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Remedial Investigation Report

Former Dangman Park Manufactured Gas Plant Site

Brooklyn, New York

Site No. 224047

Index # A2-0552-0606

July 31, 2014

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Our Ref.:
B0036704.0001.00414

Date:
July 31, 2014

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Acronyms and Abbreviations

ASP	Analytical Services Protocol
bls	below land surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAMP	Community Air Monitoring Plan
cis-1,2-DCE	cis-1,2-dichloroethene
COCs	constituents of concern
COPCs	constituents of potential concern
CSM	conceptual site model
DQO	data quality objective
DNAPL	dense non-aqueous phase liquid
DOT	Department of Transportation
DUSR	data usability summary report
EPA	United States Environmental Protection Agency
FSP	Field Sampling Plan
ft bls	feet below land surface
ft/d	feet per day
GPR	ground penetrating radar
HASP	Health and Safety Plan
HHEA	human health exposure assessment

IDW	investigation-derived waste
K	hydraulic conductivity
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
LNAPL	light non-aqueous phase liquid
MGP	manufactured gas plant
MIBK	methyl isobutyl ketone
msl	mean sea level
NAPL	non-aqueous phase liquid
National Grid	The Brooklyn Union Gas Company d/b/a National Grid NY
NGVD	National Geodetic Vertical Datum
NTUs	nephelometric turbidity units
NYCRR	New York State Codes, Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
PDI	pre-design investigation
PID	photoionization detector

PPE	personal protective equipment
PUL	precision utility location
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RI	Remedial Investigation
SC	Site Characterization
SCOs	soil cleanup objectives
SCGs	standards, criteria, and guidance
SVOCs	semi-volatile organic compounds
TAL	Target analyte list
TCE	trichloroethene
TCL	Target compound list
TOGS	Technical and Operational Guidance Series
trans-1,2-DCE	trans-1,2-dichloroethene
VAP	vertical aquifer profiling
VC	vinyl chloride
VI	vapor intrusion
VOCs	volatile organic compounds

Executive Summary

On behalf of The Brooklyn Union Gas Company d/b/a National Grid NY (National Grid), ARCADIS has prepared this Remedial Investigation (RI) Report for the former Dangman Park Manufactured Gas Plant (MGP) site (Site) located at 486 Neptune Avenue, Brooklyn, New York. The Site location is shown on Figure 1. The Site occupies portions of two parcels located along Neptune Avenue and W. 5th Street (see Figure 2). The Site was operated by the Brooklyn Borough Gas Company, which was a predecessor company to National Grid.

Based on the findings of the Site Characterization (SC) and a July 13, 2010 meeting between the New York State Department of Environmental Conservation (NYSDEC), National Grid, and ARCADIS, it was determined that the RI activities were to be conducted on two parcels (Block 7273, Lots 1 and 25) located along Neptune Avenue and W. 5th Street. In addition to the RI activities that were conducted on Lots 1 and 25, two (2) water-table monitoring wells were installed on Lot 50 to develop a further understanding of the groundwater flow regime. Furthermore, based on the RI data that were collected from Block 7273, Lots 1 and 25 and a NYSDEC request, supplemental RI activities were conducted on Block 7250, Lot 1. The RI work was conducted in accordance with the NYSDEC-approved RI Work Plan dated September 1, 2011 and the NYSDEC-approved RI Work Plan Addendum dated February 5, 2013. The RI was conducted in a dynamic manner to allow flexibility in the technical approach via phasing of field efforts to maximize the effectiveness of data collection efforts.

The Site is located in the New York City neighborhood of Coney Island, within Brooklyn Community District 13, on approximately 1 acre of land, and is contained within Lots 1 and 25 of Block 7273, which are bounded by Neptune Avenue to the north, W. 5th Street to the east, a residential parcel to the south, and a commercial parcel to the west. Currently, the Site is developed with a shopping center and a parking lot for a high-rise apartment building. The eastern portion of the shopping center is situated above the former MGP structures. The majority of the Site is either paved or developed with buildings.

Based on a review of available historical information, the Site was used as a MGP site from prior to 1895 until sometime between 1906 and 1930. The 1895 Sanborn map shows two gas holders, a retort house, two oil tanks, a tar tank, an engine room, a purifying house, and a shed. By 1906, the MGP Site was operated by the Brooklyn Borough Gas Company; an additional gas holder, generating house and cistern had been constructed, and the retort house and tar tank were no longer present. The MGP structures were removed sometime between 1906 and 1930. By 1930, the Site was occupied by a club house. By 1966, the Trump Village Shopping Center occupied the northern and central portions of the Site. Figure 2 shows the approximate location of the former MGP structures.

The investigation activities conducted during the RI provided data to address the following objectives:

- Determine the nature and extent of MGP-related constituents of concern (COCs) in soil, groundwater, and exterior soil vapor on Lots 1 and 25, and if warranted based on the sampling data collected along the perimeters of Lots 1 and 25, expand the investigation beyond Lots 1 and 25.

- Determine the extent of MGP-related by-product residuals (e.g., coal tar, non-aqueous phase liquid [NAPL], purifier wastes, petroleum, solvents).

- Assess potential impacts to human health and the environment as a result of the release of COCs at the Site.

In accordance with the provisions of the NYSDEC-approved RI Work Plan, the scope of work outlined therein was implemented, but with the allowance for modifications in scope to meet the objectives of the RI (dynamic approach). Modifications to the RI work scope were implemented based on field conditions and were discussed with the NYSDEC; larger changes in scope (i.e., drilling north of Neptune Avenue) were developed and specified in a RI Work Plan Addendum that was submitted to the NYSDEC. Data obtained from implementing the work specified in the RI Work Plan Addendum have been incorporated into this RI Report. This RI Report incorporates data obtained via the NYSDEC-approved RI Work Plan and RI Work Plan Addendum, and, as appropriate, utilizes the previously collected SC data.

The following work was conducted under the supervision of the NYSDEC and pursuant to the NYSDEC-approved RI Work Plan:

- Conducted geophysical surveying (i.e., ground penetrating radar [GPR] and precision utility location [PUL]) at proposed drilling locations to determine whether subsurface utilities were present.

- Drilled and installed four (4) water-table monitoring wells (MW-6 through MW-9) on Lots 25 and 50 to confirm the hydraulic gradient, and to develop a further understanding of the groundwater flow regime and how it influences contaminant transport.

- Drilled thirty-two (32) soil borings in the vicinity of the former MGP operations to determine the three-dimensional extent of the NAPL impacts and collected soil samples for laboratory analysis.

- Drilled five (5) temporary monitoring wells and collected groundwater samples for laboratory analysis.

- Conducted pneumatic slug testing at a subset of the temporary monitoring wells to evaluate the hydraulic conductivity of the formation.

- Drilled and installed eleven (11) monitoring wells (MW-10 through MW-20) to delineate the extent of dissolved-phase impacts. The majority of these monitoring wells are screened below the water table with the exception of MW-15, which is screened across the water table.

- Collected water-level measurements from the monitoring wells and gauged the wells for the presence of NAPL.

- Collected groundwater samples from the monitoring wells.

- Installed four (4) exterior soil vapor points and collected soil vapor samples and one ambient air sample for laboratory analysis.

- Performed a qualitative human health exposure assessment (HHEA) to determine whether Site conditions pose an unacceptable hazard to potentially exposed receptor populations.

Based on the data collected during the SC and RI, the following are the findings and conclusions:

- The Site subsurface deposits consist of fill material between 5 and 15 feet in thickness underlain primarily by glacial sand deposits. No confining layers were observed during the RI drilling activities (to a maximum drilling depth of 115 feet below land surface [bls]).

- There are no groundwater supply wells located at or in the vicinity of the Site. New York City's drinking water is supplied from reservoirs located in upstate New York.

- Beneath the Site, groundwater exists under water-table conditions and ranges from approximately 5.5 to 7.5 ft bls. A local groundwater divide is present on Lot 25 in the vicinity of monitoring well MW-8. The shallow Site groundwater flow direction north of the groundwater divide is generally to the northwest, toward Coney Island Creek. The shallow Site groundwater flow direction south of the groundwater divide is generally to the south, toward New York Bay.

- The average shallow horizontal groundwater velocity may range from approximately 0.09 to 0.5 feet per day (ft/d).

- The primary volatile organic compounds (VOCs) that were detected in soil above standards, criteria, and guidance (SCGs) include benzene, toluene, ethylbenzene, and xylenes (BTEX) constituents. BTEX constituents exceeded the restricted use protection of groundwater soil cleanup objectives (SCOs) and unrestricted use SCOs in three soil samples (SB-6 [43-45'], SB-9 [72-73.5'], and SB-22 [33-34']). In addition, toluene and xylenes exceeded the restricted use protection of public health commercial use SCOs in one soil sample (SB-9 [72-73.5']). VOCs were identified as COCs in soil.

- The primary semi-volatile organic compounds (SVOCs) that were detected in soil above SCGs include polycyclic aromatic hydrocarbons (PAHs). The highest PAH concentrations were detected in soil samples SB-6 (43-45'), SB-9 (72-73.5'), and SB-22 (33-34'). The majority of the other soil samples where PAHs were detected above SCGs were collected from either the 2-3 ft bls interval (detections appear to be associated with the shallow fill material) or the water table interface. SVOCs were identified as COCs in soil.

- Cyanide, metals, polychlorinated biphenyls (PCBs), and pesticides were not identified as COCs in soil.

- The primary VOCs that were detected in groundwater above SCGs include BTEX constituents (in monitoring wells MW-1 through MW-5, MW-10, MW-11, MW-14, MW-15, MW-17, and MW-18 and temporary monitoring wells SB-7, VP-1, and VP-2). VOCs were not detected above SCGs in monitoring wells MW-6 through MW-9, MW-12, MW-13, MW-16, MW-19, and MW-20 and temporary monitoring wells VP-3 and VP-4. VOCs were identified as COCs in groundwater.

- The primary SVOCs that were detected in groundwater above SCGs include PAHs. Naphthalene is the primary PAH that has migrated to the downgradient property boundary of Block 7273, Lot 1. SVOCs were not detected above SCGs in monitoring wells MW-6 through MW-9, MW-12, MW-19, and MW-20 and temporary monitoring wells VP-3 and VP-4. SVOCs were identified as COCs in groundwater.

- Cyanide, metals, PCBs, and pesticides were not identified as COCs in groundwater.

- Neither light non-aqueous phase liquid (LNAPL) nor dense non-aqueous phase liquid (DNAPL) were detected in any of the monitoring wells.

- Potential MGP-related constituents were detected in exterior soil vapor samples collected from soil vapor points SV-1 and SV-2. Toluene was the only potential MGP-related constituent detected in the SV-2 soil vapor sample. No MGP-related compounds were detected at SV-3 or SV-4. Non-MGP-related constituents were detected in exterior soil vapor samples collected from soil vapor points SV-1 through SV-4. Most notably, chlorinated VOCs were detected in the SV-1 (trichloroethene [TCE], cis-1,2-dichloroethene [cis-1,2-DCE], trans-1,2-dichloroethene [trans-1,2-DCE], and vinyl chloride [VC]) and SV-4 (tetrachloroethene [PCE]) exterior soil vapor samples.

- During the SC, PCE and other chlorinated VOCs (TCE, cis-1,2-DCE, and VC) were detected at elevated concentrations in the SSSV-6 sub-slab soil vapor sample. In addition, PCE was detected at an elevated concentration in the SSSV-4 sub-slab soil vapor sample. A number of non-MGP-related constituents detected in indoor air (2-butanone [methyl ethyl ketone], dichlorodifluoromethane (Freon 12), 4-methyl-2-pentanone [MIBK], and PCE) were above typical background indoor air concentrations in four indoor air quality samples. These detected compounds are not associated with historic MGP operations.

