were typically noted in moist to wet soils.
- **Odor:** if an odor was observed, it was described based on its relative intensity and characteristics. Modifier terms such as strong, moderate, and faint were used to describe relative odor intensity. Descriptive terms such as tar-like or petroleum-like odors were also used.

Subsection 4.1 discusses the soil findings and is subdivided by parcel. The soil findings for each parcel are further divided into surface-soil and subsurface-soil sections.
Subsection 4.2 discusses groundwater conditions for the entire OU-1 study area of the RI.

The nature and extent of the chemical constituents is determined by the geologic conditions, groundwater flow patterns, and historic parcel use, processes and structures located at the site. During the drilling of soil borings and the excavation of test pits, tar-saturated soil, staining from tar, and odors characteristic of tar were observed. These physical observations were recorded on the boring and test pit logs (Appendices B and C) and were summarized on the geologic cross sections A-A′ through L-L′ on Plates 2, 3, and 4.

In addition to the physical observations, this section also discusses the analytical results of the surface-soil, subsurface-soil, and groundwater samples collected during the RI and previous sampling programs. Tables 4-1 and 4-2 present the detected laboratory analytical results for surface-soil and subsurface-soil samples, respectively. Table 4-3 presents a statistical summary of the surface-soil results. Table 4-4 presents the detected laboratory analytical results for groundwater samples. Appendices E and F present the validated laboratory Form I reports and chain-of-custody forms.

BTEX compounds were the principal VOCs detected and are the common VOCs associated with tar. SVOCs were also detected at the site with PAHs being the common subset of SVOCs in tar. For purposes of this report, PAHs include the compounds listed below.

2-Methylnaphthalene
Benzo(b)fluoranthene
Fluorene
Acenaphthene
Benzo(g,h,i)perylene
Indeno(1,2,3-cd)pyrene
Acenaphthylene
Benzo(k)fluoranthene
Naphthalene
Anthracene
Chrysene
Phenanthrene
Benz(a)anthracene
Dibenz(a,h)anthracene
Pyrene
Benzo(a)pyrene
Fluoranthene

Of these PAHs, the following constituents are considered carcinogenic PAHs by EPA.

Benz(a)anthracene
Benzo(a)pyrene
Chrysene
Indeno(1,2,3-cd)pyrene
Benzo(k)fluoranthene
Benzo(b)fluoranthene
Dibenz(a,h)anthracene

The analytical results of the RI and previous investigations are discussed relative to the total BTEX, total PAHs (TPAH), and total carcinogenic PAHs (CPAH).

Tables 4-1 and 4-2 include the sum of PAHs, the sum of carcinogenic PAHs, sum of the non-carcinogenic PAHs, and the sum of BTEX constituents for surface soil and subsurface soil, along with the analytical results for individual analytes. For non-detect results ("U" qualified), the value used in these sums was 0.00. For estimated values ("J" qualified), the value used in the sums was the numerical result for each analyte.

At the request of the NYSDEC, a comparison of detected analytes to the New York State Recommended Soil Cleanup Objectives (RSCOs) was also completed. The exceedances were highlighted and bolded on the tables. The frequency of the exceedances by analyte are also presented on Tables 4-1 and 4-2. Table 4-4 includes the sum of PAHs, carcinogenic PAHs, non-carcinogenic PAHs and BTEX for groundwater, along with the analytical results for individual analytes. At the request of the NYSDEC, a comparison of detected analytes to the New York State Ambient Groundwater Standards and guidance values for a GA area for all groundwater samples collected was completed. Exceedances have been highlighted and bolded in the table. The frequency of exceedance for each analyte is also presented in Table 4-4.

4.1 Soil

Surface Soils

Surface-soil samples were collected from the 40 Willow Avenue parcel, the Lynhurst Avenue residential parcels (49 through 67 Lynhurst Avenue), and at background locations in the vicinity of the 25 and 40 Willow Avenue parcels. Table 4-1 summarizes the detected analytes for all surface-soil samples. Appendix E includes the validated laboratory Form I reports and chain-of-custody forms for the RI samples. Plate 1 and Figure 2-1 depict the surface-soil sample locations.

Subsurface Soils

Subsurface-soil samples were collected from the 40 Willow Avenue parcels, from a commercial parking lot located at the 66 Willow Avenue parcel, from residential parcels located at 49, 51, 53, 55, 59 and 63 Lynhurst Avenue, and from the Lynhurst Avenue ROW. Table 4-2 is organized by parcel and summarizes the detected analytes for all subsurface-soil samples collected during the RI and during previous investigations. Appendix E includes the validated laboratory Form I reports and chain-of-custody forms for the RI samples. Plate 1 and Figure 2-1 depict the subsurface-soil sample locations (soil borings, test pits, monitoring wells).

The overall extent of tar, staining, sheen, odors, and chemical constituents detected in soils was located primarily adjacent to the former Relief Holder No. 2 on the 40 Willow Avenue parcel. However, discrete intervals of tar-related materials were noted at depth beneath the Lynhurst Avenue residential parcels and beneath Lynhurst Avenue. As shown by cross-sections B-B′, C-C′, and E-E′ (Plates 2 and 3), no visible evidence of tar, staining or sheen, odors, or positive PID detections were observed in borings completed beneath the Lynhurst Avenue parcels or within the Lynhurst Avenue ROW at depths above 24 feet bgs. In general, the lateral extent of physically observed tar, staining, sheen, and odors within OU-1 was primarily limited to former Relief Holder No. 2 and within soils immediately surrounding this structure. Minor layers of sands with tar, staining, sheen, and odors were noted beneath the Lynhurst residential parcels and Lynhurst Avenue ROW.

In general, elevated levels of TPAH, CPAH, and BTEX correlated with the occurrence of observable tar, odors and/or sheen. Where physical evidence of tar was not encountered, analyses indicated generally low to trace levels of these chemical constituents. As with the observed extent of tar, staining, odors, etc., the overall extent of chemical constituents was generally limited to the 40 Willow Avenue parcel, and to a discrete interval beneath the Lynhurst Avenue residential parcels and Lynhurst Avenue.

In addition to these analytes, RCRA 8 metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver), total cyanide, and TOC were analyzed for in certain soil samples. Total cyanide was only detected in eight subsurface-soil samples, all except one detection being significantly below 10 ppm. Total cyanide in subsurface soils does not appear to be of concern.

Total cyanide was only detected in 12 surface-soil samples analyzed. Surface-soil sample CFSS-1 on the 40 Willow Avenue parcel had the highest concentration at 33.6 ppm. From the parcels adjoining the 40 Willow Avenue parcel, the maximum total cyanide concentration detected was 1.94 ppm in sample SS-9 from the 55 Lynhurst Avenue parcel. Elevated lead concentrations were noted within surface soils. Lead was detected in all but one surface-soil sample. Lead concentrations ranged from non-detected within SSR-46 (3’) and a maximum of 2,810 ppm within surface-soil sample SSR-58.

4.1.1 40 Willow Avenue

Surface Soil

Surface-soil samples SS-1 through SS-5 were collected from 0- to 0.5-foot on the 40 Willow Avenue parcel.

TPAHs ranged from 22.4 ppm in sample SS-1 to 84.7 ppm in sample SS-4. CPAH ranged from 10.66 ppm in SS-1 to 45.8 ppm in SS-4. BTEX constituents were not analyzed for these surface-soil samples. Total cyanide was not detected in sample SS-3, and otherwise ranged from 4.86 ppm in duplicate of SS-4 to 33.6 ppm in SS-1. The only metal detected that appeared elevated in these surface-soil samples was lead, with values ranging from 98.6 ppm in SS-3 to 383 ppm in SS-5.

Subsurface Soil

At the 40 Willow Avenue parcel, the lateral extent of tar, staining, sheens, odors and chemical constituents is generally limited to the vicinity of Relief Holder No. 2. As shown by cross sections A-A′, E-E′, K-K′, and L-L′ (Plates 2, 3 and 4), tar-saturated soils were encountered at various depths within the holder (soil borings SB-40, GP-04, GP-09, GP-13, and GP-18) beginning as shallow as 4 feet bgs and extending to the bottom of the holder at 20 feet bgs. However, tar-saturated soils were not encountered in test pits TP-10 or TP-10A or within borings GP-13, GP-14, GP-15, GP-16, and GP-17 within the center of former Relief Holder No. 2. Based upon these borings, it was determined that the bottom of former Relief Holder No. 2 had a domed shape with the depth to the bottom at the center of the holder at 14 feet bgs (-1.33 NAVD) and the depth to the bottom at the outside edge at approximately 20 feet bgs (-8.14’ NAVD).

Test pits TP-12, TP-13, and TP-14 confirmed the edge of former Relief Holder No. 2 to be larger than depicted in the historic Sanborn maps. The holder was determined to be a brick and mortar constructed holder with a concrete coating.

Tar-saturated soils are present outside the holder at soil borings SB-17/RW-7, SB-22, SB-41, SB-42/RW-14, SB-43, GP-06, GP-07 and GP-08. Tar within these borings was generally contained within sand and gravelly-sand layers.

Rotosonic™ soil boring RW-14/SB-42 was completed to characterize deep soils at the 40 Willow Avenue parcel. Soil boring SB-42 was placed adjacent to Relief Holder No. 2, which represented a location where downward migration of tar was possible.

As discussed in subsection 3.1, the ground moraine located on the northwestern portion of the 40 Willow Avenue parcel consists of a dense silt unit and silt-sand unit with stratified sand and gravelly sand layers. This transitions into the Harbor Hill terminal moraine in the northeastern portion of the parcel (Plates 2 and 3). These units appear to be behaving as a hydrogeologic confining layer between the upper (water table) aquifer and the lower confined aquifer. However, these units have not acted as a confining unit to the downward mobility of tar. Tar-saturated soils in boring RW-14/SB-42 extend down to about 79 feet bgs, with discrete tar blebs being observed to 100 feet bgs, and tar-like odors extending to the bottom of the confined aquifer (top of saprolite) at 124 feet bgs.

Soil boring SB-18 (near the former 8-inch steel well, depicted on Figure 2-1 and Plates 2 and 3) encountered tar-like odors from 65 feet to 84 feet bgs and a sheen from 71 feet to 82 feet bgs. Soil boring SB-23 encountered tar-like odors and a sheen from 70 to 93 feet bgs, and slight tar-like odors from 93 to 111 feet bgs where the boring was terminated.

Subsurface-soil analytical data for the 40 Willow Avenue parcel are discussed relative to former Relief Holder No. 2, the former 8-inch steel well and former excavation area, and data collected adjacent to Bay Street.

Within the former holder, laboratory analytical data were obtained from test pits TP-10 and TP-10A and from borings SB-21, SB-40, GP-04, and GP-09. Subsurface-soil data from within the holder indicated BTEX ranging from non-detect in sample TP-10 (3') to 10,670 ppm in sample SB-40 (18'-20') atop the holder floor [Note: sample ID was 18 to 20 feet, but the holder floor was encountered at 18 feet]. TPAH ranged from 3.4 ppm in TP-10A (3') to 85,170 ppm in GP-09 (4'-8'). CPAH ranged from 2.2 ppm in TP-10A (3') to 9,070 ppm in GP-09 (4'-8'). The BTEX and PAH detections in samples from boring SB-40, GP-04, and GP-09 corresponded to the observation of tar at the sample intervals.

Outside the former holder, laboratory analytical data were obtained from borings SB-22, SB-41, RW-14/SB-42, RW-7/SB-17, SB-43, SB-44, GP-01 through GP-03, GP-05 though GP-08, and GP-10 though GP-12. BTEX results from these borings ranged from non-detect in samples RW-14 (126'-128') and SB-41 (10'-12') to 3,580 ppm in sample GP-06 (28′-32′). TPAH ranged from non-detect in sample SB-44 (29'-31') to 19,050 ppm in sample GP-06 (28'-32'). CPAH ranged from non-detect in samples GP-10 (40-45′), GP-11 (40′-45′), GP-12 (20′-24′), and SB-44 (29'-31') to 870 ppm in sample GP-06 (32'-32').

Outside the former holder, tar, staining, sheen, and odors were observed and detected levels of BTEX and PAHs generally correlated with these observations. In shallow soils, the sample SB-22 (2 to 3 feet) exhibited the highest BTEX (334.6 ppm) levels; TPAHs and CPAHs were not measured for this sample. At the elevation of the bottom of the holder (15 to 20 feet bgs), soils exhibited the highest concentrations of BTEX (2,260 ppm), TPAH (16,350 ppm), and CPAH (850 ppm) at boring GP-08 within tar-saturated soils. Below the elevation of the holder floor, the 28- to 30-foot sample from boring GP-06 exhibited 19,050 ppm TPAH; 870 ppm CPAH; and 3,580 ppm BTEX. The 76- to 78-foot sample from RW-7 exhibited over 8,000 ppm TPAH, which coincided with a layer of tar-saturated soil.

In the vicinity of the former 8-inch steel well, soil analytical data are available from previous investigation wells (FPM-MW1, FPM-MW2, and FPM-MW3), excavation sidewall samples (FPM-SS1, FPM-SS2, and FPM-SS3), excavation bottom sample (FPM-BS-01), and from RI borings (SB-18 and SB-23). Soil data from the previous investigation monitoring well installations did not indicate the presence of BTEX or PAHs at the locations of FPM-MW1 and FPM-MW2. However, soil samples from well FPM-MW3 contained PAHs and BTEX.

Soils in this vicinity were removed during an excavation summarized in subsection 1.4. Excavation sidewall samples collected at the time indicated TPAHs at concentrations ranging between 20.5 ppm and 25.1 ppm; CPAHs ranging in concentration between 8.1 and 13.6 ppm; and BTEX ranging in concentrations between 0.01 and 0.03 ppm in samples FPM-SS1 through FPM-SS3. At the bottom of the former excavation in sample FPM-BS-01, BTEX and CPAHs were not detected; however, 5 ppm TPAHs were detected in this sample.

RI soil borings SB-18 and SB-23 were completed in the vicinity of the former 8-inch steel well and confirmed the relative low-level PAH concentrations in shallow subsurface soils. Sample SB-18 (4 to 7.5 feet) contained 17.5 ppm TPAHs, 9.6 ppm CPAH, and only 0.006 ppm BTEX. The 4- to 8-foot sample from SB-23 contained 0.027 ppm BTEX, 0.5 ppm TPAH, and 0.2 ppm CPAH.

Three samples from RI borings SB-18 and SB-23 were analyzed from depths between 73 feet and 111 feet bgs (SB-18 [73'-76'], SB-23 [92'-94'], and SB-23 [109'-111']), which was in the vicinity of the bottom of the former 8-inch well that was estimated to be 95' bgs. BTEX ranged from 0.026 ppm in sample SB-23 (109'-111') to 8.5 ppm in SB-18 (73'-76'). TPAH ranged from 0.27 ppm in SB-23 (109'-111') to 272 ppm in SB-18 (73'-76'). CPAH ranged from non-detect in SB-23 (109'-111') to 24.4 ppm in SB-18 (73'-76'). These analytical detections coincided with observed tar-like odors at these depths.

Subsurface-soil data along the Bay Street property line were obtained from boring SB-36 and RW-4. The 4- to 8-foot and the 16- to 20-foot samples from boring SB-36 detected 0.018 and 0.019 ppm BTEX, 0.65 and 0.03 ppm TPAH, and 0.15 ppm non-detect CPAH, respectively. The 88- to 90-foot sample from RW-4 detected 0.071 ppm TPAH; BTEX and CPAH were not detected.

4.1.2 Background Locations

Surface Soil

Surface-soil samples SS-33 through SS-42 were collected from locations around the 25 and 40 Willow Avenue parcels (Plate 1). BTEX ranged from non-detect in samples SS-36, SS-37, SS-38, and SS-41 to 0.001 ppm in sample SS-40. TPAH ranged from 5.3 ppm in sample SS-41 to 91.9 ppm in sample SS-34. CPAH ranged from 3.1 ppm in sample SS-41 to 54.0 ppm in sample SS-34.

The mean of the BTEX values was calculated as 0.00035 ppm and the mean of the TPAH was calculated as 22.7 ppm. Table 4-3 presents these calculated mean values along with the maximum and minimum values. Table 4-3 also presents the maximum, minimum, and mean values of RCRA 8 metals and total cyanide for these samples.

Subsurface Soil

No background subsurface-soil samples were collected.

4.1.3 Lynhurst Avenue Residential Parcels

Surface Soil

Surface soil samples were collected from Lynhurst Avenue residential parcels as follows:

Parcel	Sample ID	Depth Interval (inches)
49 Lynhurst	SS-12	0-2
	SS-19	0-2
	SS-26	0-2
51 Lynhurst	SS-11	0-6
	SSR-60	0-2, 12, 24, 36
	SSR-61	0-2, 12, 24, 36
	SSR-62	0-2, 12, 24, 36
	SSR-63	0-2, 12, 24, 36
53 Lynhurst	SS-10	0-6
	SS-14	0-2
	SS-21	0-2
	SS-28	0-2
55 Lynhurst	SS-9	0-6
	SS-15	0-2
	SS-22	0-2
	SS-29	0-2
59 Lynhurst	SS-8	0-6
	SS-16	0-2
	SS-23	0-2
	SS-30	0-2
61 Lynhurst	SS-7	0-6
	SSR-40	0-2
	SSR-41	0-2
	SSR-42	0-2
63 Lynhurst	SS-6	0-6
	SSR-43	0-2, 12, 24, 36
	SSR-44	0-2, 12, 24, 36
	SSR-45	0-2
	SSR-59	0-2, 12, 24, 36

Parcel	Sample ID	Depth Interval (inches)
67 Lynhurst	SSR-46	0-2, 12, 24, 36
	SSR-47	0-2
	SSR-48	0-2
	SSR-49	0-2
	SSR-50	6-9, 12, 24, 36
	SSR-51	0-2
	SSR-52	0-2, 6-9, 12, 24, 36
	SSR-53	0-2
	SSR-54	6-9, 12, 24, 36
	SSR-55	0-2
	SSR-56	6-9, 12, 24, 36
	SSR-57	0-2
	SSR-58	6-9, 12, 24, 36

BTEX in the residential lot surface-soil samples ranged from non-detect in samples SS-6, SS-8, SS-10, SS-11, SS-14, SS-15, SS-19, SS-23, S-26, SS-28, and SS-30, to 0.006 ppm in sample SS-7. TPAH ranged from 1.2 ppm in sample SS-28 to 38 ppm in sample SS-6. CPAH ranged from 0.6 ppm in sample SS-28 to 18.6 ppm in sample SS-23. Table 4-3 presents the calculated mean values for BTEX and PAHs, along with the maximum and minimum values. Lead was detected within surface and shallow subsurface soils located at the Lynhurst Avenue residential parcels. Lead was detected in all soil samples collected from the Lynhurst Avenue residential parcels. Concentrations ranged between non-detected within SSR-46 at 3′ bgs to a maximum of 2,700 ppm in sample SS-12 (0-2″) adjacent to the 40 Willow Avenue parcel. Table 4-3 also presents the maximum, minimum, and mean values of RCRA 8 metals and total cyanide for these samples.

Based upon the laboratory analysis, an IRM has been conducted to mitigate the elevated lead concentrations in shallow soils on 49 through 67 Lynhurst Avenue. The IRM, performed in accordance with the NYSDEC-approved IRM Work Plan, dated March 2002, removed soils containing elevated lead to a depth of 3 feet bgs. The backyards were restored to their pre-existing conditions.

Subsurface Soil

No evidence of tar, staining, sheen, or odors was observed from the ground surface to approximately 24 feet bgs in any borings (SB-58 through SB-62, SB-77, SB-79/79A, SB-80, or SB-87) completed at the residential parcels located at 49 through 63 Lynhurst Avenue (Cross-section B-B′, Plate 2). As shown in cross-section B-B′, the upper 2 to 7 feet beneath the residential parcels consists of fill. The first evidence of odors and sheen were encountered within SB-79 at approximately 24 feet, within SB-77 at approximately 25 feet bgs, and within SB-87 at approximately 36 feet bgs. Evidence of tar, staining, sheening, and odors extended through the termination depths of borings SB-79/79A, SB-77, and

SB-87. Tar-saturated gravelly sand layers were noted within borings SB-79/79A and SB-87 at a maximum depth of approximately 52 feet bgs with tar-coated soils and tar blebs noted as deep as 60 feet bgs.

Laboratory analyses detected PAHs and BTEX, as well as RCRA 8 metals and cyanide in the subsurface soils at the residential parcels. Figure 2-1 and Cross-section B-B' (Plate 2) shows the subsurface-soil sample locations.
For subsurface soils from the ground surface to 24 feet bgs, BTEX ranged from non-detect in samples SB-59 (8'-10'), SB-61 (0'-4'), SB-62 (0′-4'), and SB-80 (0′-4′) to 0.004 ppm in a duplicate of sample SB-60 (0'-4'). TPAH ranged from 0.10 ppm in a duplicate of sample SB-79 (24′-28′) to 14.4 ppm in SB-60 (0'-4'). CPAH ranged from 0.03 ppm in SB-60 (4'-8') to 6.5 ppm in SB-60 (0'-4'). The presence of PAHs in shallow soils from these residential lots coincides with observed fill material that was found from approximately 0 to 6 feet beneath the residential lots. Laboratory detections are generally higher in shallow soils from 0 to 4 feet bgs than in soil samples collected from 4 to 10 feet bgs. The remaining detections of analytes in the subsurface soils may be explained by the nature of the materials and the historic industrial and commercial land use surrounding the investigation area. The IRM conducted in September 2002 removed these fill materials to a depth of 3 feet bgs.

For deep subsurface soils collected from borings SB-77, SB-79/79A, SB-80, and SB-87 from below 24 feet bgs, BTEX ranged from non detect in SB-79 (24′-28′), SB-80 (52′-56′), and SB-87 (60′-64′) to a maximum of 155.4 ppm in sample SB-79A (51′-55′). TPAH concentrations ranged from non-detect in sample SB-80 (52′-56′) to a maximum of 1,977 ppm within sample SB-79A (51′-55′). CPAH concentrations ranged from non-detected levels within SB-80 to a maximum of 72 ppm within soil sample SB-77 (37′-39′). Trace odors were noted as deep as 64 feet bgs and were characterized with BTEX levels of 0.007 ppm, TPAH concentrations of 0.065 ppm, and non-detect CPAH concentrations. The elevated levels of BTEX, TPAHs and CPAHs coincided with observations of tar-saturated and stained soils.

4.1.4 Lynhurst Avenue Right-of-Way

No evidence of tar, staining, sheen, or odors was observed from the surface to approximately 40 feet bgs in any borings (SB-78, SB-84, SB-85, and SB-86) within the Lynhurst Avenue ROW (Plates 2 and 3). Tar staining, sheening and/or odors were noted within two of the four borings completed within the Lynhurst Avenue ROW. Boring SB-78 exhibited sheening and odors starting at 44 feet bgs and sheening, tar blebs, and odors extended to 50 feet bgs within a coarse-grained gravelly sand layer. To the south of SB-78, boring SB-84 exhibited sheening and odors within a sand lens 40 feet bgs. No odors or evidence of tar was noted from 50 feet bgs to the top of the saprolite located at 125 feet bgs.