- Potential MGP-related constituent vapors are not migrating into the shopping center building at concentrations that may result in an unacceptable human health risk. This is evidenced by the fact that potential MGP-related constituents detected in indoor air were below typical background indoor air concentrations for all indoor air quality samples. Furthermore, the potential MGP-related constituents detected in indoor air may be attributable to other sources (i.e., background sources).

- The MGP-impacted media of concern at the Site are soil and groundwater, and the COCs are principally BTEX constituents and PAHs. In general, the BTEX constituents detected in groundwater during the RI are relatively mobile in groundwater having a moderate to high solubility and/or low organic carbon partition coefficient (K_{oc}) and octanol-water partition coefficient (K_{ow}) values. In contrast, the PAHs detected in groundwater during the RI are relatively immobile in groundwater having a low solubility, with the exception of naphthalene, which has a higher solubility relative to the other PAHs detected in groundwater.

- The primary transport mechanisms for COCs are leaching from soils in source areas to groundwater, volatilization from source areas and shallow groundwater to the soil vapor/atmosphere, and advective groundwater movement.

- The hydrocarbon product identification data for soil samples collected during the SC suggest that fuel oil impacts of unknown origin are present at the water table across the entire area that the former MGP occupied and that coal tar impacts are present at the water table across the central and eastern portion of the area that the former MGP occupied.

- The former gas holders, tar tank, and cistern are all likely sources of the tar releases from the former MGP. Post-MGP operations, such as a dry cleaner, are likely a source of chlorinated VOCs detected in the media at the Site. Post-MGP site uses, such as parking lots and adjacent roadways, are potential sources of shallow petroleum impacts detected in the media at the Site.

- The former MGP operations and the soil and groundwater impacts are located north of the groundwater divide. Soil and groundwater impacts were not encountered south of the groundwater divide.

- The deepest tar-saturated soil was encountered in soil boring SB-9 (downgradient of the former MGP operations and north of the groundwater divide) in the 70 to 75 ft bls soil core. The deepest tar-impacted (i.e., tar blebs) soil was encountered in soil boring SB-4 to a depth of 80 to 90 ft bls. Tar-impacted soil was encountered south (upgradient) of the former MGP operations at shallower depths in soil borings SB-6 (between 40 and 50 ft bls) and SB-22 (between 30 and 40 ft bls); these soil borings are also located north of the groundwater divide. The extent of tar-impacted soil has been horizontally and vertically delineated.

- The highest BTEX and PAH concentrations in soil generally correspond with the observed tar and petroleum hydrocarbon impacts, which are a source of groundwater impacts.

- The highest BTEX and PAH concentrations in groundwater were detected in monitoring wells MW-5 and MW-11 (both screened from 30 to 40 ft bls).

- Concentrations of BTEX constituents and light molecular weight PAH compounds in groundwater have migrated along the groundwater flow path (northwest) to the Block 7273, Lot 1 property boundary. However, the BTEX and light molecular weight PAH concentrations in groundwater significantly attenuate between the former MGP operations area and the Block 7273, Lot 1 property boundary.

- MGP-related impacts are not present south of the soil boring SB-22 area, located immediately south of the former MGP operations area.

- The dissolved-phase groundwater impacts significantly decrease with both vertical and horizontal distance from the limits of tar-impacted soils.

- The soil and groundwater quality data collected from the MW-20 (north of Neptune Avenue) soil boring and monitoring well (screened 80 to 95 ft bls) indicate that the downgradient extent of impacts have been delineated.

- The HHEA evaluated potential exposures associated with soil, groundwater, exterior soil vapor, and ambient air. Soil, groundwater, exterior soil vapor, and ambient air associated with the former MGP Site do not present potentially complete exposure pathways for commercial workers, consumers, or residents based on current land use and are not anticipated to represent complete future exposure pathways for these receptors. Construction and utility workers may be exposed to soil and/or shallow groundwater during intrusive activities, but the use of appropriate health and safety measures can be used to mitigate these exposures.

- Indoor air quality samples were collected from Site businesses during the SC (i.e., Silent Thunder Martial Arts, Kurt Cleaners, and CVS Pharmacy). Indoor air results indicated that potential MGP-related constituent concentrations were all below New York State Department of Health (NYSDOH) typical background indoor air concentrations. As indicated in the Site Characterization Data Summary Addendum, the vapor intrusion pathway for potential MGP-related constituents at the Site is determined to be incomplete.

- Sufficient data have been obtained during the SC and RI to determine the extent of impacts from the former MGP operations. However, additional data may be required to support remedy design due to the existing shopping center building location over the former MGP footprint.

Based on the conclusions provided above, an evaluation of potential remedial actions is recommended for the Site. The majority of the SC and RI drilling locations were situated outside of the approximate former MGP site boundary due to the access limitations associated with the existing shopping center building. The soil investigation achieved the RI objective of determining the nature and extent of potential MGP-related COCs. However, additional soil investigation activities will be required beneath the existing shopping center building to refine the distribution of MGP impacts at the Site in advance of any remedial action. When conditions are amenable, a pre-design investigation (PDI) will be conducted to provide additional data within the approximate former MGP site boundary to support remedy design and implementation.

1. Introduction

On behalf of The Brooklyn Union Gas Company d/b/a National Grid NY (National Grid), ARCADIS has prepared this Remedial Investigation (RI) Report for the former Dangman Park Manufactured Gas Plant (MGP) site (Site) located at 486 Neptune Avenue, Brooklyn, New York. The Site location is shown on Figure 1. The Site occupies portions of two parcels located along Neptune Avenue and W. 5th Street (see Figure 2).

The Site was operated by the Brooklyn Borough Gas Company, which was a predecessor company to National Grid. The MGP operated from prior to 1895 until sometime between 1906 and 1930. The MGP structures were dismantled sometime between 1906 and 1930, and the Site was subsequently sold to and redeveloped by third parties.

This RI Report has been prepared in accordance with the requirements of a Multi-Site Order on Consent and Administrative Settlement (Index # A2-0552-0606) that was entered into by National Grid and the New York State Department of Environmental Conservation (NYSDEC) in February 2007.

A Site Characterization (SC) was conducted at the Site between November 2009 and March 2010 in accordance with the NYSDEC-approved SC Work Plan (ARCADIS, 2009) and the SC Work Plan Addendum – Vapor Intrusion Investigation (ARCADIS, 2010a). The findings of the SC are presented in the SC Data Summary (ARCADIS, 2010b) and SC Data Summary Addendum (ARCADIS, 2010c). Based on the findings of the SC and a July 13, 2010 meeting between the NYSDEC, National Grid, and ARCADIS, it was determined that the RI activities were to be conducted on two parcels (Block 7273, Lots 1 and 25) located along Neptune Avenue and W. 5th Street. In addition to the RI activities that were conducted on Lots 1 and 25, two (2) water-table monitoring wells were installed on Lot 50 to develop a further understanding of the groundwater flow regime. Furthermore, based on the RI data that were collected from Block 7273, Lots 1 and 25 and a NYSDEC request, supplemental RI activities were conducted on Block 7250, Lot 1. The RI work was conducted in accordance with the NYSDEC-approved RI Work Plan (ARCADIS, 2011) dated September 1, 2011 and the NYSDEC-approved RI Work Plan Addendum (ARCADIS, 2013) dated February 5, 2013. The RI was conducted in a dynamic manner to allow flexibility in the technical approach via phasing of field efforts to maximize the effectiveness of data collection efforts.

1.1 Site Background

This section provides the Site description, a summary of the Site history, and a summary of previous investigations conducted at the Site. A detailed description of the Site history is provided in Section 2 of the SC Work Plan.

1.1.1 Site Description

The Site is located at 486 Neptune Avenue in the Borough of Brooklyn, New York City, New York and occupies portions of two parcels that are identified by Tax Map Number: Block 7273, Lots 1 and 25. As shown on Figure 1, the Site is located approximately 1,300 feet southeast of Coney Island Creek and approximately 2,400 feet north of New York Bay. The Site is generally flat with an elevation of approximately 9 feet above mean sea level (msl). The closest natural surface water body is Coney Island Creek, which is located approximately 0.25 miles to the northwest of the Site.

The Site is located in the New York City neighborhood of Coney Island, within Brooklyn Community District 13, on approximately 1 acre of land, and is contained within Lots 1 and 25 of Block 7273, which are bounded by Neptune Avenue to the north, W. 5th Street to the east, a residential parcel to the south, and a commercial parcel to the west. Currently, the Site is developed with a shopping center and a parking lot for a high-rise apartment building. The eastern portion of the shopping center is situated above the former MGP structures. The majority of the Site is either paved or developed with buildings.

Land use and zoning at the Site and the other properties in the area is commercial and residential. Land use to the north is residential and commercial, land use to the east and south is residential, and land use to the west is commercial. The Site is located within a special purpose zoning district designated as the “Special Ocean Parkway District” (New York City Planning Commission Zoning Map, 2013).

1.1.2 Site History

This section discusses the historical use of the Site, with emphasis on the former MGP operations. The information reviewed to produce this summary included:

- Sanborn fire insurance maps
- Aerial photographs (EDR, 2008)

An overview of the historical MGP operations is discussed below. A detailed timeline of key observations based on the review of historical information in connection with the Site and an overview of land use in the Site vicinity is presented in Section 2.2.2 of the SC Work Plan (ARCADIS, 2009).

Based on a review of available historical information, the Site was used as a MGP site from prior to 1895 until sometime between 1906 and 1930. The 1895 Sanborn map shows two gas holders, a retort house, two oil tanks, a tar tank, an engine room, a purifying house, and a shed. By 1906, the MGP Site was operated by the Brooklyn Borough Gas Company; an additional gas holder, generating house and cistern had been constructed, and the retort house and tar tank were no longer present. The MGP structures were removed sometime between 1906 and 1930. By 1930, the Site was occupied by a club house. By 1966, the Trump Village Shopping Center occupied the northern and central portions of the Site. A dry cleaner formerly operated in the shopping center at a different location within the building than that of the current dry cleaner. Figure 2 shows the approximate location of the former MGP structures.

1.1.3 Previous Investigations

This section summarizes the previously completed SC at the Site. The SC data were considered during the preparation of the RI Work Plan and are presented in the SC Data Summary (ARCADIS, 2010b) and SC Data Summary Addendum (ARCADIS, 2010c).

The SC involved the following activities:

- A soil investigation including the drilling of soil borings and the collection of subsurface soil samples for analysis.

- A groundwater investigation including collection of a groundwater sample from a temporary monitoring well, installation of groundwater monitoring wells, collection of groundwater samples, characterization of groundwater flow and quality, and determination of the presence/absence of non-aqueous phase liquid (NAPL).

- A vapor intrusion (VI) investigation including the installation of temporary sub-slab soil vapor points and characterization of sub-slab soil vapor quality, ambient air quality sampling, and indoor air quality sampling.

The key findings of the SC were as follows:

- The primary volatile organic compounds (VOCs) that were detected in soil above standards, criteria, and guidance (SCGs) include benzene, toluene, ethylbenzene, and xylenes (BTEX). VOCs were identified as constituents of concern (COCs) in soil.

- The primary semi-volatile organic compounds (SVOCs) that were detected in soil above SCGs include polycyclic aromatic hydrocarbons (PAHs). SVOCs were identified as COCs in soil.

- Pesticides were not identified as COCs.

- Polychlorinated biphenyls (PCBs) were not identified as COCs in soil.

- Three (3) metals (manganese, selenium, and mercury) were detected in soil above SCGs. These metals may be associated with former MGP operations, but may be present at the Site due to the post-MGP placement of fill material. Metals were identified as potential MGP-related COCs in soil.

- Total cyanide was detected in soil above its SCG in one soil sample; similar to metals, cyanide may be associated with the post-MGP placement of impacted fill material. Free cyanide was only detected in one soil sample. Total cyanide was identified as a potential MGP-related COC in soil.

- The primary VOCs and SVOCs that were detected in groundwater above SCGs include BTEX and PAHs, respectively. VOCs and SVOCs were identified as COCs in groundwater.

- Pesticides, metals, and cyanide were not identified as COCs in groundwater.

- PCBs were not detected in groundwater above the laboratory reporting limits.

- Neither light non-aqueous phase liquid (LNAPL) nor dense non-aqueous phase liquid (DNAPL) were detected in any of the monitoring wells.

- The hydrocarbon product identification data for soil samples suggest that fuel oil impacts of unknown origin are present at the water table across the entire area that the former MGP occupied and that coal tar impacts are present at the water table across the central and eastern portion of the area that the former MGP occupied.

- The former gas holders, tar tank, and cistern are all likely sources of the tar releases from the former MGP. Tar-saturated soils were observed in the glacial outwash deposits underlying the Site. The deepest tar-saturated soils were encountered in soil boring SB-1 in the 55 to 60 feet below land surface (ft bls) soil core.

- The highest BTEX and PAH concentrations in soil generally correspond with the observed tar and petroleum impacts, which are a continuing source of groundwater impacts.

- The extent to which elevated concentrations of BTEX and light molecular weight PAH compounds in groundwater have migrated along the groundwater flow path (northwest) is unknown.

- Further investigation is required to characterize the distribution of MGP residuals on Block 7273, Lot 1 and the adjacent parcel to the south (Lot 25), and to delineate the lateral and vertical extent of groundwater impacts downgradient (i.e., northwest) of the former MGP.

- Potential MGP-related constituent vapors are not migrating into the shopping center building at concentrations that may result in an unacceptable human health risk. This is evidenced by the fact that potential MGP-related constituents detected in indoor air were below typical background indoor air concentrations for all indoor air quality samples. Furthermore, the potential MGP-related constituents detected in indoor air may be attributable to other sources (i.e., background sources).

- Tetrachloroethene (PCE) and other chlorinated VOCs (trichloroethene [TCE], cis-1,2-dichloroethene [cis-1,2-DCE], and vinyl chloride [VC]) were detected at elevated concentrations in the SSSV-6 sub-slab soil vapor sample. A number of non-MGP-related constituents detected in indoor air (2-butanone [methyl ethyl ketone], dichlorodifluoromethane (Freon 12), 4-methyl-2-pentanone [MIBK], and PCE) were above typical background indoor air concentrations in four indoor air quality samples. These detected compounds are not associated with historic MGP operations. The SC Data Summary Addendum, which includes the VI investigation data and a figure showing the sub-slab soil vapor and indoor air quality sample locations, is provided in Appendix I.

1.2 Remedial Investigation Objectives and Approach

This section lists the specific objectives of the RI, provides an overview of the scope of RI activities, and describes the methods employed to implement the scope and achieve the objectives of the RI.

1.2.1 Objectives

The activities conducted during the RI provided data to address the following objectives:

- Determine the nature and extent of potential MGP-related COCs in soil, groundwater, and exterior soil vapor on Lots 1 and 25, and if warranted based on the sampling data collected along the perimeters of Lots 1 and 25, expand the investigation beyond Lots 1 and 25.

- Determine the extent of MGP-related by-product residuals (e.g., coal tar, NAPL, purifier wastes, petroleum, solvents).

- Assess potential impacts to human health and the environment as a result of the release of COCs at the Site.

1.2.2 Scope

In accordance with the provisions of the NYSDEC-approved RI Work Plan, the scope of work outlined therein was implemented, but with the allowance for modifications in scope to meet the objectives of the RI (dynamic approach). Modifications to the RI work scope were implemented based on field conditions and were discussed with the NYSDEC; larger changes in scope (i.e., drilling north of Neptune Avenue) were developed and specified in a RI Work Plan Addendum that was submitted to the NYSDEC. Data obtained from implementing the work specified in the RI Work Plan Addendum have been incorporated into this RI Report. This RI Report incorporates, as appropriate, data obtained via the NYSDEC-approved RI Work Plan and RI Work Plan Addendum, and utilized the previously collected SC data. The data collection plans, reports, and report results used to guide the RI data collection efforts are listed below:

- Remedial Investigation Work Plan Addendum dated February 5, 2013 (ARCADIS, 2013).

- Remedial Investigation Work Plan dated September 1, 2011 (ARCADIS, 2011).

- SC Data Summary Addendum (ARCADIS, 2010c).

- SC Data Summary (ARCADIS, 2010b).

1.2.3 Methods

The NYSDEC-approved RI Work Plan developed the framework and rationale for RI decision-making using a dynamic approach. Specifically, real-time acquisition of screening-level data, vertical profiles of soil and groundwater, and acquisition of exterior soil vapor data, coupled with ongoing data analysis and interpretation, allowed for timely decisions to be made. By proceeding in this manner, screening-level data were considered during the decision-making process and thereby subsequent data collection was optimized. Additionally, the provision for development of a supplemental RI Work Plan was included in the NYSDEC-approved RI Work Plan so that additional data collection could be approved by the NYSDEC. In total, one RI Work Plan Addendum was prepared, submitted to the NYSDEC, and implemented. The RI Work Plan Addendum outlined the proposed soil boring drilling and monitoring well installation (on Block 7250, Lot 1) that was requested by the NYSDEC to delineate the downgradient extent of MGP-related impacts that were identified on Block 7273, Lot 1.

1.2.4 Quality Assurance/Quality Control

In accordance with the procedures and protocols set forth in the NYSDEC-approved RI Work Plan, approved quality assurance/quality control (QA/QC) protocols were implemented during the RI process. These included:

1. Following approved methods and standard operating procedures for RI field work, including drilling, sample collection activities, field decontamination procedures, and investigation-derived waste (IDW) management, in accordance with the Field Sampling Plan (FSP).

2. Following methods for sample control, handling, and shipment, as well as laboratory and field QA/QC, in accordance with the Quality Assurance Project Plan (QAPP).

3. Following acceptable health and safety practices in accordance with the Health and Safety Plan (HASP).

4. Maintaining project QA/QC in field decision-making, data management, data reduction, and analysis through utilization of the chain-of-command structure set forth in the Project Management Plan.

2. Physical Characteristics

This section describes the Site characteristics including surface features, surface water hydrology, and drainage. Also described in this section is a summary of regional geology and hydrogeology, as well as demography and land use, that collectively provided the basis for development of the strategy to meet RI objectives. The understanding of local geology and hydrogeology and other local physical characteristics, as developed based on the SC and RI data, is provided in Section 4.

2.1 Surface Features

The Site is generally flat with an elevation of approximately 9 feet above msl. The Site has been fully developed as a shopping center and a parking lot for a high-rise apartment building as described in Section 1.1.1.

2.2 Surface Water Hydrology

Natural surface water features do not exist at the Site. The Site is located approximately 1,300 feet southeast of Coney Island Creek and approximately 2,400 feet north of New York Bay. The closest natural surface water body is Coney Island Creek, which is located approximately 0.25 miles to the northwest of the Site.

2.3 Drainage

Storm drains are located throughout the parking areas and receive stormwater runoff from the paved areas. The storm drains discharge the stormwater runoff to the New York City sewer system.

2.4 Demography and Land Use

Land use and zoning at the Site and the other properties in the area is commercial and residential. Land use to the north is residential and commercial, land use to the east and south is residential, and land use to the west is commercial. The Site is located within a special purpose zoning district designated as the "Special Ocean Parkway District" (New York City Planning Commission Zoning Map, 2013).

2.5 Geology

The unconsolidated geologic deposits underlying Kings County consist of clay, silt, sand, and gravel that overlie southward-dipping consolidated bedrock. The crystalline bedrock consists mainly of Precambrian age granite, gneiss, and schist. The overlying unconsolidated sediments were deposited during the Cretaceous and form, in ascending order, the Raritan and Magothy Formations. During the Pleistocene, several episodes of glaciation eroded the Cretaceous deposits (Smolensky, et al, 1989). The oldest Pleistocene deposit is the Jameco Gravel (Jameco aquifer), which overlies the Magothy Formation and Raritan confining unit and is present only in western Long Island. The Gardiners Clay overlies the Jameco Gravel, Magothy Formation, and Raritan confining unit in western Long Island (including Kings County). The Upper Pleistocene deposits formed when the glacial ice and glacial meltwater deposited till and outwash material, forming what is presently known as the Upper Glacial aquifer.

The Raritan Formation consists of the Lloyd Sand and the Raritan Clay. The Lloyd aquifer (the hydrogeologic equivalent of the Lloyd Sand) consists of fine to coarse sand, gravel, commonly with a clayey matrix, and lenses and layers of silty and solid clay. The Raritan confining unit (the hydrogeologic equivalent of the Raritan Clay) is regionally continuous and consists of silty and solid clay, and lenses and layers of sand. Because of its low permeability, the Raritan Clay serves as a confining unit for the underlying Lloyd Sand.

The Magothy Formation is a deltaic deposit consisting of fine to medium sand, clayey in part, interbedded with lenses and layers of coarse sand, silt, and sandy and solid clay. Gravel is common in the basal zone of the Magothy Formation.

The Jameco aquifer (the hydrogeologic equivalent of the Jameco Gravel) is a channel filling consisting of fine to very coarse sand and gravel with few layers of clay and silt (Smolensky, et al, 1989).

The Gardiners Clay is a lagoonal/shallow-bay clay consisting of clay, silt, and few layers of sand and gravel (Smolensky, et al, 1989).

The Upper Glacial aquifer consists primarily of till and glacial outwash deposits. The till, composed of clay, sand, gravel, and boulders, forms the Harbor Hill and Ronkonkoma terminal moraines. These terminal moraines represent the farthest advance of late-Pleistocene glaciation on Long Island. South of the morainal deposits is a glacial outwash plain, which, in Kings County, extends from the Harbor Hill moraine to Jamaica Bay and New York Bay, and consists of fine to very coarse sand and pebble to boulder sized gravel (Smolensky, et al, 1989).

Based on a review of the U.S. Geological Survey publication entitled *Hydrologic Framework of Long Island, New York, U.S. Geological Survey Hydrologic Investigations Atlas HA-709* (Smolensky, et al, 1989), bedrock beneath the Site is found at an approximate elevation of 650 feet below msl. The Lloyd aquifer, which overlies bedrock, has a surface elevation of approximately 500 feet below msl. The Raritan Clay has a surface elevation of approximately 400 feet below msl. The Magothy aquifer has a surface elevation of approximately 250 feet below msl. The Jameco aquifer has a surface elevation of approximately 200 feet below msl. The Gardiners Clay has a surface elevation of approximately 150 feet below msl. The Upper Glacial aquifer corresponds to the saturated upper part of the highly permeable Pleistocene deposits of sand and gravel.

2.6 Hydrogeology

The principal aquifers underlying the project area are the Upper Glacial aquifer, Jameco aquifer, and Magothy aquifer. The Gardiners Clay hydraulically confines the Magothy and Jameco aquifers in most of Kings County; the Jameco aquifer and Magothy aquifer hydrogeologic units are in direct hydraulic connection with each other. Groundwater in the Upper Glacial aquifer occurs under unconfined conditions at and near the Site. Based on available regional data, the average horizontal hydraulic conductivity within the project area for the Upper Glacial aquifer is approximately 270 feet per day (ft/d), with an anisotropy ratio of approximately 10:1 (horizontal to vertical, respectively) (McClymonds and Franke, 1972). The average horizontal hydraulic conductivity of the Jameco aquifer in the project area is approximately 200 to 300 ft/d, with an anisotropy ratio of approximately 10:1 (horizontal to vertical, respectively) (McClymonds and Franke, 1972). The average horizontal hydraulic conductivity of the Magothy aquifer in the project area is approximately 50 ft/d, with an anisotropy ratio of approximately 100:1 (horizontal to vertical, respectively) (McClymonds and Franke, 1972).