Laboratory analyses detected PAHs and BTEX, as well as RCRA 8 metals, in the subsurface soils at the residential parcels. Figure 2-1 shows the subsurface-soil sample locations. For borings SB-78, SB-84, SB-85, and SB-86 within Lynhurst Avenue, BTEX was only detected within SB-78 at a maximum of 155 ppm within the 49- to 50-foot sample interval and at a minimum of 0.011 ppm in the 114- to 115-foot interval. BTEX was not detected within samples from SB-84, SB-85, and SB-86. TPAH concentrations ranged from non-detected in samples collected from SB-78 (114′-115′), SB-84 (48′-52′), SB-85 and SB-86 to a maximum of 5,053 ppm within sample SB-78 (49′-50′). CPAH concentrations ranged from non-detect within samples collected from SB-85 and SB-86 to a maximum of 11 ppm within SB-78 (49′-50′). The elevated levels of BTEX, TPAHs, and CPAHs coincided with observations of tar-stained, sheened, and odors within soil samples.

4.1.5 66 Willow Avenue Parcel

Surface Soil

No surface-soil samples were collected on this parcel because the parcel is paved.

Subsurface Soil

Black staining was noted in borings SB-66 from 0 to 2 feet bgs and in SB-67 from approximately 3.0 to 3.2 feet bgs (Plate 3). Slight naphthalene odors were noted from 12 to 20 feet bgs at SB-66.

Subsurface-soil laboratory analytical results were obtained from borings SB-65, SB-66, and SB-67. BTEX was not detected in samples SB-65 (0'-4'), SB-65 (4'-8'), SB-67 (0'-4'), or SB-67 (4'-6). The highest BTEX concentration (0.13 ppm) was detected in sample SB-66 (12'-16'). TPAH ranged from non-detect in sample SB-65 (4'-8') to 31.4 ppm in sample SB-66 (0'-2'). CPAH ranged from non-detect in samples SB-65 (4'-8'), SB-66 (12'-16'), and SB-67 (4'-6') to 10.4 ppm in sample SB-66 (0'-2'). Laboratory detections of BTEX in sample SB-66 (12'-16') coincided with observed naphthalene odors and PID field measurements of 57.4 ppm. Laboratory detections of PAHs in samples SB-66 (0'-2') and SB-67 (0'-4') coincided with observed black soil staining.

4.2 Groundwater

All available groundwater analytical data from the RI and previous investigations are summarized in Table 4-4. Appendix F includes the validated laboratory Form I reports from the RI investigation. A summary of TPAH, CPAH, and BTEX results from the October 1999 RI sampling event is presented on the shallow aquifer and deep aquifer groundwater contour maps (Plate 5 and Plate 6). A summary of the January 2002 (Round 4) and June (Round 5)

RI groundwater sampling is presented on the shallow groundwater aquifer contour maps (Plates 5 and 6).

Groundwater samples in the vicinity of former Relief Holder No. 2 contained BTEX constituents and the lighter molecular weight SVOCs (also referred to as non-carcinogenic PAHs), which are generally more soluble than the heavier molecular weight SVOCs. Concentrations of BTEX and non-carcinogenic PAHs were noted at higher concentrations in the vicinity of the former relief holder. Concentrations of these compounds decreased by orders of magnitude away from the holder.

Shallow groundwater beneath the residential Lynhurst Avenue parcels is not impacted by chemical constituents associated with the former MGP at 40 Willow Avenue. Trace detections of benzene and toluene (0.3 parts per billion [ppb]) within the PZ-11 groundwater sample and duplicate were the only detected concentrations within the shallow groundwater aquifer on the Lynhurst Avenue residential parcels.

4.2.1 Shallow Aquifer

Measurements for the presence of NAPL (dense and light) were taken at each groundwater monitoring well during Round 1, Round 2, Round 4, and Round 5 of the RI groundwater sampling events. No measurable NAPL was observed in any shallow groundwater monitoring wells or piezometers sampled as part of OU-1. Tar odors were noted within PZ-3, PZ-4A, and PZ-TP-13 during development (40 Willow Avenue parcel).

As discussed in subsection 3.2.1, shallow groundwater within OU-1 flows radially to the northwest and the northeast. On the northwestern portion of the 40 Willow Avenue parcel, 66 Willow Avenue parcel, and Lynhurst Avenue parcels (59 through 67), groundwater flows northwesterly and appears to generally be flowing toward the former stream trace on the western portion of the 25 Willow Avenue parcel. Groundwater beneath the remaining portion of the 40 Willow Avenue and Lynhurst Avenue parcels (49 through 55) appears to flow northeasterly towards New York Harbor. Plate 5, Plate 7, and Figure 3-1 present a summary of BTEX, TPAH, and CPAH analytical findings on the water table (shallow aquifer) contour map for Round 2, Round 4, and Round 5 RI groundwater sampling events.

Shallow groundwater sample results obtained from the 40 Willow Avenue parcel are summarized below. Historic data from 1993 and 1994 exist for previous investigation wells FPM-MW1, FPM-MW2, and FPM-MW3. Wells FPM-MW1, FPM-MW2, and FPM-MW3 are located downgradient (to the east) of Relief Holder No. 2. Data from these sampling events indicate trace levels of BTEX (maximum of 17 ppb in FPM-MW2 in 1993), and trace levels of TPAH. Groundwater samples from FPM-MW3 contained the highest levels of TPAH at 22 ppb during the 1993 sampling event. Individual PAH compounds detected in these wells included naphthalene, pyrene, fluorene, acenaphthene, acenaphthylene, and phenanthrene. CPAHs were not detected above the detection limit in these three wells.

Shallow groundwater samples were collected for potential dewatering parameter analysis during Round 5 from piezometers PZ-3, PZ-4A, and PZ-TP-13. These piezometers are located on the 40 Willow Avenue parcel, directly adjacent to the former relief holder. Water levels from monitoring well FPM-MW-2 and piezometer PZ-2 were also gauged as part of the Round 4 sampling. Groundwater samples contained BTEX and TPAHs. CPAHs were not detected above the detection limit in these three samples. BTEX ranged in concentration from 7,700 ug/L within PZ-3 to a maximum of 20,400 ug/L within PZ-TP-13. TPAH concentrations ranged in concentration from 833 ug/L within groundwater sample PZ-4A to a maximum concentration of 7,900 ug/L within PZ-TP-13. Elevated BTEX and TPAHs are likely attributable to dissolved fractions immediately adjacent to the holder.

Groundwater samples were also collected from piezometers PZ-5 through PZ-11 on the Lynhurst Avenue residential parcels as part of Round 5. Only BTEX was detected in the groundwater sample from PZ-11 and its duplicate. BTEX concentrations ranged from 0.03 ug/L to 0.6 ug/L within this sample. No TPAHs were present above the laboratory detection limit in any of the residential groundwater samples. The trace levels of BTEX are likely attributable to an aboveground heating oil UST located nearby at 53 Lynhurst Avenue.

4.2.2 Deep Aquifer

Measurements for the presence of NAPL (dense and light) were taken at each groundwater monitoring well during Round 1 and Round 2 of the RI groundwater sampling events. A measurable amount of DNAPL (tar) was observed in monitoring well RW-7 during the Round 1 and Round 2 groundwater sampling events. One sample of NAPL was collected for laboratory analysis. The analytical results of this sample (CF-TAR01) are presented in Table 4-4. NAPL thickness in the bottom of RW-7 was 3.95 feet in Round 1 and 1.5 feet in Round 2. The change in thickness was likely attributable to the pumping of tar product from the bottom of RW-7 for laboratory analysis in Round 1. No measurable NAPL was observed in the remainder of the deep wells sampled (RW-4 and RW-14).

Groundwater quality in the deep aquifer was assessed by the collection of groundwater samples from wells RW-4, RW-7, and RW-14 (see Plate 6). A summary of the TPAH, CPAH, and BTEX analytical results is shown on Plate 6 along with the groundwater elevation contours from October 13, 1999.

Groundwater quality from RW-4 at the eastern edge of the 40 Willow Avenue parcel exhibited trace levels of BTEX (0.2 ppb) and TPAH (0.2 ppb). However, groundwater from well RW-07 and RW-14 adjacent to Relief Holder No. 2 exhibited higher concentrations of

TPAH and BTEX. Within RW-07, TPAH was detected at 8,911 ug/L and BTEX was detected at 32,290 ug/L. These detections are consistent with the DNAPL within the bottom of the well and the tar-saturated gravelly-sand aquifer. Detections deeper within RW-14 exhibited decreased TPAH (3,634 ppb) and BTEX (4,240 ppb) concentrations. CPAHs were not detected, but the detection limits were elevated. The presence of PAHs and BTEX constituents in the deep aquifer at RW-14 is consistent with the physical observation of tar-like odors near the bottom of the aquifer, where the well is screened.

5. Fate and Transport

This section provides an analysis and discussion of the data presented in previous sections to provide an interpretation of the interaction between physical and chemical processes that affect the behavior of chemical constituents in the subsurface. Through an understanding of these physical and chemical processes, mechanisms affecting the fate and transport of chemicals at the site will be evaluated.

The following analysis takes into account the physical characteristics of the OU-1 parcels, including the 40 Willow Avenue, 66 Willow Avenue, Lynhurst Avenue residential parcels and the Lynhurst Avenue ROW parcels; the interaction of the surface and groundwater hydrogeology; the nature of chemical compounds encountered during the sampling and analysis program; and any apparent trends in the distribution of these materials with the OU-1 parcels. This section provides a discussion of the physical and chemical characteristics of BTEX and PAHs, and a discussion of the sources and transport pathways for these constituents.

The chemical constituents can exist in four different phases, nonaqueous phase liquid, dissolved in an aqueous phase, sorbed to a solid, or as a vapor. Transport of chemical constituents between these four phases will depend upon the physical and chemical properties of the specific chemicals and the physical characteristics of the OU-1 parcels. The transport pathway and how it relates to chemical constituents is discussed below.

- **Solubility.** Is the measure of a chemical's ability to dissolve in water. Chemical constituents sorbed to soil or in a NAPL may dissolve in water as groundwater flows through the soil matrix, or may dissolve in stormwater runoff. BTEX compounds have a high solubility. PAHs have a varying degree of solubility. The lighter molecular weight PAHs are generally more soluble while the heavier molecular weight PAHs are less soluble and typically do not dissolve into an aqueous phase.

- **Sorption.** Is usually defined as the reversible binding of a chemical to a solid matrix. However, there is evidence in the published literature that there is a partially irreversible component related to the time that the compound has been sorbed to a soil matrix (Brusseau, et al., 1989; Brusseau, et al., 1991; Loehr, et al., 1996).

- **Volatilization.** Describes the movement of a chemical from the surface of a liquid or solid matrix to a gas or vapor phase. BTEX constituents are highly volatile and are therefore readily transported into the atmosphere from surficial soil. PAHs are nonvolatile and transport of these chemicals by this process is not considered a major pathway for transport.

Sorption of the COCs to solids limits the fraction available for other fate processes such as volatilization and/or solubility. In general, BTEX compounds have low sorption potential, coupled with high water solubility and volatility, which make sorption a relatively minor environmental fate process for BTEX compared to other mechanisms. PAHs exhibit varying degrees of binding affinity to organic matter and soil particles and this affinity is dependent upon their individual molecular structures. In general, the higher molecular weight PAHs, (e.g., benzo(a)pyrene) are strongly sorbed, whereas the lighter PAHs (e.g., naphthalene) are less strongly sorbed (EPA, 1979; EPA, 1986). Therefore, the lighter-molecular weight PAHs may be desorbed and transported by other mechanisms.