The Site is located approximately 1,300 feet southeast of Coney Island Creek and approximately 2,400 feet north of New York Bay. Based on the RI water-level elevation data, a local groundwater divide exists and influences groundwater flow at the Site. The east-west trending groundwater divide is present in the vicinity of monitoring well MW-8, as shown on Figures 3 and 4. The shallow groundwater flow direction north of the groundwater divide is generally to the northwest, toward Coney Island Creek, whereas the groundwater flow direction south of the groundwater divide is generally to the south, toward New York Bay, which is a major groundwater discharge boundary. The depth to groundwater at the Site ranges from approximately 5.5 to 7.5 ft bls.

3. Remedial Investigation Activities

This section discusses the implementation of the RI. The RI was implemented in a dynamic manner, by considering the SC data as well as screening-level data collected during the RI. The SC data are summarized above in Section 1.1.3 (Previous Investigations). Descriptions of the scope of work and methodologies employed during the RI for the investigations of soil, groundwater, and exterior soil vapor/ambient air, and performance of a geophysical survey are provided in this RI Report section. The scope of the RI is summarized in Table 1. The RI sample locations are shown on Figure 2. The majority of the SC and RI drilling locations were situated outside of the approximate former MGP site boundary due to the access limitations associated with the existing shopping center building.

The RI field work utilized a number of subcontractors who acted under the direction of ARCADIS. The identification of and activities performed by RI subcontractors are as follows:

- TestAmerica Laboratories, Inc.: Provided laboratory analytical services associated with soil and groundwater samples.
- Alpha Analytical, Inc.: Provided laboratory analytical services associated with exterior soil vapor samples.
- Boart Longyear Company: Drilled soil borings, installed monitoring wells, and installed exterior soil vapor points.
- Cascade Drilling, L.P.: Drilled soil boring and installed monitoring well.
- Summit Drilling Co., Inc.: Drilled soil borings and installed monitoring wells.
- ZEBRA Environmental Corp.: Drilled temporary monitoring wells and performed pneumatic slug testing.
- Hager-Richter Geoscience, Inc.: Geophysical surveying.
- Donald G. DeKenipp L.S., P.C.: Surveying.

3.1 Geophysical Survey

Geophysical surveying (i.e., ground penetrating radar [GPR] and precision utility location [PUL]) was conducted as part of the RI at proposed drilling locations to determine whether subsurface utilities were present.

3.2 Soil Investigation

This section discusses the soil investigation that was performed during the RI. The data were used to meet RI objectives and to further develop the conceptual site model (CSM) as it relates to soil impacts. Specific activities performed included the drilling of soil borings and collection of subsurface soil samples. The soil investigation achieved the RI objective of determining the nature and extent of potential MGP-related COCs. Additional soil investigation activities will be required beneath the existing shopping center building to refine the distribution of MGP impacts at the Site in advance of any remedial action.

Following the SC, to further characterize soil, a soil boring program was developed for the Site, as outlined in the RI Work Plan. Soil borings were drilled and soil samples were collected in accordance with the procedures and scope outlined in the RI Work Plan. The soil boring sampling activities were conducted between September 2011 and November 2013.

The soil borings were drilled to total depths ranging from 15 to 115 ft bls utilizing direct push drilling techniques (Geoprobe®) and sonic drilling techniques. The final total depths of the soil borings were determined by the field geologist based on field observations (i.e., the boring continued to approximately 10 feet beyond the observed impacts for vertical delineation purposes). Continuous soil core sampling was performed and soil core samples were lithologically logged. Figures 15 through 18 show the impacts that were observed in the soil cores collected from the soil borings. Soil boring SB-1 was drilled during the SC and is located adjacent to RI soil boring/monitoring well SB-5/MW-11; the SB-1 impacts are not shown on Figures 15 and 18 because SB-5/MW-11 serves as the soil boring representative of the impacts at this location. Likewise, soil boring/monitoring well SB-3/MW-5 was drilled during the SC and is located adjacent to RI soil boring/monitoring well SB-4/MW-10; the SB-3/MW-5 impacts are not shown on Figures 15 and 17 because SB-4/MW-10 serves as the soil boring representative of the impacts at this location. It is also relevant to note that the soil cores collected from SB-1 and SB-3/MW-5 were obtained using either a split-spoon sampler or Macro-Core® soil sampler, whereas the soil cores collected from SB-4/MW-10 and SB-5/MW-11 were obtained using a sonic drilling core barrel. These different soil core collection methods can result in a difference in field observations such as the degree of pore fluid saturation (e.g., tar saturated versus tar blebs). Therefore, the observations in the SC soil borings drilled adjacent to the RI soil borings are not shown on the cross sections.

A total of thirty-two (32) soil borings were drilled at the locations shown on Figure 2 and soil samples were collected from twenty-six of the soil borings for laboratory analysis. Six of the soil borings (MW-6 through MW-9, MW-15, and MW-16) were drilled during monitoring well installation activities and soil cores were collected exclusively for lithologic logging purposes. MW-6 through MW-9 are upgradient water-table monitoring wells, and MW-15 and MW-16 are co-located with MW-17 where soil samples were collected for laboratory analysis. As outlined in the RI Work Plan, each soil sample was analyzed for VOCs, SVOCs, target analyte list (TAL) metals, target compound list (TCL) PCBs, total cyanide, and free cyanide. In addition, twenty percent of the soil samples collected from the soil borings were analyzed for TCL pesticides. A summary of the soil samples collected for laboratory analysis during the RI along with the constituents analyzed is provided in Table 1. A discussion of the soil analytical results is provided in Section 5 (Nature and Extent of Constituents in Media).

The number of soil samples collected for laboratory analysis from each soil boring was determined in the field based on visual observations and field screening (i.e., photoionization detector [PID] measurements). Soil samples were denoted by their respective boring number followed by the depth interval (in ft bls) from which the sample was retrieved. Sample/Core Logs prepared for each soil boring are provided in Appendix A.

Proposed soil boring SB-15 was not drilled due to utility conflicts that were identified during the utility clearance activities. Multiple attempts were made to find a safe drilling location for the soil boring. Mr. Hank Willems of the NYSDEC was notified of the field conditions and concurred that the soil boring could not be drilled along the east side of the Block 7273, Lot 1 shopping center building.

Proposed soil boring SB-18 was relocated from the northeast portion of Block 7273, Lot 1 to Lot 25 because soil borings SB-10 and SB-12 served to delineate the extent of tar-impacted soil to the east on the northern portion of Block 7273, Lot 1. Mr. Hank Willems of the NYSDEC requested that a soil boring be drilled to the west of soil boring SB-13 to confirm that tar-impacted soil was not present to the west.

Proposed soil boring SB-23 was relocated on Lot 25 to delineate the extent of tar-impacted soil to the south of soil boring SB-22. Soil boring SB-24 was added to the RI scope to assist in delineating the extent of tar-impacted soil to the south of SB-22. Soil boring MW-20 was added to the RI scope (as described in the RI Work Plan Addendum) to delineate the extent of impacts to the north of Block 7273, Lot 1. The NYSDEC Analytical Services Protocol (ASP) Category B deliverables for the MW-20 soil analytical samples are provided in Appendix H; the NYSDEC ASP Category B deliverables for all other soil analytical samples associated with the RI are provided in the RI Data Summary (ARCADIS, 2012).

3.3 Groundwater Investigation

This section discusses the groundwater investigation that was performed during the RI. The data were used to meet RI objectives and to further develop the CSM for contaminant transport and fate in groundwater. Specific activities performed included the drilling of temporary monitoring wells and collection of groundwater samples, pneumatic slug testing, drilling and installation of monitoring wells, collection of water-level measurements from monitoring wells, and collection of groundwater samples from monitoring wells.

3.3.1 Temporary Monitoring Wells

To further characterize groundwater and to support the decision making process for permanent monitoring well locations and screen intervals, a temporary monitoring well program was developed for the Site, as outlined in the RI Work Plan. Temporary monitoring wells were drilled and groundwater samples were collected in accordance with the procedures and scope outlined in the RI Work Plan. The temporary monitoring well sampling activities were conducted in October 2011 and January 2012.

The temporary monitoring wells were drilled to total depths ranging from 57 to 90 ft bls utilizing sonic (SB-7) and direct push drilling techniques (Geoprobe®) (VP-1 through VP-4). The final total depths of the temporary monitoring wells were determined based on observations from previously installed soil borings (i.e., the downgradient temporary monitoring wells were drilled to 90 ft bls based on the observed impacts in soil borings). In addition to the anticipated sample intervals discussed in the RI Work Plan, the sample intervals were adjusted as necessary based on the soil boring observations and additional sample intervals were included to characterize deeper groundwater quality (i.e., at 90 ft bls).

A total of five (5) temporary monitoring wells were drilled and a total of eighteen (18) groundwater samples (not including QA/QC samples) were collected for laboratory analysis. Each groundwater sample was analyzed for VOCs and SVOCs as outlined in the RI Work Plan. A summary of the groundwater samples collected for laboratory analysis during the RI along with the constituents analyzed is provided in Table 1. A discussion of the groundwater analytical results is provided in Section 5 (Nature and Extent of Constituents in Media).

Groundwater samples were denoted by their respective temporary monitoring well number (as shown on Figure 2) followed by the depth interval (in ft bls) from which the sample was retrieved.

Temporary monitoring well VP-5 was not drilled because the groundwater quality data collected from temporary monitoring wells SB-7 and VP-4 served to delineate the upgradient extent of dissolved-phase impacts. Mr. Hank Willems of the NYSDEC concurred that VP-5 did not need to be drilled.

3.3.2 Pneumatic Slug Testing

Concurrent with the collection of groundwater samples from the direct push temporary monitoring wells (VP borings), pneumatic slug testing was conducted at VP-1 and VP-3 to evaluate the hydraulic conductivity of the formation. The pneumatic slug testing activities were conducted in January 2012. The pneumatic slug testing was performed at the VP-1 and VP-3 locations at each groundwater sample interval within these borings. A discussion of the pneumatic slug testing results is provided in Section 4.

3.3.3 Monitoring Well Installation

To further characterize groundwater, fifteen (15) permanent monitoring wells (MW-6 through MW-20) were installed during the RI in accordance with the procedures and scope outlined in the RI Work Plan. The monitoring wells were completed to depths that either: 1) permitted the screened section of the well to straddle the water table, 2) allowed for an evaluation of groundwater quality in the vicinity of the MGP-related NAPL release areas (i.e., screened below the water table), or, 3) allowed for an evaluation of dissolved-phase impacts outside of the areas where MGP-related NAPL impacts were observed (generally screened below the water table). The monitoring well construction details are provided in Table 2 and well construction logs are provided in Appendix B. The monitoring well installation activities were conducted between September 2011 and November 2013.

The monitoring wells were installed to total depths ranging from 16 to 103 ft bls utilizing sonic drilling techniques. The final total depths of the monitoring wells were determined based on soil boring observations. The locations of the monitoring wells are shown on Figure 2.

The RI Work Plan indicated that the locations and screen intervals of monitoring wells MW-13 through MW-16 would be determined based on the vertical aquifer profiling (VAP) groundwater quality data. Based on the soil boring observations, monitoring wells MW-17 through MW-19 were added to the RI scope to delineate the extent of dissolved-phase impacts along the downgradient (northern) boundary of Block 7273, Lot 1. Monitoring well MW-20 was added to the RI scope (as described in the RI Work Plan Addendum) to delineate the extent of dissolved-phase impacts to the north of Block 7273, Lot 1.

Following installation, each well was developed by surging and pumping water from the well until the turbidity was below 50 nephelometric turbidity units (NTUs) or until pH and conductivity measurements had stabilized.

Subsequent to the well installation activities, a New York State licensed surveyor field surveyed the monitoring well locations. For each monitoring well, the surveyor determined the location relative to the New York State Plane Coordinate System, and the ground surface elevation and measuring point elevation (defined as the top of the inner casing) relative to the National Geodetic Vertical Datum of 1929 (NGVD 29).