Once released into the environment, COCs have the potential to interact with organisms. The following is a brief summary of the process of the bioconcentration of MGP-related compounds.

Bioconcentration factors (BCFs), which relate the concentration of the chemical in an organism at equilibrium to the concentration of the chemical in water, are used to assess the potential for chemical bioconcentration. BCFs are related to the octanol/water partition coefficient and solubility of a chemical. Since VOCs have log K_{ow} and high water solubilities, these chemicals have a low potential to bioconcentrate in organisms (Howard 1990).

PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular or cluster arrangements. In general, most PAHs can be characterized as having low vapor pressure, low to very low water solubility, low Henry's Law constant, high log K_{ow}, and high organic carbon partition coefficient (K_{oc}). Thus, PAHs remain bound to soil and do not freely enter groundwater.

High partition coefficients and low solubilities suggest that PAHs are likely to be sorbed onto sediment particles. Conversely, these properties indicate that most PAHs will not readily volatilize into the atmosphere.

Although PAHs are regarded as persistent in the environment, they are degradable by microorganisms. Environmental factors, microbial flora and physicochemical properties of the PAHs themselves influence degradation rates and degree of degradation. Important environmental factors influencing degradation include temperature, pH, redox potential (the tendency of a chemical to accept or donate electrons, or to become reduced or oxidized) and microbial species. Physicochemical properties, which influence degradation, include chemical structure, concentration and lipophilicity ("fat-loving" tendency). In general, PAHs show little tendency to biomagnify in food chains despite their high lipid solubility because most PAHs are rapidly metabolized by the organisms that are exposed to them (Eisler 1987).

Metals, which do mobilize from the soil into groundwater, are usually mobile under acid conditions. Higher pH usually reduces their bioavailability (McIntosh 1992).

A qualitative human health exposure assessment and fish and wildlife impact analysis is presented in Section 7.

The environmental media that are of primary concern for the subject properties are NAPL, subsurface and surface soil, and groundwater. Section 4 provides a detailed description of the nature and extent of chemical constituents. Plates 2, 3, and 4 illustrate the vertical and lateral extent of tar, staining, sheen, odors, along with the geology and hydrogeology at the OU-1 parcels.

5.1 NAPL

NAPL (tar) is present at the site. NAPL is considered to include the visual observation of tar-saturated material or soil containing tar blebs or tar lenses (see Section 4 for a description of these terms). NAPL was observed within the subsurface foundations of the former relief holder and in the subsurface materials surrounding the former holder that handled tar. The chemical constituents addressed that are in NAPL include BTEX and PAHs.

NAPL (tar) generally migrated downward through permeable fill and other permeable soils on the 40 Willow Avenue parcel. NAPL was observed to a depth of 80 feet beneath the 40 Willow Avenue parcel. NAPL was generally observed in near proximity to the former historic structures and lateral migration of NAPL away from the 40 Willow Avenue parcels through soils above 20 feet is not considered a major pathway for transport. Some lateral migration of NAPL within more permeable layers was noted at depths greater than 24 feet beneath the Lynhurst Avenue parcels and within the Lynhurst Avenue ROW (Cross-sections B-B′, C-C′ and E-E′, Plates 2 and 3).

NAPL present within the subsurface will desorb and contribute to chemical constituents in the soil and groundwater beneath the 40 Willow Avenue, Lynhurst Avenue residential parcels and the Lynhurst Avenue ROW. BTEX and lighter molecular weight PAHs will dissolve into groundwater and can be transported with groundwater flow. Heavier PAHs will sorb to soil and will remain relatively immobile. BTEX in NAPL above the water table on the 40 Willow Avenue parcel can also volatilize and diffuse through the soil pore spaces in the vadose zone.

5.2 Subsurface Soil

In general, the distribution of BTEX and PAHs in subsurface soil correlates with the presence of NAPL (tar). Chemicals sorbed to soils in the subsurface will continue to be a source of dissolved chemical constituents in groundwater. BTEX and lighter molecular weight PAHs can desorb from soil, dissolve into groundwater, and be transported with groundwater flow. BTEX can also volatilize from soil and diffuse through the vadose zone. Heavier molecular weight PAHs will remain sorbed to soil and will remain relatively immobile.

5.3 Surface Soil

Surface-soil samples were not collected from the paved portions of the 40 Willow Avenue parcel (approximately half of the parcel area). PAHs were identified in surface soil present on the southern, unpaved portion of the 40 Willow Avenue parcel. Total BTEX concentrations in surface soil range from non-detect to 2.5 ppm. Low levels of PAHs were also detected in surface soils on the residential parcels. These surface soils were mitigated during the IRM conducted in September 2002.

Lighter molecular weight PAHs sorbed to surface soil could desorb and dissolve in stormwater. PAHs dissolved in infiltrating precipitation could be transported to shallow groundwater and move with groundwater flow. PAHs that potentially dissolve in runoff will be transported through storm sewer systems. Lighter molecular weight PAHs could also migrate through the surface soil by volatilization. In addition, PAHs sorbed to soil could be transported off the 40 Willow Avenue parcels and Lynhurst Avenue parcels as airborne particulates or as particulates entrained in surface water runoff.

5.4 Groundwater

Two groundwater aquifers have been identified at OU-1 and are described in Section 3. Chemical constituents detected in the shallow groundwater aquifer include BTEX and PAHs. Chemical constituents in the deeper artesian aquifer are primarily BTEX, but PAHs are also present in groundwater within the deep aquifer at the well locations of RW-7 and RW-14.

BTEX and PAHs dissolved in groundwater are present in the vicinity of NAPL. Groundwater in the shallow aquifer under the OU-1 parcels flows radially to the northwest and northeast.

Groundwater flow direction in the deep aquifer is unclear and is either split along a divide or is heterogeneously affected by tidal influences. Based on the available data, it appears that on the eastern portions of the 40 Willow Avenue parcel, groundwater flow in the deep aquifer is generally to the east towards the bay. On the western portions of the 40 Willow Avenue parcel, groundwater flow in the deep aquifer appears to be toward the southwest.

Dissolved BTEX and lighter molecular weight PAHs will be transported with groundwater flow within the shallow groundwater towards the former stream trace along the northwestern portion of OU-1 and towards New York Harbor. The decrease in concentrations away from the relief holder makes this unlikely. Groundwater elevations within the deep groundwater aquifer reveals flow towards the harbor; however, based upon the decrease in detected concentrations away from the holder towards the harbor, it is unlikely that deep aquifer dissolved phase constituents migrate beyond the site.

6. Conceptual Site Model

This section discusses the conceptual site model as it pertains to the nature of the physical observations of tar, staining, sheening and odors, migration pathways and receptors. From all the five successive rounds of investigation that have taken place at the site, it has become apparent that the primary area of concern within OU-1 is former Relief Holder No. 2 located at the 40 Willow Avenue parcel.

The former gas holder is located in the northwest to central portion of the 40 Willow Avenue parcel where the former holder foundation currently exists today. Upon its decommissioning, fill material was used to backfill the brick masonry holder. Some tar and tar-impacted material may have remained within the former holder mixed with the fill. This tar, in conjunction with tar historically produced and handled on site during the operation of the former MGP, appears to represent the source of DNAPL (tar) observed within soils on site. Cross-sections A-A′ located on Plate 2 and cross-sections E-E′ and F-F′ located on Plate 3 depict the vertical extent of tar and tar-impacted soils within OU-1. Cross-sections L-L′ and K-K′ depict the contents of the former holder.

The inferred alluvial sand and gravelly sand located at the base of the former holder may have been impacted by the seepage of tar through the bottom of the brick and masonry holder side and bottom in the vicinity of SB-22 and GP-06 on the northern portion of the site. Once released, the tar is hypothesized to have continued to migrate downward through the subsurface by micro-fractures and grain-to-grain movement within coarser grained materials and preferentially collected within localized sand and sandy-gravel layers within the glacially derived soil unit (ground moraine). These layers also may have allowed small amounts of tar to migrate from the former holder laterally to the southeast to as far as Lynhurst Avenue. Increased frequency and size of the more permeable sand/gravelly glacial outwash sands facilitated the continued migration of tar downward in the vicinity of the former holder to a depth of approximately 80 feet bgs at the 40 Willow Avenue parcel. No physical observations of tar were noted within soils beneath Lynhurst Avenue at this depth. In the vicinity of the holder, physical observations of tar odors were present to the top of weathered bedrock interface at approximately 125 feet bgs.

Zones of tar-impacted soils that do not contain source or residual NAPL surround the source area laterally and vertically at depth within OU-1. These areas are distinguished by having sheens and odors. Concentrations of BTEX and PAHs are significantly reduced away from the source.

Groundwater is impacted in the areas associated with DNAPL residuals in the vicinity of the former holder foundation. Dissolved tar-related constituents (BTEX and PAHs) are limited in extent to the vicinity of the former holder and concentrations decrease in both the shallow and deep groundwater aquifer in the direction of New York Harbor. No tar-related impacts were noted in the shallow groundwater aquifer on the Lynhurst Avenue residential parcels adjacent to the site.

7. Qualitative Human Exposure Assessment and Fish and Wildlife Impact Analysis

This report section presents the qualitative human exposure assessment and fish and wildlife impact analysis (FWIA) for the site. These assessments consider the chemical distribution at the site in terms of possible human exposure and impact(s) to fish and wildlife and are part of an Order on Consent (Index No. D1-0002-98-11) between KeySpan and the NYSDEC concerning the former MGP site located in Clifton, Richmond County, New York. These assessments used data collected as part of GEI's initial remedial investigation and supplemental data collected in 2001 and 2002. The qualitative human health exposure assessment was performed to meet the requirements identified in the NYSDOH's November 9, 2000 guidance memorandum titled *New York State Department of Health, Qualitative Human Health Exposure Assessment*. The ecological portion of the assessment presented here is consistent with the NYSDEC's *Fish and Wildlife Impact Analysis* guidance (NYSDEC 1994b). The objectives of the assessments are:

- To identify chemicals of potential concern (COPCs) that are related to the former gas manufacturing activities conducted at the site
- To identify potential pathways of exposure to people, plants, animals, and fish
- To estimate and characterize the potential ecological impact associated with these exposures
- To indicate whether there is a need for mitigative measures to reduce potential exposures

For purposes of the qualitative human health exposure assessment and the FWIA, OU-1 is discussed in terms of potential on-site exposures associated with the former plant parcel (40 Willow Avenue); and potential off-site exposures which are associated with the residential parcels located along Lynhurst Avenue. The site location and description are discussed in Section 1 of this report. The site-specific hydrogeologic characteristics of OU-1 are discussed in Section 3.

KeySpan conducted an interim remedial measure (IRM) (from September 2002 to July 2003) to remove lead-impacted soils from the Lynhurst Avenue residential backyards (Figure 7-2A). The IRM removed the upper 3 feet of soil from the areas. The analytical results for samples collected from soils that were removed during the IRM were not used in the human health exposure assessment OU-1. The current site plan for OU-1 is presented in Figure 7-2A.

7.1 Qualitative Human Exposure Assessment

7.1.1 Nature and Extent of Chemical Constituents

BTEX constituents were the principal VOCs detected in soil and groundwater samples at the site and are the common VOCs associated with coal tar. SVOCs also were detected at the site. PAHs are the common subset of SVOCs found in coal tar. Certain metals as well as cyanide are also commonly associated with MGP sites. Section 4 of this report provides a detailed description of the nature and extent of chemical constituents found on-site and at relevant off-site locations. Section 5 of this report provides a detailed description of the fate and transport of analytes commonly associated with MGP sites. The potential migration pathways for chemical constituents are illustrated on Figure 7-1.

7.1.2 Selection of Chemicals of Potential Concern

Several classes of chemicals were detected in soil and groundwater. COPCs were selected following the practice established by EPA in the Risk Assessment Guidance for Superfund, Volume I, Part A (EPA, 1989). Selection criteria were as follows:

- Chemicals not detected at least once above the limit of detection were automatically excluded from the assessment, regardless of the size of the data set.
- Frequency of detection was considered. Chemicals with a frequency of detection of less than 5% in a data set of 20 or more samples were excluded from the assessment.
- Chemicals present at concentrations statistically greater than background.
- Chemicals that are not associated with MGP operations were not considered COPCs.

Tables 7-1 through 7-6 list for each medium (i.e., surface soil, subsurface soil, and groundwater) and location, the chemicals reported at least once above the limit of detection, their frequency of detection, and their minimum and maximum concentrations. The chemicals listed in these tables are those that meet the frequency of detection criteria listed above. Chemicals that are both MGP-related and exceed either background or applicable

NYSDEC SCGs are considered COPCs and appear in bold italics in these tables. The distribution of the data set also is provided in the tables where appropriate. Additionally, these tables present the 95 percent upper confidence limit (UCL) of the mean for the applicable data set, and relevant and appropriate concentrations (i.e., background concentrations for surface soil, and NYSDEC TAGM and TOGS concentrations for subsurface soil and groundwater, respectively). Except for soils removed during the IRM, soil sample data obtained from the 1999 and 2001-2002 field investigations were combined to estimate the 95 percent UCL.

Data sets were developed to estimate the UCL according to the exposure scenario being evaluated. For off-site Lynhurst Avenue residents, surface and subsurface soil and groundwater sample results from the residential parcels were used to evaluate exposure pathways. For the on-site exposure scenarios, surface soil, subsurface soil, and groundwater samples collected from the 40 Willow Avenue parcel were used to evaluate the exposure pathways. Samples collected to a maximum depth of 16 feet were used to estimate exposure point concentrations for ingestion and dermal contact. The depth of samples used depended on the scenario being evaluated, *i.e.*, excavation scenarios considered soil to a depth of 16 feet.

For surface soil, the 95 percent UCL background concentration is presented in Tables 7-1 and 7-2. This background concentration was calculated using samples collected from depths of zero (0) to two (2) inches below ground surface. A description of how the background sampling locations were selected is presented in Section 4.1.2 of this report.

The 95% UCL is determined from the detected concentrations and the substitution of one-half the limit of detection for samples reported as non-detected (U-qualified). U-qualified chemical concentrations were used in the exposure assessment at one-half the limit of detection if other samples in the data set were reported at least once above the limit of detection (USEPA 1989).

Prior to calculating the 95 percent UCL, statistical tests were performed to identify the best distributional assumption of the data (i.e., lognormal or normal). Normally distributed data are those that, when plotted, exhibit a bell-shaped curve, while lognormally distributed data exhibit a skewed curve. All data sets in this assessment contained fewer than 50 samples; consequently, the data were evaluated using the W-test developed by Shapiro and Wilk (Gilbert 1987). The W-test was performed using an Excel add-in called Analyse-It™. If the results of the W-test indicated the data did not represent a normal distribution and/or the data did not exhibit a bell-shaped curve, then a lognormal distribution was assumed. The appropriate equation was then used to calculate the 95 percent UCL concentrations (USEPA 2002).

If the data set was found to be consistent with the normal distribution, then the 95% UCL was calculated from the following equation (USEPA 2002):

$$95\%\ UCL = \bar{x} + t\left(\frac{s}{\sqrt{N}}\right)$$

where:

$\bar{x}$ = mean of the (untransformed) data
t = Student t-statistic (from Gilbert 1987)
S = standard deviation of the (untransformed) data
N = number of samples

If the data set was assumed to be consistent with the lognormal distribution, then the 95% UCL concentration was calculated from the following equation (USEPA 2002):

$$95\%\ UCL = e^{\left(\bar{x} + 0.5s^2 + \frac{SH}{\sqrt{N-1}}\right)}$$

where:

e = base of the natural log = 2.718
$\bar{x}$ = mean of the log transformed data
S = standard deviation of the log transformed data
H = H-statistic (interpolated from Gilbert 1987)
N = number of samples

Maximum concentrations were used to represent the mean concentration in small data sets (sample size < 10). Additionally, if the calculated 95 percent UCL exceeded the maximum detected concentration, the maximum concentration was used to represent the mean (USEPA 1992).

In order to aid remedial planning for the site, the exposure point concentration (EPC) calculated for each data set was compared to the 95 percent UCL or maximum detected concentration determined from the background data set for surface soil (Tables 7-1 and 7-2). The EPCs calculated for subsurface soil were compared to NYSDEC TAGM concentrations (Tables 7-3 and 7-4, NYSDEC 1994). Concentrations detected in groundwater samples were compared to NYSDEC TOGS (Tables 7-5 and 7-6, NYSDEC 1998). These comparisons are discussed in Section 7.2.7.

7.1.3 Current and Reasonably Foreseeable Site Use

It is anticipated that the eastern portion of the 40 Willow Avenue lot (on-site) will continue as a commercial property for the foreseeable future. Likewise, the 60 Willow Avenue lot (on site) (the western portion of the parcel herein referred to as 40 Willow Avenue) will continue as a gate station for the purposes of controlling gas distribution. Furthermore, the 40 Willow Avenue parcel is located in a M3-1 zone, which indicates manufacturing. Consequently, the land use of the property is not expected to change substantially from the current commercial/manufacturing use (see Figure 7-2D). Additionally, no new residences or community facilities are permitted. Therefore, a future on-site residential scenario was not considered in this exposure assessment.

The Lynhurst Avenue residential parcels (off-site) are located in an R3-A zone which is a residential zoning designation. The off-site residential area located along Lynhurst Avenue, south of the 40 Willow Avenue parcel is expected to remain residential for the foreseeable future.

7.1.4 Exposure Setting and Identification of Potentially Exposed Populations

The human health exposure assessment provides qualitative descriptions of potential exposure to site-related COPCs for human populations who may reasonably be expected to contact site media under present or future conditions. The exposure assessment is comprised of two components:

- Description of exposure setting and identification of potentially exposed populations
- Identification of exposure pathways

Under current and future site use conditions, the potentially exposed populations (*i.e.*, potential receptors) are those that might come into contact with those COPCs identified above. Figure 7-1 presents a conceptual risk system model (CRSM), and Table 7-7 identifies the potential exposure routes for current and future on-site (40 Willow Avenue) and off-site (homes along Lynhurst Avenue, south of the 40 Willow Avenue parcel) human populations. Potentially exposed populations and pathways of exposure, as outlined in the CRSM and Table 7-7, are described below.

40 Willow Avenue Parcel (On-Site) Current Scenarios
The 40 Willow Avenue parcel is currently an operational regulating gate station for KeySpan. It consists of an open vegetated area; a small building and a small paved parking area all surrounded by a locked, barbed wire-topped chain-link fence. While trespassers have not been observed at the site, the potential for trespasser exposure is considered because the facility could be accessed, with difficulty, over the fence or through unlocked gates during the day. The parking area is used periodically to store cars by the tenant of the 25 Willow Avenue parcel (OU-2). Potential exposures to individuals at the parking area were not considered here because the area is paved, which precludes potential direct contact with soils and inhalation of particulates and vapors.

Thus, receptors considered in the assessment under current site conditions include (see Figure 7-1 and Table 7-7):

- On-site KeySpan employees – i.e., those employees working at the gate station building

- On-site trespassers – children, adolescents, and adults

40 Willow Avenue (On-site) Future Scenarios
As discussed above, future uses of the site and immediate off-site areas are not expected to change substantially from the current commercial/residential uses. As a consequence, the current exposure scenarios also hold for future use of the site. However, to account for the possibility that construction activities may occur at the site to accommodate facility expansion or reorganization or conversion for other commercial use, a future on-site construction worker and future on-site commercial workers and visitors to these commercial establishments were considered (see Figure 7-1 of this report). Other potential exposure populations include nearby off-site utility workers.

Lynhurst Avenue parcels (Off-site)
The residential properties evaluated in this assessment are immediately adjacent to the southern boundary of the gate station parcel. The receptors for the Lynhurst Avenue residential parcels include adults and children who reside in the homes. As previously stated, the future use of the residential parcels is presumed to remain residential.

7.1.5 Identification of Exposure Pathways

Generally, human populations may be potentially exposed to COPCs in the following impacted media: surface soil, subsurface soil, groundwater, ambient air, and indoor air.

40 Willow Avenue Parcel (On-Site)
Under current on-site conditions, dermal contact, incidental ingestion, vapor inhalation and inhalation of particulates from chemical constituents in soil is possible for on-site KeySpan employees and on-site trespassers.

For KeySpan employees, exposure to surface soil may occur during the course of their normal workday activities.

Given the nature of their work (*i.e.*, trenching, excavation, installing deep piles, etc.), future on-site construction workers may reasonably be expected to contact surface and subsurface soil via ingestion, dermal contact, inhalation of soil particulates, and vapor inhalation. In addition, construction workers may contact groundwater during trenching activities, since the depth to groundwater is one to eight feet below ground surface. If current KeySpan employees engage in on-site excavation work, they are required to have appropriate training. They also have the potential for exposure via the aforementioned pathways. Chemical exposures for nearby, off-site utility workers may occur because of the presence of subsurface sewer, telephone, gas, and water facilities in the areas immediately adjacent to the site. The exposure pathways through which this population could be potentially exposed are identical to those for the construction worker.

Future on-site commercial workers are assumed to be inside workers. These individuals as well as visitors to these commercial establishments may be exposed, absent remedial measures, to vapors in indoor air.

Exposures associated with direct contact with groundwater are limited to those individuals who engage in excavation work (*e.g.*, on-site construction workers and nearby off-site utility workers). There is no on-site use of groundwater for consumptive or other purposes. Consequently, the only potential complete exposure pathways for groundwater are dermal contact and inhalation of vapors emanating from the groundwater. These potential exposures are most likely to occur for the construction worker, the utility worker and the KeySpan employee.

Lynhurst Avenue Residential Parcels (Off-Site)

Under current off-site conditions, dermal contact, incidental ingestion, vapor inhalation, and inhalation of particulates from chemical constituents in soil is possible for off-site residents. Residents may contact surface soil during everyday activities such as playing, gardening, etc. Therefore, a gardening scenario (composed of ingestion and dermal contact with surface soils, inhalation of particulates, and consumption of homegrown produce) is included for the off-site resident.

The residential properties along Lynhurst Avenue are served by municipal water supplies and no wells were observed to be in use (even for the irrigation of gardens/lawns). Although off-site residents may contact groundwater through excavation work in their yards, this exposure is considered minimal as compared to other potential exposure pathways (*i.e.*, direct contact with surface soils). Therefore, the only potential exposure pathway for the residents is inhalation of vapors emanating from the groundwater. Water table groundwater samples collected as part of the off-site investigation of these parcels did not reveal the presence of VOCs at concentrations that would results in an indoor or ambient air concern. Therefore, the potential for this exposure pathway to be complete is considered minimal.

7.1.6 Screening Level Assessment

The exposure point concentrations determined for each portion of OU-1, the 40 Willow Avenue parcel (on-site), and the residential area along Lynhurst Avenue (off-site), were compared to background or appropriate NYSDEC concentrations, and the results of this screening are as follows.

40 Willow Avenue (On-Site)

Surface Soils

Comparisons of the surface soil concentrations for the 40 Willow Avenue parcel indicate that 21 chemicals are present at concentrations above the 95% UCL of the background samples. However, 12 of these chemicals (anthracene, fluoranthene, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, arsenic, barium, cadmium, chromium, lead, and mercury) are present at concentrations within the range of background samples (see Table 7-1).