3.3.4 Water-Level Measurements

Two rounds of water-level measurements were collected on October 4, 2011 and March 20, 2012 from the monitoring well network (i.e., MW-1 through MW-9 in October 2011 and MW-1 through MW-19 in March 2012) in accordance with the procedures outlined in the RI Work Plan. The water-level measurement data are provided in Tables 3 and 4. Section 4 provides a discussion of groundwater flow at the Site.

The monitoring wells were gauged for the presence of NAPL during the water-level measurement round. Neither LNAPL nor DNAPL were observed to be present in any of the monitoring wells based on the gauging that was conducted using an interface meter on March 20, 2012. Upon retrieving the submersible pump after sampling was completed in monitoring wells MW-5 and MW-11, there was visual evidence of NAPL on the pump.

3.3.5 Monitoring Well Sampling

Groundwater samples were collected between March 21 and 28, 2012 from the monitoring well network (i.e., MW-1 through MW-19) in accordance with the procedures outlined in the RI Work Plan. A groundwater sample was collected from monitoring well MW-20 on December 10, 2013. The NYSDEC ASP Category B deliverables for the MW-20 groundwater analytical samples are provided in Appendix H; the NYSDEC ASP Category B deliverables for all other groundwater analytical samples associated with the RI are provided in the RI Data Summary (ARCADIS, 2012). The groundwater samples were analyzed for VOCs, SVOCs, TAL metals, and total cyanide. In addition, twenty percent of the groundwater samples collected from the monitoring wells were analyzed for TCL PCBs and TCL pesticides as outlined in the RI Work Plan. A summary of the groundwater samples collected for laboratory analysis during the RI along with the constituents analyzed is provided in Table 1. A discussion of the groundwater analytical results is provided in Section 5 (Nature and Extent of Constituents in Media).

Groundwater samples were denoted by their respective monitoring well number (as shown on Figure 2). Low-Flow Groundwater Sampling Logs are provided in Appendix C.

3.4 Soil Vapor Investigation

This section discusses the exterior soil vapor investigation that was performed during the RI. The data were used to meet RI objectives and to further develop the CSM for exterior soil vapor. Specific activities performed included the installation of soil vapor points (exterior) and collection of soil vapor samples.

During the SC, sub-slab soil vapor samples and indoor air quality samples were collected. The SC Data Summary Addendum, which includes the VI investigation data and a figure showing the sub-slab soil vapor and indoor air quality sample locations, is provided in Appendix I.

3.4.1 Soil Vapor Points

To characterize soil vapor, an exterior soil vapor point program was developed for the Site, as outlined in the RI Work Plan. Soil vapor points were installed and soil vapor samples were collected in accordance with the procedures and scope outlined in the RI

Work Plan. The soil vapor point sampling activities were conducted on March 29, 2012.

The exterior soil vapor points were installed to a total depth 5 ft bls utilizing hand digging techniques and were constructed with a 6-inch long stainless steel screen from 4.5 to 5 ft bls. The soil vapor samples were collected from depths approximately 2 feet above the water table.

A total of four (4) exterior soil vapor points (SV-1 through SV-4) were installed and a total of four (4) soil vapor samples (not including QA/QC samples) were collected for laboratory analysis (i.e., one soil vapor sample per soil vapor point). Each soil vapor sample was analyzed for VOCs as outlined in the RI Work Plan. A summary of the soil vapor samples collected for laboratory analysis during the RI along with the constituents analyzed is provided in Table 1. A discussion of the soil vapor analytical results is provided in Section 5 (Nature and Extent of Constituents in Media).

Soil vapor samples were denoted by their respective soil vapor point number (as shown on Figure 2). Soil Vapor Sample Collection Logs prepared for each exterior soil vapor point are provided in Appendix D.

3.4.2 Ambient Air Sampling

One (1) ambient air sample was collected concurrent with the exterior soil vapor sampling activities. The ambient air sample was collected on March 29, 2012 and was analyzed for VOCs. A summary of the ambient air sample collected for laboratory analysis during the RI along with the constituents analyzed is provided in Table 1. A discussion of the ambient air analytical results is provided in Section 5 (Nature and Extent of Constituents in Media).

The ambient air sample was denoted as AA-1 and was collected in the vicinity of SV-3 and SV-4. The AA-1 Ambient Air Sample Collection Log is provided in Appendix E.

3.5 Community Air Monitoring Program

In accordance with the Community Air Monitoring Plan (CAMP), prepared in accordance with NYSDEC requirements and contained in the NYSDEC-approved RI Work Plan, real-time community air monitoring was performed and recorded by ARCADIS for VOCs (using a PID) and dust (using a particulate monitor). In accordance with the CAMP, drill cuttings and groundwater were containerized in 55-

gallon drums with the cover secured. During the course of the RI there were generally no exceedances of the CAMP action levels, and therefore corrective actions to reduce or abate emissions were not required.

Exceedances of the VOC action level were recorded downwind of the work zone on September 9, 2011 at the monitoring well MW-9 location; however, these measurements appeared to be related to vehicular exhaust on W. 5th Street or another background source since VOC measurements in the work zone were non-detect.

Discrete, short-interval (less than five minutes in duration) exceedances of the particulate matter action level were recorded upwind or downwind of the work zone at various drilling locations; however, these measurements were not sustained and appeared to be related to background dust-generating activities. These short-duration particulate exceedances were not the result of any intrusive activities or subsurface sources.

3.6 Investigation-Derived Waste Disposal

IDW was managed in accordance with the RI Work Plan. Soil, plastic materials, personal protective equipment (PPE), and water generated from drilling, sampling, well development, and decontamination activities were containerized in Department of Transportation (DOT)-approved 55-gallon drums pending analytical results. Waste sampling data were used to support IDW characterization for disposal purposes. The IDW was transported off-site for disposal at Bayshore Soil Management, LLC in Keasbey, New Jersey and Clean Water of New York, Inc. in Staten Island, New York.

4. Site Physical Setting

Evaluation of the Site physical setting, geology, hydrogeology, groundwater flow characteristics, and Site-specific aquifer parameters are essential in understanding and evaluating COC fate and transport mechanisms (Section 6) and refining the CSM (Section 7). This section evaluates Site geology and hydrogeology.

4.1 Local Geology

The Site is located south of the Harbor Hill terminal moraine and the surficial deposits consist of glacial outwash deposits (Upper Glacial aquifer) at the Site.

Based on the soil borings that were drilled during the RI, primarily fine to coarse sand deposits (glacial outwash deposits of the Upper Glacial aquifer) were encountered during the subsurface investigation. Varying amounts of silt or silty sand, some of which is associated with fill material, was observed in a number of soil borings. Clay, silty clay, or clayey sand was observed in the shallow portion (i.e., upper 15 feet) of a limited number of soil borings and may be associated with fill material. Approximately 5 to 15 feet of fill material was encountered in the upper portion of the soil borings. No confining layers were observed during the RI drilling activities.

4.2 Local Hydrogeology

The following RI Report subsections discuss groundwater use, groundwater flow, hydraulic gradients, and an estimate of shallow groundwater velocity.

4.2.1 Groundwater Use

There are no groundwater supply wells located at or in the vicinity of the Site. New York City's drinking water is supplied from reservoirs located in upstate New York.

4.2.2 Groundwater Flow, Hydraulic Gradients and Groundwater Velocity

The depth to groundwater at the Site ranges from approximately 5.5 to 7.5 ft bls. Groundwater exists under water-table conditions beneath the Site (i.e., under unconfined conditions). Water-level elevation data collected at the Site in October 2011 and March 2012 indicate that a local groundwater divide is present on Lot 25 in the vicinity of monitoring well MW-8. The groundwater north of the groundwater divide flows in a northerly/northwesterly direction toward Coney Island Creek, whereas groundwater south of the groundwater divide flows in a southerly direction toward New York Bay (see Figures 3 and 4). The former MGP operations and the soil and groundwater impacts are located north of the groundwater divide.

The pneumatic slug testing conducted in the VP-1 and VP-3 borings during the RI indicated an average horizontal hydraulic conductivity (K) of approximately 25 ft/d for the shallow water table region (approximately 12 ft bls). Hydraulic conductivity values were higher for the deposits beneath the shallow water table region (at depths ranging from 36 to 90 ft bls), and ranged from approximately 52 to 89 ft/d. Based on the water-level elevation data that were obtained from monitoring wells that are screened to straddle the water table, the horizontal hydraulic gradient in the shallow groundwater system is relatively flat (approximately 0.00085 ft/ft). Based on the hydraulic conductivity (25 ft/d) for the shallow water table region and hydraulic gradient data, and assuming an average effective porosity value of 24 percent, the average horizontal groundwater velocity in the shallow water table region is approximately 0.09 ft/d. However, assuming an estimated mobile porosity value of 15 percent, the average horizontal groundwater velocity in the shallow water table region is approximately 0.14 ft/d. Based on the range of calculated hydraulic conductivity values and considering the average effective porosity and estimated mobile porosity values discussed above, the average horizontal groundwater velocity at the Site may range from approximately 0.09 to 0.5 ft/d.

5. Nature and Extent of Constituents in Media

This section discusses the analytical data for samples of soil, groundwater, and exterior soil vapor collected at the Site. The nature and extent of the COCs are described in the following sections.

5.1 Development of Standards, Criteria, and Guidance

SCGs have been identified for the Site that pertain to meeting applicable regulations and RI objectives.

The SCGs for the Site soils are based upon the selection of applicable values from the New York State Codes, Rules and Regulations Title 6 (6 NYCRR) Part 375 Remedial Program Soil Cleanup Objectives (SCOs). The applicable SCGs are as follows:

- Unrestricted use SCOs;
- Restricted use protection of public health commercial use SCOs; and,
- Restricted use protection of groundwater SCOs

The majority of the impacts are present on Block 7273, Lot 1 (shopping center property), which is located in a commercial overlay district (New York City Planning Commission Zoning Map, 2013). The remainder of the impacts are present on a portion of Block 7273, Lot 25 (residential high-rise apartment building) beneath an asphalt parking lot. Both the unrestricted use and restricted use protection of public health commercial use SCOs were used to evaluate the soil data based on the distribution of the impacts relative to the zoning designations (commercial and residential). It is important to note that there is limited potential for soil contact (i.e., cover system of asphalt pavement or concrete building slab).

The SCGs for groundwater are based on the NYSDEC Division of Water Technical and Operational Guidance Series (TOGS) (1.1.1) Ambient Water Quality Standards and Guidance Values and Groundwater Effluent Limitations.

No SCGs currently exist for exterior soil vapor.

5.2 Summary of Data Usability

This section provides a summary of RI data quality based on validation performed and usability toward meeting data quality objectives (DQOs) for the Site. Data Usability Summary Reports (DUSRs) are provided in Appendix F.

ARCADIS prepared Data Validation Checklists for the sample data that was collected during the RI. The NYSDEC ASP Category B data deliverables underwent a review process following NYSDEC DUSR guidelines. Analytical methods utilized were acceptable NYSDEC or United States Environmental Protection Agency (EPA) methods, as specified in the NYSDEC-approved RI Work Plan. Data validation was conducted by ARCADIS.

Nine sample delivery groups (SDGs) were associated with the RI soil data. Four SDGs were associated with the RI groundwater data. One SDG was associated with the RI soil vapor data. The data were determined to be acceptable and usable.

It is the opinion of ARCADIS that the analytical data generated from samples collected and analyzed as part of the RI underwent a thorough data review process in accordance with QAPP requirements. Based on the data validation, the data met DQOs of sufficient quality.

5.3 Nature and Extent of Constituents in Soil

This section provides an evaluation of the nature and extent of constituents in soil. The data obtained from soil sampling met the RI goal of determining the extent of MGP-related by-product residuals and is sufficient for determining the nature and extent of MGP-related constituents in soil at the Site. An analysis of constituents in soil is presented below.

The soil quality data evaluated and presented in this RI Report were generated from the collection of soil samples as described in Section 3.2. The laboratory analytical results of soil samples are summarized in Tables 5 through 16. VOCs and SVOCs in soil exceeding SCGs (restricted use and unrestricted use SCOs) are shown on Figures 5 through 8.