Subsurface Soils

Subsurface soil concentrations at the 40 Willow Avenue Parcel also were compared to NYSDEC TAGM concentrations. This comparison indicates that the majority of chemicals are present at concentrations that exceed applicable TAGM concentrations. The following chemicals were detected at concentrations below TAGM concentrations: acetone, 4-methylphenol, di-n-butylphthalate, diethylphthalate, phenol, bis(2-ethylhexyl)phthalate, arsenic, barium, and selenium; Table 7-3).

Groundwater

Evaluation of groundwater concentrations at the 40 Willow Avenue parcel indicates that seven chemicals (benzene, ethylbenzene, toluene, xylenes, 2,4-dimethylphenol, phenol, and total cyanide) exceed applicable TOGS concentrations. TOGS concentrations were not available for some of the detected chemicals (Table 7-5).

Lynhurst Avenue Residential Parcels (Off-Site)

Surface Soils

Six chemicals detected in surface soil samples from the residential parcels (fluoranthene, pyrene, arsenic, barium, chromium, and selenium) were present at concentrations that exceed the 95 percent UCL for background (see Table 7-2). However, with the exception of selenium, these chemicals were present at concentrations within the range detected in background samples. The maximum Lynhurst Avenue concentration for selenium, 2.7 mg/kg, is slightly above the maximum detected background concentration of 2.4 mg/kg. Benzene was detected in one surface soil sample collected from Lynhurst Avenue. This sample result, 0.0006 mg/kg is essentially the same as the maximum detected background concentration of 0.0005 mg/kg.

Subsurface Soil
Chemicals detected in subsurface soils at the Lynhurst Avenue parcels were compared to available NYSDEC TAGM concentrations (see Table 7-4). Results of this comparison indicate that twelve chemicals (benzene, ethylbenzene, xylenes, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, arsenic, barium, chromium, and mercury) are present at concentrations that exceed the applicable TAGM concentration. TAGM concentrations are not available for some of the chemicals detected in these subsurface soils. Although these chemicals exceed their respective TAGM concentrations, the potential for exposure to these subsurface soils is unlikely.

Lynhurst Avenue – Groundwater
Six chemicals (benzene, toluene, methyl bromide, methyl chloride, tetrachloroethylene, and diethylphthalate) were detected infrequently in groundwater samples collected from the residential parcels. Methyl bromide, methyl chloride, tetrachloroethylene, and diethylphthalate are not associated with MGP sites; therefore, these chemicals are not considered COPCs. Concentrations of benzene and toluene were compared to appropriate TOGS concentrations and are present at concentrations that are lower than the TOGS concentration (see Table 7-6).

7.1.7 Conclusions

7.1.7.1 Lynhurst Avenue Residential Parcels (Off Site)

Surface Soils
Results of the screening of surface soil sample results for the Lynhurst Avenue parcels against background concentrations indicates that only one analyte, selenium, is present at a concentration that is slightly above the range of background concentrations. The surface soil sample results used here are for samples collected from the front yards of the residences along Lynhurst Avenue. These front yards are very small and children's play areas and gardens were not observed in these areas. As discussed previously, significant portions of the backyards were excavated to a depth of three feet in order to address lead-impacted soils. These excavated soils are being replaced with clean fill. Given the relative size of the front and back yards, child and adult residents are much more likely to recreate/garden in their backyards. The results of the screening indicate that the concentrations of chemicals in surface soils to which residents may potentially be exposed are representative of background conditions. This information, coupled with the observed and anticipated activity patterns of the residents of homes along Lynhurst Avenue, indicate that potential exposures to surface soils at these homes are not exposure pathways of concern.
Subsurface Soils

Results of subsurface soil screening indicate that while some chemicals are present at concentrations above the TAGM concentrations, the potential for residential exposure to subsurface soils at these parcels is minimal for two reasons: 1) the infrequent nature of excavation work in a residential setting and 2) the presence of clean fill to a depth of three feet in the backyards.

Groundwater

Chemicals detected in groundwater are present at concentrations below applicable NYSDEC concentrations. Additionally, groundwater wells were not observed during the field investigation and these homes and surrounding properties are served by a municipal water supply. It is expected that any new construction would be connected to the municipal water supply; consequently, exposure to potentially MGP-related constituents that may be present in groundwater does not occur under existing conditions (*i.e.*, potential exposure to groundwater is an incomplete exposure pathway), nor is it expected to occur under future use conditions.

Results of the screening analysis suggest that potential inhalation of vapors in ambient and indoor air and inhalation of wind-borne particulates derived from chemicals present in soils are not exposure pathways of concern. In addition, the evaluation of a gardening scenario indicates that inhalation of wind-borne particulates from surface soils is not an exposure pathway of concern.

7.1.7.2 40 Willow Avenue (On-Site)

This assessment indicates that chemicals are present in surface soil at concentrations that exceed the range of background concentrations. Additionally, chemicals were detected in subsurface soil at the 40 Willow Avenue parcel at concentrations that exceed the applicable TAGM concentrations. Consequently, potential exposure to these soils may be considered a pathway of concern. However, under current site conditions, access to the site is restricted by a gated fence so the potential for trespasser exposure to these soils is minimal. A KeySpan employee visits the regulating station on average once per week and a portion of this time is spent in the on-site building where direct contact with soil does not occur.

Because future redevelopment of the site or conversion to another commercial use would likely entail construction and utility work and, by definition, direct contact with subsurface soils, the concentrations of chemicals detected in subsurface soil at the 40 Willow Avenue parcel indicate that direct contact with these soils may be an exposure pathway of concern.

Several chemicals in groundwater are present at concentrations that exceed TOGS. Potential direct contact exposures to groundwater are expected to be limited to those individuals engaged in excavation work (e.g., construction worker, KeySpan employee, and utility worker). Results of the screening analysis indicate that this may be an exposure pathway of potential concern. However, under current site conditions, direct contact with groundwater is an incomplete exposure pathway.

Based on this analysis, potential inhalation of vapors from soil and groundwater and particulates from soil at the 40 Willow Avenue parcel is an exposure pathway of potential concern.

7.1.8 Summary

In summary, results of this screening level assessment indicate that chemicals present in soil and groundwater at the Lynhurst Avenue residential parcels (off site) are either not of concern or the exposure pathways through which individuals could potentially be exposed to these chemicals are incomplete. Data for the 40 Willow Avenue parcel (on site) indicate that under future site use conditions, and absent remedial measures, exposure to soil and groundwater are potential pathways of concern.

7.2 Fish and Wildlife Impact Analysis (FWIA)

This FWIA has been conducted to identify actual or potential impacts to fish and wildlife residing in the vicinity of the site from chemicals potentially migrating from the former MGP. Specifically, it focuses on impacts associated with site-related chemicals detected in soil and groundwater.

This analysis contains:

- Site descriptions including a characterization of the floral and faunal resources present and the concentration of these resources to humans;
- The identification of applicable regulatory standards and criteria for fish and wildlife;
- Evaluations of potential exposure pathways to fish and wildlife from site-related chemicals of potential ecological concern (COPECs);
- Comparison of chemical concentrations for COPECs to regulatory criteria or derived toxicological benchmarks for the protection of fish and wildlife;
- Conclusions regarding the potential of exposure and possible impacts to fish and wildlife on or about the site.

This FWIA was initially prepared for the RI report issued in 2000 that encompassed the entire Clifton site. Because the conclusions regarding the potential for adverse impacts to flora and fauna were not significantly altered by the additional data collected during the supplemental RI, a decision was made not to revise the previously submitted FWIA. Consequently, the initial FWIA is being re-issued in this report and is reproduced in its entirety on the following pages.

7.2.1 Fish and Wildlife Resources

Terrestrial Resources

The U.S. Fish and Wildlife Service and the NYSDEC Natural Heritage Program were contacted regarding species of concern, significant habitats, and fishery resources within two miles of the site. In addition, a field reconnaissance survey of the site and surrounding 0.5-mile radius was conducted on September 2, 1999. The objectives of the survey were to:

- Map and describe plant communities and aquatic resources on and adjacent to the site;
- Observe wildlife species;
- Identify significant ecological resources; and
- Observe evidence of stress to plants and animals, if any, from site-related chemicals.

Approximately two-thirds of the area within the 0.5-mile radius of the site is upland. Currently, commercial uses dominate the land within 0.5 mile of the site. The residential areas consist of buildings surrounded by maintained lawns and ornamental plantings. Commercial establishments are covered by buildings and asphalt. Little vegetation exists to support wildlife populations. As a result, much of the area is classified as paved road or urban structure exterior. The paved road category includes much of the site, parking lots, streets, and sidewalks. The residential areas consist of buildings surrounded by maintained lawns and ornamental plantings.

Aquatic Resources – New York Harbor

The site lies within the New York Harbor drainage basin. A Comprehensive Conservation and Management Plan (CCMP) has been developed for the Harbor. The areas of concern outlined in the CCMP are: habitat and living resources, toxic contamination, nutrients and organic enrichment, pathogenic contamination, dredged material management, floatable debris, and rainfall-induced discharges. The NYSDEC classifies the New York Harbor as "SI" indicating the water is suitable for fish propagation and fish survival.

The Narrows section of New York Harbor is approximately 600 feet to the east and northeast of the site. The drowned mouth of the Hudson River forms much of New York Harbor. The physical constraints of Manhattan and New Jersey, Brooklyn and Staten Island define the harbor in the area known as the Upper Bay. The Narrows links the Upper Bay to the Lower Bay, south of Staten Island and the Atlantic Ocean.

The estuarine setting to the east of the site within the 0.5-mile radius includes intertidal and subtidal communities formed largely by artificial conditions and the influence of the Hudson River. To the south-southeast of the site and south of commercial piers, the intertidal and higher shoreline consists of rip/rap and artificial structures. The developed shoreline within 0.5-mile southeast and east of the site involves pilings from two former piers that remain in near-shore water north of the site. The pilings and shoreline bulkheads that extend through intertidal and subtidal zones provide substrate for sedentary life forms, such as microbes, algae and invertebrate epifauna (hydroids, polychaete worms, amphipods and bryozoans), as well as refuge, browsing habitat and spacial reference for mobile organisms, such as crabs and fish, including such species as tautog (*Tautoga onitis*) and cunner (*Tautogolabrus ad.spersus*).

Offshore, beyond the piers, the Narrows constitute a coastal inlet between the Atlantic Ocean and the Hudson River. Resident and seasonal fish species known from the coastal ocean and lower Hudson estuary could be expected in the Narrows. Resident fish include bay anchovy (Anchoa mitchilli), silverside (Membras martinica and Menidia spp.), scup (Stenotomus chrysops), spot (Leiostomus xanthurus), and winter flounder (Pseudopleuronectes americanus). Seasonal species include warm-weather visitors: menhaden (Brevortia tyrannus), Atlantic needlefish (Strongylura marina), juvenile bluefish (Pomatomus saltatrix), weakfish (Cynoscion regalis); and anadromous species, that pass through the area when moving to and from Hudson River waters, such as Atlantic sturgeon (Acipenser oxyrhynchus), shad (Alosa sapidissima) and striped bass (Morone saxatilis).

Redevelopment of the Staten Island waterfront to the northeast and north of the site, between 0.5 and 1 mile away, occurred during the early 1990s as part of the US Navy’s Stapleton Homeport Program. Former piers were removed, a million cubic yards of dredging occurred and a new pier was constructed. One maintenance dredging event occurred following construction of the new pier. Planned Navy use of the new facility never occurred, but the US Coast Guard operated from the facility until recently (USACOE, 2000). As a result of the Homeport project, significant modification occurred during the past 10 years within the subtidal and intertidal zones between 0.5 and 1.0 miles from the site.

The Narrows area is inherently a relatively deep part of the harbor. The waters northeast and southeast between one and two miles of the site include areas with depths >50 feet. In the vicinity of active piers, water depths may be as much as 40 feet.

7.2.2 Freshwater and Tidal Wetlands

Wetlands have been identified on the U.S. Fish and Wildlife National Wetland Inventory (NWI) Maps (The Narrows and Jersey City, NY-NJ quadrangles) and NYSDEC Tidal Wetland Maps (see Figure 7-2C). Portions of the New York Harbor near the site are mapped as an estuarine, intertidal, aquatic bottom, agael, regularly flooded wetland (E2AB1N). Some of the remaining wetlands are downgradient from the site. However, there are no known direct migration pathways from the site into the wetlands. Also, due to distance involved and fate and transport mechanisms, no significant effects on wetlands are expected.

7.2.3 Fish and Wildlife Resources

Wildlife uses in the area were evaluated using literature sources and field observations. Wildlife sightings included direct observations and identifications based on vocalizations, tracks, browse, and scat. General wildlife values (e.g., food and cover availability) also were noted.

Federally listed endangered, threatened or species of concern are not known to occur within two miles of the site (Clough, 1999). Seven state-listed endangered species were identified as occurring within two miles of the site (Christoffel, 2000) (see Figure 7-2C). In addition, one significant habitat, serpentine barrens, was identified as occurring within two miles of the site.

The surrounding two-mile radius consists of residential homes and industrial/ commercial properties. These areas typically consist of mowed lawns interspersed with trees and shrubs, which often times are introduced exotics used for ornamental purposes. These areas do not support an abundance of wildlife because of the lack of vegetation, which could provide food and cover, and constant human activity. The unmown lot near the gate station and the narrow strip of vegetation along the right-of-way do provide habitat for wildlife. However, the small size limits the size of the population it can support. The herptile (amphibian and reptile), bird, and mammal species that may potentially occur within and adjacent to the site based on the land uses identified during the field reconnaissance are listed in the table below. The species observed during the field reconnaissance (which are representative for the point in time of the field reconnaissance) are also identified.

7.2.4 Observation of Stress

Signs of stress to vegetation and wildlife from site-related chemicals were not observed during the field reconnaissance.

7.2.5 Value of Habitat to Associated Fauna

The site and adjoining terrestrial properties are of little value to wildlife. The area is developed, and only isolated pockets of vegetation exists, and in most cases these areas are maintained by frequent mowing. The wildlife expected to occur in the vicinity of the site includes more urbanized bird and mammalian species such as mockingbird (*Mimus polyglottos*), gray squirrel (*Sciurus carolinensis*), and Norway rat (*Rattus norvegicus*).

Species That May Potentially Occur on or Adjacent to the Site

Common Name	Scientific Name	Habitat Preference
Northern brown snake	*Stirerua dekayi*	Ubiquitous.
Eastern garter snake	*Thamnophis sirtalis*	Ubiquitous.
Eastern American toad	*Bufo americanus*	Found in almost any habitat.
Killdeer	*Charadrius vociferous*	Lawns, open areas.
Rock dove[a]	*Columba livia*	Open areas near human habitations.
Mourning dove	*Zenaida macroura*	Open areas, lawns, and woodland edges.
Chimney swift	*Chaetura pelagica*	The vicinity of buildings in towns, cities and farms.
Barn swallow	*Hirundo rustica*	Man-made structures near open areas.
House wren	*Troglodytes aedon*	Near human dwellings with sufficient wooded vegetation.
European starling	*Sturnus vulgaris*	Farms, cities, gardens, parks.
Common grackle	*Quiscalus quisscula*	Suburbs, parks, cities.
House Finch	*Carpodacus mexicanus*	Suburban and Urban yards.
House sparrow[a]	*Passer domesticus*	Villages, cities.
Eastern mole	*Scalopus aquaticus*	Lawns.
Norway rat	*Rattus norvegicus*	Near human habitation.
House mouse	*Mus musculus*	Buildings.
Meadow	*Microtis pennsylvanicus*	Fields, lawns.

Notes:
[a] Species observed by sight or sound during field reconnaissance.
Source: DeGraaf and Rudis, 1983; Conat and Collins, 1975; Burt and Grossenheider, 1976

7.2.6 Value of Resources to Humans

The site and surrounding area are of little value to humans for recreational use of wildlife. Bird feeders may be in residential yards. The developed nature of the area precludes small game and deer hunting.

7.2.7 Applicable Fish and Wildlife Criteria and Standards

Site-specific criteria protective of fish and wildlife resources associated with the site that may be applicable to future remediation are included in:

- Migratory Bird Treaty Act, which protects migratory birds, their eggs and nests from harm.

7.2.8 Exposure Pathways Analysis

Chemicals of Potential Ecological Concern

A number of substances were detected in soil and groundwater. Some are naturally occurring. Some are less toxic than others. In order to focus the FWIA on those chemicals that may pose risks to the environment, COPECs were selected.

For this assessment, the chemicals detected in groundwater are not considered COPECs for ecological receptors except indirectly as a potential source of contamination to the surface water or sediment downgradient of the site. The depth to groundwater is generally greater than three feet below ground surface (bgs), which is below the root zone of most plants. Where groundwater is less than three feet bgs, the area is unvegetated and/or paved. Therefore, no exposure routes exist, and the chemicals detected in groundwater are not discussed.

Surface and subsurface soil samples were collected from the site and analyzed for VOCs, SVOCs, RCRA metals and total cyanide. Only shallow subsurface soils (up to four feet below ground surface) were considered in this FWIA. A total of 64 samples (36 surface soil and 28 subsurface soil) were analyzed in this depth interval. Data for deeper subsurface soils were not evaluated due to lack of exposure routes to wildlife. Most burrowing animals create dens in the upper four feet of soil. In addition, the deeper subsurface soil samples (i.e., greater than four feet) are below the root zone of most plants. Essential nutrients (calcium, iron, potassium, sodium and magnesium) are not considered COPECs.

Sec-butylbenzene, 3-Nitroaniline, di-n-butylphthalate, hexachlorobenzene and isophorone were detected infrequently (i.e., in less than 5% of the samples with sample sizes greater than 20 samples). Therefore, these chemicals are not considered COPECs for this assessment.

Chemical Migration and Fate

The COPECs consist of VOCs, PAHs and metals.

Volatile Organic Compounds – The VOCs of concern have high vapor pressures and, therefore, would be expected to volatilize readily from surface soil to the atmosphere. Once released to the atmosphere, these compounds are rapidly photodegraded.

In deeper soils, these compounds degrade slowly, are water soluble and may leach into groundwater. These compounds have low octanol/water coefficients (log K_{ow}) and, therefore, do not sorb to sediment or particulate matter present in the water column.

PAHs - PAHs are a major component of coal tars. PAHs contain only carbon and hydrogen and consist of two or more fused benzene rings in linear, angular or cluster arrangements. The number of rings in a PAH molecule affects its biological activity, and fate and transport in the environment. In general, most PAHs can be characterized as having low vapor pressure, low to very low water solubility, low Henry's Law constant, high log K_{ow}, and high K_{oc}.

Although PAHs are regarded as persistent in the environment, they are degradable by microorganisms. Environmental factors, microbial flora and physicochemical properties of the PAHs themselves influence degradation rates and degree of degradation. Important environmental factors influencing degradation include temperature, pH, and redox potential and microbial species. Physicochemical properties, which influence degradation, include chemical structure, concentration and lipophilicity.

Metals – In a terrestrial setting, trace elements released to the environment accumulate in the soil (Sposito and Page, 1984). Mobility of these trace elements in soil is low and accumulated metals are depleted slowly by leaching, plant uptake, erosion, or chelation. The half-life of trace elements in temperate climate ranges from 75 years for cadmium to more than 3,000 for zinc.

The transport of trace elements in soil may occur via the dissolution of metals into pore water and leaching to groundwater, or colloidal or bulk movement (i.e., wind or surface water erosion). The rate of trace element migration in soil is affected by the chemical, physical and biological characteristics of the soil. The most important characteristics include:

- Eh-pH system;
- Cation exchange capacity and salt content;
- Quantity of organic matter;
- Plant species;
- Water content and temperature; and
- Microbial activity.

Metals that do mobilize from the soil into the water column are most mobile under acid conditions and increasing pH usually reduces their bioavailability (McIntosh, 1992).

The migration pathways for chemicals are illustrated on Figure 7-1 of the report.

Exposure Pathways

Wildlife resources in the commercial/residential area surrounding the site are limited due to the lack of food and cover. Also, constant human disturbance limits the population to wildlife species more tolerant of human activity. No state or federally listed species were identified as occurring on the site. Several wetlands were identified in the two-mile radius study area. These wetlands are currently too distant and/or up-gradient of the site for any likely exposure to site-related chemicals. Also, some of the COPECs are selected metals and PAHs. The fate and transport mechanisms of these chemicals reduce the likelihood of future migration into these areas. Thus, exposure is likely to be limited to wildlife on, near, or immediately downgradient from the site.

Plant roots are not discriminating in the uptake of small organic molecules (molecular weight less than 500) except on the basis of polarity. The more water soluble molecules pass through the root epidermis and translocate throughout the plant and are eventually volatilized from the leaves (Efroymson *et al.*, 1997a). Plants selectively uptake metals in soil by absorption from soil solution by the root. Metals may be bound to exterior exchange sites on the root and not actually taken up. They may enter the root passively in organic or inorganic complexes or actively by way of metabolically controlled membrane transport (Kabata-Pendias and Pendias, 1992). Once in the plant, a metal can be stored in the root or translocated to other plant parts. Potential exposure to wildlife could occur through direct contact with or accidental ingestion of contaminated soil or through the terrestrial food chain.

7.2.9 Criteria-Specific Toxicity Assessment

Soil

The NYSDEC does not have soil cleanup criteria relating to the protection of wildlife and the availability of applicable soil screening values in scientific literature is limited. The screening of soil COPECs was conducted by comparing the chemical concentrations to available screening benchmark values derived by the Oak Ridge National Laboratory (Efroymson *et al.*, 1997a, 1997b and Sample *et al.*, 1996) for the U.S. Department of Energy. The benchmark values are the 10^{th}-percentile of the distribution of various toxic effects threshold for the chemicals in soil for a group of organisms.

Transformation or loss due to environmental degradation is not considered in this assessment. It is assumed that following uptake, concentration in soil will equal concentrations in organisms. This assumption overestimates potential risk in that wildlife has limited contact with these chemicals in soil and plants.

Benchmark values for three groups of organisms, where available or derived, are presented in Table 7-9. Terrestrial plants were selected since they are critical in nutrient cycling and are a source of food in the diets of higher animals. Also, plants readily take up the COPECs. Earthworms were selected because of their importance in maintaining soil fertility through burrowing and feeding activities. Also, earthworms are at the base of the food chain and are an important food for higher organisms. Meadow voles were selected to represent an herbivorous small mammal. The benchmark values for meadow vole is presented as dietary concentrations in milligram (mg) of chemical per kilogram (kg) of diet that would result in no observed adverse effect levels (NOAELs). For screening purposes, it was assumed that the chemical concentration in soil would be found in the food items of each species. As stated previously, this is a conservative approach that should result in the overestimation of potential exposure and risk.

As indicated in the table on the following page, screening values are available for a few of the COPECs. Therefore, the methodology of the Oak Ridge National Laboratory (Sample *et al.,* 1996) was used to derive toxicological benchmarks for the meadow vole from published toxicological data for laboratory animals. Literature sources included IRIS (USEPA, 2000), HEAST (USEPA, 1997), and the National Toxicology Program. It should be emphasized that the resulting benchmarks obtained from this methodology and toxicological data are based on a conservative approach whose resulting relationship to potential population effects is uncertain.

No observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs) are daily dose levels normalized to the weight of the test animal [*e.g.,* mg of chemical per kg body weight per day (mg/kg/day)]. The presentation of toxicity data on a mg/kg/day basis allows for comparison across species with appropriate consideration for differences in body sizes. If a NOAEL (or LOAEL) for a mammalian test species ($NOAEL_t$) is available, then the equivalent NOAEL (or LOAEL) for a mammalian wildlife species ($NOAEL_w$) can be calculated by using an adjustment factor for the difference in body size:

$$NOAEL_w = NOAEL_t \times \left({bw_t}/{bw_w} \right)^{1/4}$$

where:

$NOAEL_w$ = No observed adverse effect level for wildlife species (mg/kg/day)
$NOAEL_t$ = No observed adverse effect level for test species (mg/kg/day)
bw_w = Body weight for wildlife species (kg)
bw_t = Body weight for test species (kg)

In some cases, a NOAEL for a specific chemical was not available, but a LOAEL or lethal dose (LD_{50}) had been determined experimentally. The NOAEL can be estimated by applying an uncertainty factor (UF) to the LOAEL or LD_{50}. In the USEPA methodology (USEPA, 1989), the LOAEL or LD_{50} can be reduced by a factor of 10 or 50, respectively, to derive the NOAEL.

The dietary level or concentration in food (C_f) of a chemical in mg of chemical per kg of food that would result in a dose equivalent to the NOAEL can be calculated from the food factor (*f*):

$$C_f = \frac{NOAEL_w}{f}$$

The food factor, (*f*) is the amount of food consumed per day per unit of body weight. The table below provides the body weight, food intake and food factors used in the derivation of chemical-specific NOAELS for the meadow vole. Table 7-8 provides the derived toxicological benchmarks for the meadow vole. When literature values were not available for a chemical, a structurally similar surrogate was used. These surrogates are provided in Table 7-8.

Parameters for Calculation of Toxicological Benchmarks

Organism	Body Weight (kg)	Food Intake (kg/day)	Food Factor *f*
Mouse	0.03	0.0055	0.18
Rat	0.35	0.028	0.08
Dog	12.7	0.301	0.024
Rabbit	3.8	0.135	0.034
Meadow vole	0.044	0.005	0.114

Screening the maximum concentrations of the COPECs against the literature and derived benchmark values (Table 7-9) indicated:

- Several chemicals did not exceed their respective benchmark values and do not pose a risk to environmental receptors. These include 1,3,5-trimethylbenzene, n-butylbenzene, n-propylbenzene, p-isopropyltoluene, tert-butylbenzene, isopropylbenzene, benzene, ethylbenzene, isopropylbenzene, methylene chloride, styrene, anthracene, benzoic acid, benzo(k)fluoranthene, benzyl alcohol, butylbenzylphthalate, diethylphthalate, fluoranthene, bis(2-ethylhexyl)phthalate, beryllium, chromium, cobalt, manganese, nickel, selenium, cyanide, dieldrin, heptachlor, indeno(1,2,3-cd)pyrene, and endosulfan sulfate.

- Several chemicals exceeded their respective benchmark values and may pose a risk to environmental receptors. They include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, dibenzofuran, 1,2,4-trimethylbenzene, acetone, carbon tetrachloride, toluene, xylene, 2,4-dimethylphenol, 2-methylnaphthalene, 4-methylphenol, acenaphthene, carbazole, di-n-octylphthalate, fluorene, n-nitrosodiphenylamine, naphthalene, phenanthrene, phenol, pyrene, antimony, arsenic, barium, cadmium, copper, lead, mercury, silver, thallium, vanadium, and zinc.

7.2.10 Conclusions

Habitat Characteristics

The site reconnaissance conducted as part of this analysis indicates the site and surrounding area are poor quality environmental resources, due to the limited presence of vegetation. The site is mostly covered with buildings and asphalt. Wildlife species, typically present are adapted to urban setting. Due to the size of the vegetated areas, only a few individuals will be present. The New York Harbor and several wetland areas are located within 2 miles of the site. Potential migration of COPECs into these resources should be prevented.

Soil

Several COPECs were detected at concentrations greater than the toxicological benchmark values. This suggests that these chemicals may pose a risk to wildlife. In addition, toxicological benchmarks were not derived for several COPECs. However, these potential effects have minimal ecological significance.

The potential risk from COPECs is minimal, for several reasons. Exposure frequency, chemical concentration (especially within the upper 6 inches), mechanism of exposure, and duration of exposure determines risk. The commercial area (i.e., paved areas, buildings, etc.) provides minimal habitat in the form of "weedy" patches that would not support a wildlife population. This area experiences constant physical disturbance that prevents populations of wildlife from developing. Because only transient species and a few individual animals would use this area, the frequency and duration of exposure is limited. Thus, the observed chemicals detected on-site do not pose a current impact, nor is any expected in the future.

8. Summary of Findings

The overall extent of tar, staining, sheen, odors, and chemical constituents detected in soils was located primarily adjacent to former Relief Holder No. 2 located at the 40 Willow Avenue parcel because the ground moraine unit was not as fine-grained and tar blebs and odors extended up to 100 feet bgs. In all instances, the vertical extent of tar ceased prior to encountering saprolite (weathered bedrock) at about 125 feet deep. Some tar impacts were noted deeper than 24 feet bgs beneath the Lynhurst Avenue residential parcels and within the Lynhurst Avenue ROW. These tar-related observations were confined to discrete intervals within minor layers of sands with tar, staining, sheen, and odors. No visible evidence of tar, staining or sheen, odors, or positive PID detections were observed in borings completed on the Lynhurst Avenue parcels above 24 feet bgs or within the Lynhurst Avenue ROW above 40 feet bgs.

In general, elevated levels of TPAH, CPAH, and BTEX correlated with the occurrence of observable tar, odors and/or sheen. Where physical evidence of tar was not encountered, analyses indicated generally low to trace levels of these chemical constituents. As with the observed extent of tar, staining, odors, etc., the overall extent of chemical constituents was generally limited to the 40 Willow Avenue parcel, and to a discrete interval beneath the Lynhurst Avenue residential parcels and Lynhurst Avenue.

Soil analytical data from the adjoining parcels, where tar was not observed, indicated very low to non-detect concentrations of BTEX and total PAHs. Adjoining the 40 Willow Avenue parcel, the highest BTEX concentration in soil was 0.1 ppm in the 12- to 16-foot sample from boring SB-66. This BTEX level corresponds with observed odors at this interval. The highest total PAH concentration detected was 31.4 ppm in the 0- to 2-foot sample from boring SB-66. The elevated PAHs correspond with observed black staining at this interval.

Surface-soil analytical data from the Lynhurst Avenue residential parcels indicates that elevated lead levels were encountered. These lead-impacted surface soils were mitigated as part of an IRM conducted at the parcels.

Similarly, dissolved chemical constituents in groundwater within the water table aquifer appear predominantly limited to the 40 Willow Avenue parcel. Dissolved phase BTEX and PAHs were present in groundwater within the deep aquifer at well RW-14, adjacent to Relief Holder No. 2 (40 Willow Avenue parcel).

Shallow soils containing lead were identified on the off-site residential parcels on Lynhurst Avenue during the course of investigation. From September 2002 to July 2003, an interim remedial measure (IRM) was conducted in accordance with the approved March 2002 IRM work plan to remove lead-containing soils to a target depth of 3 feet below ground surface on the residential parcels. The implementation of this IRM eliminated any potential contact by the residents with the lead containing soil.

The findings of VHB's human health risk assessment indicate that measures are required to mitigate potential on-going exposures to site-related chemicals at the 40 Willow Avenue parcel. A feasibility study report has been prepared to assess the appropriate means to mitigate the conditions related to the former relief holder on the 40 Willow Avenue parcel. The draft feasibility study was issued in December 2002. The findings of the qualitative human exposure assessment and the fish and wildlife impact analysis are discussed further below.

8.1 Qualitative Human Exposure Assessment

The qualitative human exposure assessment focused on chemical distribution and the potential human exposure that may exist within OU-1. The results of this assessment are presented by media (surface soil, subsurface soil, and groundwater) and are organized by off-site (Lynhurst Avenue residential parcels) and on-site (40 Willow Avenue). A summary of the findings is presented below.

Lynhurst Avenue Residential Parcels (Off site)

Results of the screening of the surface soil sample results against background concentrations indicate that soils were generally consistent with background conditions with the exception of soils with levels of lead that were above background conditions. The Lynhurst Avenue residential parcel backyards (off-site parcels adjacent to 40 Willow Avenue) have undergone excavation to 3 feet bgs as part of an IRM to mitigate elevated lead levels within soils. The excavation was subsequently backfilled with clean fill. Based on current and expected future use by the residents and concentrations consistent with background conditions, potential exposures to surface soils are not exposure pathways of concern.

Analytical subsurface soil results compared to TAGM values revealed that concentrations were above established TAGM values. However, the potential for exposure to subsurface soils was considered minimal based upon the current residential land use and the clean material placed into the backyards of the residences as part of the IRM currently being completed.

Analytical groundwater results were present at levels that were detected below applicable TAGM standards. Currently, residences are served by municipal water supply and any future residential development would also be connected to the current municipal water supply system. In addition, no groundwater supply wells were observed during the investigation activities at the parcels. As a result, exposure to potentially groundwater analytes would likely not occur under current or future land use.

Analysis of potential inhalation of vapors in ambient and indoor air and inhalation of wind-born particles present in soils and waters were determined not to be an exposure pathway of concern.

40 Willow Avenue (On site)

Results of the screening of the surface soil samples indicate that constituents were detected in surface soils that exceeded the range of background concentrations and exceeded the applicable TAGM concentrations. Consequently, exposure to these soils presents a potential pathway of concern. However, based on the current site conditions, access to these soils is limited by a locked chain-link fence. Under current operation as a gate station, minimal visits are made to the site by KeySpan personnel to maintain the operation of the facilities. During these visits, time is spent within the gate station and soils are not disturbed. Any future intrusive activities that involve soils on the 40 Willow Avenue could likely result in a potential exposure pathway.

Several chemicals in groundwater are present at conditions that exceed applicable TOGS. Potential exposure pathways would likely include direct contact exposures to those involved with intrusive work. This is consequently a potential pathway of concern for future activities; however, direct contact to groundwater is currently an incomplete exposure pathway.

Based upon detected values of analytes within soils and groundwater at the parcel, the potential inhalation of vapors and particulates from soils and groundwater was evaluated and was determined to be a potential exposure pathway.

8.2 Fish and Wildlife Impact Analysis

The site reconnaissance conducted as part of the RI indicated the site and surrounding area to be poor quality environmental resources, due to the limited presence of vegetation. As such, the wildlife species typically present are adapted to the current urban setting. Due to the limited size of the vegetated areas, only a few individuals will be present. The New York Harbor and several upgradient wetland areas are located within 2 miles of the site.

The potential risk from COPECs observed at the site is minimal for several reasons: exposure frequency, chemical concentration (especially within the upper 6 inches), mechanism of exposure, and duration of exposure determine risk. The commercial area (i.e., paved areas, buildings, etc.) provides minimal habitat in the form of "weedy" patches that would not support a wildlife population. This area experiences constant physical disturbance that prevents populations of wildlife from developing. Because only transient species and a few individual animals would use this area, the frequency and duration of exposure is limited. Thus, the chemicals detected on site do not pose a current risk to wildlife, nor is any expected in the future.

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