5.3.1 Volatile Organic Compounds

The analytical results indicate that a number of VOCs were detected in soil above SCGs (see Tables 5 and 6 and Figures 5 and 6). Consistent with the SC that was performed by ARCADIS, the primary VOCs that were detected in soil above SCGs include BTEX constituents. BTEX constituents exceeded the restricted use protection of groundwater SCOs and unrestricted use SCOs in three soil samples (SB-6 [43-45'], SB-9 [72-73.5'], and SB-22 [33-34']). In addition, toluene and xylenes exceeded the restricted use protection of public health commercial use SCOs in one soil sample (SB-9 [72-73.5']). Additional VOCs that were detected above SCGs include n-butylbenzene, n-propylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and acetone, and were generally associated with the SB-9 (72-73.5') and SB-22 (33-34') soil samples. VOCs were identified as COCs in soil. Section 7 (CSM) discusses the distribution of BTEX constituents that were detected in soil above SCGs.

The hydrocarbon product identification data for soil samples collected during the SC suggest that fuel oil impacts of unknown origin are present at the water table across the entire area that the former MGP occupied and that coal tar impacts are present at the water table across the central and eastern portion of the area that the former MGP occupied.

5.3.2 Semi-Volatile Organic Compounds

The analytical results indicate that a number of SVOCs were detected in soil above SCGs (see Tables 7 and 8 and Figures 7 and 8). Consistent with the SC, the primary SVOCs detected in soil above SCGs were PAHs. The highest PAH concentrations were detected in soil samples SB-6 (43-45'), SB-9 (72-73.5'), and SB-22 (33-34'). The majority of the other soil samples where PAHs were detected above SCGs were collected from either the 2-3 ft bls interval (detections appear to be associated with the shallow fill material) or the water table interface. SVOCs were identified as COCs in soil. Section 7 discusses the distribution of SVOCs that were detected in soil above SCGs.

5.3.3 Total and Free Cyanide

The analytical results indicate that total cyanide was not detected in soil above SCGs (see Tables 9 and 10). Free cyanide was detected in eight soil samples at concentrations ranging from 0.14 to 0.96 mg/kg. Total and free cyanide were not identified as COCs in soil.

5.3.4 Metals

The analytical results indicate that three (3) metals (barium, lead, and mercury) were detected in soil above restricted use SCOs (see Table 11). These metals exceedances were generally detected in the 2 to 3 ft bls interval and are likely associated with the post-MGP placement of fill material. Additional metals that were detected in soil above unrestricted use SCOs include chromium, copper, nickel, silver, and zinc (see Table 12). With the exception of nickel in the SB-6 (43-45') and SB-22 (33-34') soil samples and copper in the MW-20 (80-82') soil sample, the exceedances of the unrestricted use SCOs were detected in soil samples collected from the upper 9 feet of the soil borings and are likely associated with the post-MGP placement of fill material. Metals were not identified as COCs in soil.

5.3.5 Polychlorinated Biphenyls

The analytical results indicate that PCBs were detected in six soil samples at concentrations below restricted use SCOs (see Table 13). PCBs were detected above unrestricted use SCOs in the SB-11 (6-8'), SB-12 (2-3'), and MW-19 (2-3') soil samples (see Table 14). PCBs are not generally associated with MGP operations. PCBs were not identified as COCs in soil.

5.3.6 Pesticides

The analytical results indicate that two (2) pesticides (endrin and alpha-chlordane) were detected in one soil sample (SB-6 [2-3']) above the restricted use protection of groundwater SCOs (see Table 15). Pesticides were detected in nine soil samples above unrestricted use SCOs and are likely associated with the post-MGP placement of fill material (see Table 16). Pesticides are not generally associated with MGP operations. Pesticides were not identified as COCs in soil.

5.4 Nature and Extent of Constituents in Groundwater

This section provides an evaluation of the nature and extent of constituents in groundwater. The data obtained from groundwater sampling (temporary monitoring wells and monitoring wells) met the RI goal of determining the nature and extent of MGP-related COCs in groundwater. An analysis of constituents in groundwater is presented below.

The groundwater quality data evaluated and presented herein were generated from analysis of the groundwater samples collected as described in Section 3.3. The laboratory analytical results of groundwater samples collected from temporary monitoring wells and monitoring wells are summarized in Tables 23 through 30. VOCs and SVOCs in groundwater exceeding SCGs are shown on Figures 9 and 10, respectively.

5.4.1 Volatile Organic Compounds

The analytical results indicate that a number of VOCs were detected in groundwater above SCGs (see Tables 23 and 25). The primary VOCs that were detected in groundwater above SCGs were BTEX constituents. The distribution of BTEX concentrations in groundwater is shown on Figure 11. Additional VOCs that were detected above SCGs include styrene, isopropylbenzene, n-propylbenzene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene. VOCs were not detected above SCGs in monitoring wells MW-6 through MW-9, MW-12, MW-13, MW-16, MW-19, and MW-20 and temporary monitoring wells VP-3 and VP-4. VOCs were identified as COCs in groundwater. Section 7 discusses the distribution of VOCs that were detected in groundwater above SCGs.

The hydrocarbon product identification data for soil samples collected during the SC suggest that fuel oil impacts of unknown origin are present at the water table across the entire area that the former MGP occupied and that coal tar impacts are present at the water table across the central and eastern portion of the area that the former MGP occupied. The highest concentrations of BTEX constituents were detected in monitoring wells MW-5 and MW-11 (both screened 30 to 40 ft bls). Concentrations of BTEX constituents were also detected in water-table monitoring wells MW-1 through MW-4 and MW-15, albeit at lower concentrations than in MW-5 and MW-11, indicating the water table soil impacts from fuel oil and coal tar may be contributing to the BTEX constituents in the groundwater.

5.4.2 Semi-Volatile Organic Compounds

The analytical results indicate that a number of SVOCs were detected in groundwater above SCGs (see Tables 24 and 26). The primary SVOCs that were detected in groundwater above SCGs were PAHs; naphthalene is the primary PAH that has migrated to the downgradient property boundary of Block 7273, Lot 1, as evidenced by the groundwater quality data in monitoring wells MW-14, MW-17, and MW-18 and temporary monitoring wells VP-1 and VP-2 (see Figure 12). SVOCs were not detected above SCGs in monitoring wells MW-6 through MW-9, MW-12, MW-19, and MW-20 and temporary monitoring wells VP-3 and VP-4. SVOCs were identified as COCs in groundwater. Section 7 discusses the distribution of SVOCs that were detected in groundwater above SCGs.

5.4.3 Total Cyanide

The analytical results indicate that total cyanide was detected in groundwater below its SCG (see Table 27). Total cyanide was detected in monitoring wells MW-1, MW-2, MW-3, MW-4, and MW-16. Total cyanide was not identified as a COC in groundwater.

5.4.4 Metals

The analytical results indicate that a number of metals were detected in groundwater above SCGs (see Table 28). However, four of the metals that were detected above SCGs (iron, magnesium, manganese, and sodium) are naturally occurring, and are considered to be naturally occurring at the Site. Two other metals were detected above SCGs, chromium (MW-12) and lead (MW-15). Metals were not identified as COCs in groundwater.

5.4.5 Polychlorinated Biphenyls

The analytical results indicate that PCBs were not detected in groundwater above the laboratory reporting limits (see Table 29). PCBs were not identified as COCs in groundwater.

5.4.6 Pesticides

The analytical results indicate that pesticides were not detected in groundwater above the laboratory reporting limits (see Table 30), with the exception of endrin, which was detected at the laboratory reporting limit in MW-5. Pesticides were not identified as COCs in groundwater.

5.5 Nature and Extent of Constituents in Exterior Soil Vapor and Ambient Air

This section provides an evaluation of the nature and extent of constituents in exterior soil vapor beneath the parking area (Block 7273, Lot 1) and beneath the grass area (Block 7273, Lot 25) at the Site. The data obtained from soil vapor sampling met the

RI goal of determining the nature and extent of MGP-related COCs in soil vapor at the Site. An analysis of constituents in soil vapor is presented below.

The exterior soil vapor data evaluated and presented herein were generated from the collection of soil vapor samples as described in Section 3.4. The laboratory analytical results of soil vapor samples collected from soil vapor points are summarized in Table 31.

The analytical results indicate that potential MGP-related compounds were detected at soil vapor point SV-1, which is located in the vicinity of the leading edge of the dissolved-phase impacts. At SV-2, toluene was detected in the soil vapor sample. Toluene may or may not be related to MGP impacts. No MGP-related compounds were detected at SV-3 or SV-4. There were non-MGP-related constituents detected in all of the soil vapor samples and ambient air sample. Most notably, chlorinated VOCs were detected in the SV-1 (TCE, cis-1,2-DCE, trans-1,2-DCE, and VC) and SV-4 (PCE) exterior soil vapor samples and are likely associated with the post-MGP operations, such as a dry cleaner. The constituents most commonly detected are often associated with vehicle exhaust (acetone) and refrigerants (dichlorodifluoromethane).

During the SC, PCE and other chlorinated VOCs (TCE, cis-1,2-DCE, and VC) were detected at elevated concentrations in the SSSV-6 sub-slab soil vapor sample. In addition, PCE was detected at an elevated concentration in the SSSV-4 sub-slab soil vapor sample. A number of non-MGP-related constituents detected in indoor air (2-butanone [methyl ethyl ketone], dichlorodifluoromethane (Freon 12), 4-methyl-2-pentanone [MIBK], and PCE) were above typical background indoor air concentrations in four indoor air quality samples. These detected compounds are not associated with historic MGP operations.

Potential MGP-related constituent vapors are not migrating into the shopping center building at concentrations that may result in an unacceptable human health risk. This is evidenced by the fact that potential MGP-related constituents detected in indoor air during the SC were below typical background indoor air concentrations for all indoor air quality samples. Furthermore, the potential MGP-related constituents detected in indoor air may be attributable to other sources (i.e., background sources).

5.6 Quality Assurance/Quality Control Samples

This section evaluates the results of QA/QC sample analysis during the RI. The results of QA/QC sample analysis are provided in Tables 17 through 22. The data were incorporated into the data usability assessment performed by ARCADIS for the RI. The results show no detections that adversely affected the acceptability of the results of samples obtained during the RI.

6. Fate and Transport

This section provides a discussion of the processes that control the movement and distribution of the COCs related to the Site. Site COCs were identified in Section 5 (Nature and Extent of Constituents in Media).

In general, after a chemical is released to the environment, it may be transported, transformed physically, chemically, or biologically, or accumulated in one or more media. The evaluation of the fate and transport of the COCs identified for the Site will aid in predicting future potential risks.

6.1 Constituents of Concern

As described in Section 5, COCs were selected based on comparison (i.e., exceedance) to SCGs (as applicable). The following are the primary COCs that were identified in soil and/or groundwater at the Site:

- VOCs
  - Benzene
  - Toluene
  - Ethylbenzene
  - Xylenes
  - n-butylbenzene
  - n-propylbenzene
  - 1,2,4-trimethylbenzene
  - 1,3,5-trimethylbenzene
  - Isopropylbenzene
  - Styrene

- PAHs
  - Naphthalene
  - Acenaphthene
  - Acenaphthylene
  - Phenanthrene
  - Fluoranthene
  - Pyrene
  - Benzo(a)anthracene
  - Chrysene
  - Benzo(b)fluoranthene
  - Benzo(k)fluoranthene
  - Benzo(a)pyrene
  - Indeno(1,2,3-cd)pyrene
  - Dibenz(a,h)anthracene

6.2 Constituent Fate and Transport Processes

A discussion of the various fate and transport processes for COCs identified during the RI for the Site is provided in the following sections.

6.2.1 Sorption/Precipitation

Sorption and precipitation are chemical processes that retard or prohibit chemical constituent migration in the subsurface. Sorption refers collectively to those processes (adsorption and absorption) where constituents chemically attach to soil or sediment.

Precipitation is a chemical reaction in which a dissolved constituent reacts with another dissolved species and forms an insoluble product (e.g., a solid).

For VOCs and SVOCs, solubility and adsorption to naturally occurring organic matter in soil or sediment are the dominant processes affecting mobility and migration. The mobility of VOCs and SVOCs in groundwater may be evaluated by examining their aqueous solubilities and partition coefficients. In general, the higher the solubility, the greater the mobility, and the higher the organic carbon partition coefficient (K_{oc}) and octanol-water partition coefficient (K_{ow}) values, the lower the aqueous mobility and the higher the affinity for organic matter in the soil.

6.2.2 Volatilization

Volatilization refers to the transfer of constituents from the dissolved phase or liquid state to the gaseous (vapor) state. Volatilization can occur directly from a spill or leak, from COCs in water at or near the water table, or from COCs in groundwater.

Volatilization is assessed by examining the Henry’s Law constant and vapor pressure for each constituent. Henry’s Law constants provide a semi-quantitative rate at which a constituent will volatilize from soil and/or water. The higher the vapor pressure, the more easily the constituent will volatilize. Volatilization of constituents in the environment is a function of the constituent’s Henry’s Law constant and vapor pressure, as well as the saturation of the surrounding media and ambient conditions (such as atmospheric and/or hydrostatic pressure).

6.2.3 Degradation/Transformation

Degradation is a chemical or biochemical process that removes or transforms organic constituents. Chemical degradation usually involves hydrolysis or oxidation, while biochemical processes (biodegradation) can involve oxidation or reduction depending on whether aerobic (oxygen) or anaerobic (without oxygen) conditions are present. The wide range of environmental conditions that control degradation processes makes it infeasible to characterize the degradability of a constituent with a measured value. In general, hydrolysis and oxidation reactions (chemical degradation) in groundwater are slow compared with transformations mediated by biochemical processes.

6.2.4 Advection

Advection describes the process of constituent migration by the average bulk movement of groundwater, and typically is the most important factor governing the transport of COCs in groundwater. Advection defines the direction and rate of travel of a plume's center of mass. The advective transport term is computed using velocities determined by solving the groundwater flow equation, which is a function of hydraulic conductivity, hydraulic gradient, and porosity (see Section 4.2 – Local Hydrogeology).

6.3 Environmental Fate

The media of concern at the Site are soil and groundwater, and the COCs are principally BTEX constituents and PAHs. In general, the BTEX constituents detected in groundwater during the RI are relatively mobile in groundwater having a moderate to high solubility and/or low K_{oc} and K_{ow} values. In contrast, the PAHs detected in groundwater during the RI are relatively immobile in groundwater having a low solubility, with the exception of naphthalene, which has a higher solubility relative to the other PAHs detected in groundwater.

6.4 Transport Mechanisms

Transport mechanisms are physical processes governing the movement of constituents from points of origin (i.e., sources). At the Site, the primary transport mechanisms for COCs are leaching from soils in source areas to groundwater, volatilization from source areas and shallow groundwater to the soil vapor/atmosphere, and advective groundwater movement. In groundwater, the subsurface lithology and structure, and local pumpage and recharge, are the primary influences on the movement of groundwater.

7. Conceptual Site Model

This section develops and discusses the CSM for the Site. Previous sections summarized relevant Site conditions, including the Site history and usage, geology and hydrogeology, and distribution of COCs in the environment (i.e., quality of soil, groundwater, and exterior soil vapor). The CSM presented herein relates current conditions to the former MGP operations.

The purpose of the CSM is to more specifically explain the source(s) of COCs and the mode(s) of transport of COCs in and between media (i.e., soil, groundwater, and exterior soil vapor) (a general discussion of fate and transport mechanisms is provided in Section 6). The discussion below also considers the strength of the conclusions reached, as related to the occurrence and migration of COCs, from the data. By the end of this section it should be understood, to the extent it can be known, how and why COCs entered the soil, groundwater, and soil vapor and where COCs will migrate if left unabated. During the development of the CSM, an assessment of data gaps was made.

Consistent with the SC, the data collected at the Site during the RI indicate that the former gas holders, tar tank, and cistern are all likely sources of the tar releases from the former MGP. The former locations of these structures are based on Sanborn Maps. In addition, holders, tar tanks, and storage vessels are common sources of coal tar at MGP sites.

Post-MGP operations, such as a dry cleaner, are likely a source of chlorinated VOCs detected in the media at the Site. Post-MGP site uses, such as parking lots and adjacent roadways, are potential sources of shallow petroleum impacts detected in the media at the Site. Accordingly, petroleum impacts contribute to observations of VOCs (such as BTEX) at the Site, but are not necessarily MGP-related.

Coal tar impacts were observed primarily in borings drilled in the central and eastern portions of the Site and generally correspond with the footprint of the former MGP operations and areas adjacent to the former MGP operations (see Figure 13). The deepest tar-saturated soil was encountered in soil boring SB-9 (downgradient of the former MGP operations) in the 70 to 75 ft bls soil core. The deepest tar-impacted (i.e., tar blebs) soil was encountered in soil boring SB-4 to a depth of 80 to 90 ft bls. Tar-impacted soil was encountered south (upgradient) of the former MGP operations at shallower depths in soil borings SB-6 (between 40 and 50 ft bls) and SB-22 (between 30 and 40 ft bls). The extent of tar-impacted soil has been horizontally and vertically delineated.

The tar-impacted soil encountered in soil boring SB-9 (northern portion of Block 7273, Lot 1) is delineated to the north by the Block 7273, Lot 1 northern property boundary soil borings, to the east by soil borings SB-10 and SB-12, and to the west by soil borings SB-8, SB-11, and MW-19. The tar-impacted soil observed in SB-9 appears to be the downgradient extent that tar migrated from the source area region. Trace blebs were observed in the MW-14 boring in the 80 to 85 ft bls and 85 to 90 ft bls soil cores; however, the soil and groundwater quality data collected from the MW-14 soil boring and monitoring well (screened 80 to 90 ft bls) are not indicative of source-strength impacts and, in conjunction with other northern property boundary monitoring wells (e.g., MW-17 and MW-18), suggest that this area represents the leading edge of the downgradient dissolved-phase groundwater impacts. The soil and groundwater quality data collected from the MW-20 (north of Neptune Avenue) soil boring and monitoring well (screened 80 to 95 ft bls) indicate that the downgradient extent of impacts have been delineated.

Tar-impacted soil encountered in soil borings SB-6 and SB-22 (northern portion of Lot 25) is delineated to the south by soil borings SB-23 and SB-24, to the east by soil borings SB-7, SB-14 and SB-20, and to the west by soil borings SB-13, SB-18, SB-19 and SB-21. The tar-impacted soil observed in SB-6 and SB-22 represents the upgradient extent that tar migrated from the source area region.

It is likely that coal tar encountered the water table in the vicinity of the former gas holders and tar handling structures, spread out laterally after encountering the water table, and then penetrated into the unconfined saturated zone. The tar released from the MGP sources generally continued to migrate downward through the saturated permeable glacial outwash deposits until the volume of tar was insufficient to maintain a DNAPL fluid pressure capable of overcoming the pressure of the surrounding water (i.e., the DNAPL pressure head no longer exceeded the capillary pressure, which impeded further downward migration of the tar). Neither LNAPL nor DNAPL were detected in any of the monitoring wells.

Petroleum hydrocarbon impacts (staining and/or odors, sheens, PID readings) were observed in the water table region in a number of soil borings (e.g., MW-17, SB-6, SB-9, SB-11). Visual evidence of potentially mobile LNAPL (i.e., oil-saturated soil) was not observed in these soil borings. The distribution of these petroleum hydrocarbon impacts, in conjunction with the petroleum hydrocarbon impacts that were observed during the SC, suggests that the impacts may be related to the former MGP operations. However, some of the petroleum hydrocarbon impacts may be related to a former filling station that was identified to the west/southwest of the Site on the 1930 and 1950 Sanborn Maps. In addition, shallow petroleum hydrocarbon impacts, as observed in the soil borings or in analytical samples, may be related to post-MGP site uses (e.g., parking lots and adjacent roadways).

VOCs and SVOCs were detected above SCGs in soil and groundwater and were identified as COCs in these media. The highest BTEX and PAH concentrations in soil generally correspond with the observed coal tar and petroleum hydrocarbon impacts, which are a continuing source of groundwater impacts. A local groundwater divide is present on Lot 25 in the vicinity of monitoring well MW-8. The groundwater north of the groundwater divide flows in a northerly/northwesterly direction toward Coney Island Creek, whereas groundwater south of the groundwater divide flows in a southerly direction toward New York Bay (see Figures 3 and 4). The former MGP operations and the soil and groundwater impacts are located north of the groundwater divide.

The highest BTEX and PAH concentrations in groundwater were detected in monitoring wells MW-5 and MW-11 (both screened from 30 to 40 ft bls). Monitoring wells MW-5 (installed during SC) and MW-11 (installed during RI) are located in the source area region (near the former gas holders and tar tank) and were installed in intervals where tar impacts were observed (see Figures 15, 17, and 18). Concentrations of BTEX and light molecular weight PAH compounds in groundwater have migrated along the groundwater flow path (northwest) to the Block 7273, Lot 1 property boundary as evidenced by the groundwater quality data collected from monitoring wells MW-13 through MW-18 (see Figures 11, 12, 15, and 16). However, the BTEX and light molecular weight PAH concentrations in groundwater significantly attenuate between the former MGP operations area and the Block 7273, Lot 1 property boundary as evidenced by the groundwater quality data in monitoring well MW-16, which is also screened from 30 to 40 ft bls. VOCs and SVOCs were not detected above SCGs in monitoring well MW-19. Monitoring wells MW-13 and MW-19 generally bound the dissolved-phase groundwater impacts to the west. The observations in soil borings SB-10, SB-12, and SB-14, in conjunction with the northerly/northwesterly direction of groundwater flow, suggest that significant groundwater impacts are not present along the eastern portion of the Site. The decrease in dissolved-phase concentrations from monitoring well MW-18 to temporary monitoring well VP-2 suggests that the dissolved-phase groundwater impacts to the east of these locations are minimal and outside of the primary region where elevated BTEX and light molecular weight PAH dissolved-phase mass is present. VOCs and SVOCs were not detected above SCGs in monitoring well MW-20, which indicates that the dissolved-phase groundwater impacts to the north are delineated.

Impacts were not observed and VOCs and SVOCs were not detected above SCGs in soil borings SB-21, SB-23, and SB-24. Collectively, the groundwater quality data from monitoring wells MW-6 through MW-9 and MW-12, and the soil quality data and observations from soil borings SB-21, SB-23, and SB-24, indicate that MGP-related impacts are not present south of the soil boring SB-22 area.

The dissolved-phase groundwater impacts significantly decrease in the zone underlying tar-impacted (i.e., tar blebs present in 80 to 90 ft bls interval at SB-4) soil, as evidenced by the groundwater quality data in monitoring well MW-10 (screened from 90 to 100 ft bls). Only three compounds (naphthalene, 1,1'-biphenyl, and ethylbenzene) were detected above SCGs in monitoring well MW-10. The soil quality data collected from the 98 to 100 ft bls interval indicate that the tar-impacted soil is vertically delineated. The groundwater impacts detected in monitoring well MW-10 are likely attributable to diffusion from the overlying groundwater that contains significantly higher concentrations of BTEX and PAHs.

The MGP-related exterior soil vapor impacts detected at soil vapor point SV-1 appear to be associated with the leading edge of the dissolved-phase groundwater impacts. The SV-2, SV-3, and SV-4 soil vapor data suggest that MGP-related soil vapor impacts are generally limited to the area where tar-impacted soil and groundwater impacts are present. Chlorinated VOCs were detected in the SV-1 (TCE, cis-1,2-DCE, trans-1,2-DCE, and VC) and SV-4 (PCE) exterior soil vapor samples and are likely associated with the post-MGP operations, such as a dry cleaner.

During the SC, PCE and other chlorinated VOCs (TCE, cis-1,2-DCE, and VC) were detected at elevated concentrations in the SSSV-6 sub-slab soil vapor sample. In addition, PCE was detected at an elevated concentration in the SSSV-4 sub-slab soil vapor sample. A number of non-MGP-related constituents detected in indoor air (2-butanone [methyl ethyl ketone], dichlorodifluoromethane (Freon 12), 4-methyl-2-pentanone [MIBK], and PCE) were above typical background indoor air concentrations in four indoor air quality samples. These detected compounds are not associated with historic MGP operations.

Potential MGP-related constituent vapors are not migrating into the shopping center building at concentrations that may result in an unacceptable human health risk. This is evidenced by the fact that potential MGP-related constituents detected in indoor air during the SC were below typical background indoor air concentrations for all indoor air quality samples. Furthermore, the potential MGP-related constituents detected in indoor air may be attributable to other sources (i.e., background sources).

8. Human Health Exposure Assessment

In accordance with *DER-10 Technical Guidance for Site Investigation and Remediation* (NYSDEC, 2010), a qualitative exposure assessment was performed and a Human Health Exposure Assessment (HHEA) report was prepared. The HHEA report is provided as Appendix G. The HHEA identified constituents of potential concern (COPCs), identified potentially complete exposure pathways, and evaluated the potential for exposure of human receptors to Site-related COPCs assuming no further remedial actions are conducted.

Soil, groundwater, exterior soil vapor, and ambient air associated with the former MGP Site do not present potentially complete exposure pathways for commercial workers, consumers, or residents based on current land use and are not anticipated to represent complete future exposure pathways for these receptors. Construction and utility workers may be exposed to soil and/or shallow groundwater during intrusive activities, but the use of appropriate health and safety measures can be used to mitigate these exposures.

Constituent concentrations in exterior soil vapor in excess of typical background indoor air concentrations do not automatically indicate a potential human health risk. Rather, these soil vapor data should be considered as one line of evidence in the overall evaluation of the indoor air (vapor intrusion) pathway. Indoor air samples were collected from Site businesses during the SC (i.e., Silent Thunder Martial Arts, Kurt Cleaners, and CVS Pharmacy). Indoor air results indicated that potential MGP-related constituent concentrations were all below NYSDOH typical background indoor air concentrations (ARCADIS, 2010c). As indicated in the Site Characterization Data Summary Addendum (ARCADIS, 2010c), the vapor intrusion pathway for potential MGP-related constituents at the Site is concluded to be incomplete.

9. Findings and Conclusions

This section summarizes the findings of the SC and RI and presents the conclusions, based on the data presented in this document.

9.1 Geology/Hydrogeology

- The Site subsurface deposits consist of fill material between 5 and 15 feet in thickness underlain primarily by glacial sand deposits. No confining layers were observed during the RI drilling activities.

- There are no groundwater supply wells located at or in the vicinity of the Site. New York City's drinking water is supplied from reservoirs located in upstate New York.

- Beneath the Site, groundwater exists under water-table conditions and ranges from approximately 5.5 to 7.5 ft bls. A local groundwater divide is present on Lot 25 in the vicinity of monitoring well MW-8. The shallow Site groundwater flow direction north of the groundwater divide is generally to the northwest, toward Coney Island Creek. The shallow Site groundwater flow direction south of the groundwater divide is generally to the south, toward New York Bay.

- The average shallow horizontal groundwater velocity may range from approximately 0.09 to 0.5 ft/d.

9.2 Nature and Extent of Constituents in Media

9.2.1 Soil

- The primary VOCs that were detected in soil above SCGs include BTEX constituents. BTEX constituents exceeded the restricted use protection of groundwater SCOs and unrestricted use SCOs in three soil samples (SB-6 [43-45'], SB-9 [72-73.5'], and SB-22 [33-34']). In addition, toluene and xylenes exceeded the restricted use protection of public health commercial use SCOs in one soil sample (SB-9 [72-73.5']). VOCs were identified as COCs in soil.

- The primary SVOCs that were detected in soil above SCGs include PAHs. The highest PAH concentrations were detected in soil samples SB-6 (43-45'), SB-9 (72-73.5'), and SB-22 (33-34'). The majority of the other soil samples where PAHs were detected above SCGs were collected from either the 2-3 ft bls interval (detections appear to be associated with the shallow fill material) or the water table interface. SVOCs were identified as COCs in soil.

- Cyanide, metals, PCBs, and pesticides were not identified as COCs in soil.

9.2.2 Groundwater

- The primary VOCs that were detected in groundwater above SCGs include BTEX constituents (in monitoring wells MW-1 through MW-5, MW-10, MW-11, MW-14, MW-15, MW-17, and MW-18 and temporary monitoring wells SB-7, VP-1, and VP-2). VOCs were not detected above SCGs in monitoring wells MW-6 through MW-9, MW-12, MW-13, MW-16, MW-19, and MW-20 and temporary monitoring wells VP-3 and VP-4. VOCs were identified as COCs in groundwater.

- The primary SVOCs that were detected in groundwater above SCGs include PAHs. Naphthalene is the primary PAH that has migrated to the downgradient property boundary of Block 7273, Lot 1. SVOCs were not detected above SCGs in monitoring wells MW-6 through MW-9, MW-12, MW-19, and MW-20 and temporary monitoring wells VP-3 and VP-4. SVOCs were identified as COCs in groundwater.

- Cyanide, metals, PCBs, and pesticides were not identified as COCs in groundwater.

- Neither LNAPL nor DNAPL were detected in any of the monitoring wells.

9.2.3 Soil Vapor

- Potential MGP-related constituents were detected in exterior soil vapor samples collected from soil vapor points SV-1 and SV-2. Toluene was the only potential MGP-related constituent detected in the SV-2 soil vapor sample. No MGP-related compounds were detected at SV-3 or SV-4.

- There were non-MGP-related constituents detected in all of the soil vapor samples and ambient air sample. Most notably, chlorinated VOCs were detected in the SV-1 (TCE, cis-1,2-DCE, trans-1,2-DCE, and VC) and SV-4 (PCE) exterior soil vapor samples and are likely associated with the post-MGP operations, such as a dry cleaner.

- During the SC, PCE and other chlorinated VOCs (TCE, cis-1,2-DCE, and VC) were detected at elevated concentrations in the SSSV-6 sub-slab soil vapor sample. In addition, PCE was detected at an elevated concentration in the SSSV-4 sub-slab soil vapor sample. A number of non-MGP-related constituents detected in indoor air (2-butanone [methyl ethyl ketone], dichlorodifluoromethane (Freon 12), 4-methyl-2-pentanone [MIBK], and PCE) were above typical background indoor air concentrations in four indoor air quality samples. These detected compounds are not associated with historic MGP operations.

- Potential MGP-related constituent vapors are not migrating into the shopping center building at concentrations that may result in an unacceptable human health risk. This is evidenced by the fact that potential MGP-related constituents detected in indoor air during the SC were below typical background indoor air concentrations for all indoor air quality samples. Furthermore, the potential MGP-related constituents detected in indoor air may be attributable to other sources (i.e., background sources).

9.3 Fate and Transport

- The media of concern at the Site are soil and groundwater, and the COCs are principally BTEX constituents and PAHs. In general, the BTEX constituents detected in groundwater during the RI are relatively mobile in groundwater having a moderate to high solubility and/or low K_{oc} and K_{ow} values. In contrast, the PAHs detected in groundwater during the RI are relatively immobile in groundwater having a low solubility, with the exception of naphthalene, which has a higher solubility relative to the other PAHs detected in groundwater.

- The primary transport mechanisms for COCs are leaching from soils in source areas to groundwater, volatilization from source areas and shallow groundwater to the soil vapor/atmosphere, and advective groundwater movement.

9.4 Conceptual Site Model

- The former gas holders, tar tank, and cistern are all likely sources of the tar releases from the former MGP. Post-MGP operations, such as a dry cleaner, are likely a source of chlorinated VOCs detected in the media at the Site. Post-MGP site uses, such as parking lots and adjacent roadways, are potential sources of shallow petroleum impacts detected in the media at the Site.

- The hydrocarbon product identification data for soil samples collected during the SC suggest that fuel oil impacts of unknown origin are present at the water table across the entire area that the former MGP occupied and that coal tar impacts are present at the water table across the central and eastern portion of the area that the former MGP occupied.

- The former MGP operations and the soil and groundwater impacts are located north of the groundwater divide. Soil and groundwater impacts were not encountered south of the groundwater divide.

- The deepest tar-saturated soil was encountered in soil boring SB-9 (downgradient of the former MGP operations) in the 70 to 75 ft bls soil core. The deepest tar-impacted (i.e., tar blebs) soil was encountered in soil boring SB-4 to a depth of 80 to 90 ft bls. Tar-impacted soil was encountered south (upgradient) of the former MGP operations at shallower depths in soil borings SB-6 (between 40 and 50 ft bls) and SB-22 (between 30 and 40 ft bls). The extent of tar-impacted soil has been horizontally and vertically delineated.

- The highest BTEX and PAH concentrations in soil generally correspond with the observed tar and petroleum hydrocarbon impacts, which are a source of groundwater impacts.

- The highest BTEX and PAH concentrations in groundwater were detected in monitoring wells MW-5 and MW-11 (both screened from 30 to 40 ft bls).

- Concentrations of BTEX constituents and light molecular weight PAH compounds in groundwater have migrated along the groundwater flow path (northwest) to the Block 7273, Lot 1 property boundary. However, the BTEX and light molecular weight PAH concentrations in groundwater significantly attenuate between the former MGP operations area and the Block 7273, Lot 1 property boundary.

- MGP-related impacts are not present south of the soil boring SB-22 area, located immediately south of the former MGP operations area.

- The dissolved-phase groundwater impacts significantly decrease with both vertical and horizontal distance from the limits of tar-impacted soils.

- The soil and groundwater quality data collected from the MW-20 (north of Neptune Avenue) soil boring and monitoring well (screened 80 to 95 ft bls) indicate that the downgradient extent of impacts have been delineated.

- The HHEA evaluated potential exposures associated with soil, groundwater, exterior soil vapor, and ambient air. Soil, groundwater, soil vapor, and ambient air associated with the former MGP Site do not present potentially complete exposure pathways for commercial workers, consumers, or residents based on current land use and are not anticipated to represent complete future exposure pathways for these receptors. Construction and utility workers may be exposed to soil and/or shallow groundwater during intrusive activities, but the use of appropriate health and safety measures would likely mitigate these exposures.

- Indoor air quality samples were collected from Site businesses during the SC (i.e., Silent Thunder Martial Arts, Kurt Cleaners, and CVS Pharmacy). Indoor air results indicated that potential MGP-related constituent concentrations were all below NYSDOH typical background indoor air concentrations. As indicated in the Site Characterization Data Summary Addendum, the vapor intrusion pathway for potential MGP-related constituents at the Site is concluded to be incomplete.

- Sufficient data have been obtained during the SC and RI to determine the extent of impacts from the former MGP operations. However, additional data may be required to support remedy design due to the existing shopping center building location over the former MGP footprint.

10. Recommendations

Based on the conclusions provided above, an evaluation of potential remedial actions is recommended for the Site. The majority of the SC and RI drilling locations were situated outside of the approximate former MGP site boundary due to the access limitations associated with the existing shopping center building. The soil investigation achieved the RI objective of determining the nature and extent of potential MGP-related COCs. However, additional soil investigation activities will be required beneath the existing shopping center building to refine the distribution of MGP impacts at the Site in advance of any remedial action. When conditions are amenable, a pre-design investigation (PDI) will be conducted to provide additional data within the approximate former MGP site boundary to support remedy design and implementation.

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