nationalgrid

Patrick J. Van Rossem
Project Manager
Site Investigation and Remediation

November 30, 2017

Mr. John Miller, PE
New York State Department of Environmental Conservation
Division of Environmental Remediation, Remedial Bureau C
625 Broadway, 11th Floor
Albany, New York 12233-7014

Re: 100% Remedial Design Report
Site Remediation
Former Citizens Gas Works Manufactured Gas Plant Site
Carroll Gardens/Public Place
Borough of Brooklyn, Kings County, New York
Site No. C224012

Dear Mr. Miller:

Please find enclosed the *100% Remedial Design Report* (100% RD) for Parcels I, II, and III of the former Citizens Gas Works manufactured gas plant (MGP) site (hereinafter, the "Site") located in Brooklyn, New York. The 100% RD presents the design details for the Site remedy and addresses the Department's comments, dated April 20, 2017, on the January 2017 *95% Remedial Design Report*.

As of the date of this letter, Parcels I and II of the Site are occupied by Ferrara Brothers Building Materials Corporation (hereinafter, the "Concrete Facility"). Contractor procurement and implementation of the remedial action are predicated on the following:

- Complete demobilization of the Concrete Facility from Parcels I and II (including the existing concrete plant and associated materials, equipment, aggregate bins, and facilities);
- Regulatory agency approval of the enclosed 100% RD; and
- Obtaining all necessary permits and access agreements.

Assuming that regulatory agency approval of the 100% RD is received by the end of December 2017, and the Concrete Facility is completely demobilized from the Site by March 31, 2018, then mobilization for the remedial action would be anticipated to start in the fourth quarter of 2018. However, if there are any issues or delays related to any of the above items, or any significant modifications to the design, then this timeline is likely to be extended. Upon mobilization to the

Site Investigation and Remediation, 175 East Old Country Road, Hicksville, New York 11801
T: (516) 545-2578 ■ patrick.vanrossem@nationalgrid.com ■ www.nationalgrid.com

Site, the remedial action is anticipated to be implemented over a period of approximately 20 months.

If you have any questions, please call me at (516) 545-2578, or contact me by e-mail at patrick.vanrossem@nationalgrid.com.

Sincerely,

Patrick J. Van Rossem/MJB

Patrick J. Van Rossem
Project Manager
Site Investigation & Remediation

Enclosure

cc: G. Cross, NYSDEC
C. Doroski, NYSDOH
C. Tsiamis, USEPA
T. Leissing, National Grid
A. Prophete, National Grid
K. Vater, PE, National Grid
J. Alonzo, de maximis
C. Young, de maximis
T. Young, PE, Arcadis
M. Benoit, PE, Arcadis

ARCADIS Design & Consultancy for natural and built assets

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100% REMEDIAL DESIGN REPORT

Site Remediation

Former Citizens Gas Works Manufactured Gas Plant Site

Carroll Gardens/Public Place

Borough of Brooklyn, Kings County, New York

Site No. C224012

November 2017

I, Terry W. Young, certify that I am currently a New York State-registered professional engineer and that this remedial design was prepared in accordance with all applicable statutes and regulations and in substantial conformance with the DER *Technical Guidance for Site Investigation and Remediation* (DER-10) and that all activities were performed in full accordance with the DER-approved work plan and any DER-approved modifications.

November 30, 2017

Terry W. Young, PE
Vice President

Date

100% REMEDIAL DESIGN REPORT

Site Remediation

Former Citizens Gas Works Manufactured Gas Plant Site

Carroll Gardens/Public Place

Borough of Brooklyn, Kings County, New York

Site No. C224012

Prepared for:

National Grid USA

175 East Old Country Road

Hicksville, New York 11801

Prepared by:

Arcadis of New York, Inc.

One Lincoln Center

110 West Fayette Street

Suite 300

Syracuse

New York 13202

Tel 315 446 9120

Fax 315 449 0017

Our Ref.:

B0036728.0001.00003

Date:

November 2017

CONTENTS

TABLES

FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

Arcadis	Arcadis of New York, Inc.
ASCE	American Society of Civil Engineers
BTEX	benzene, toluene, ethylbenzene, and xylenes
CLSM	controlled low-strength material
DNAPL	dense non-aqueous phase liquid
gpm	gallon per minute
MGP	manufactured gas plant
NAVD88	North American Vertical Datum of 1988
NYCBC	New York City Building Code
NYSDEC	New York State Department of Environmental Conservation
PAH	polycyclic aromatic hydrocarbon
psf	pound per square foot
SDI	supplemental design investigation
SVOC	semi-volatile organic compound
VOC	volatile organic compound

1 INTRODUCTION

1.1 General

This 100% Remedial Design Report (RD) has been prepared by Arcadis of New York, Inc. (Arcadis), on behalf of National Grid, to summarize the design basis and technical details for the remediation of Parcels I, II, and III of the former Citizens Gas Works manufactured gas plant (MGP) site (hereinafter, the "Site") located in Brooklyn, New York. The Site is currently in the New York State Brownfield Cleanup Program (designated as Site No. C224012) and is being remediated by National Grid pursuant to the: (1) *Voluntary Cleanup Program Decision Document* (Decision Document; New York State Department of Environmental Conservation [NYSDEC] 2007); and (2) Brownfield Site Cleanup Agreement (Index No. A2-0610-0808), effective February 19, 2009, between NYSDEC and National Grid, the City of New York (hereinafter, the "City"), Vichar, Inc., and Harvic International Ltd.

As further described in Section 4 of this RD, the remedial construction activities to be performed as part of this remedial action (hereinafter, the "Project") will generally include the following:

- Site preparation activities after Ferrara Brothers Building Materials Corporation (hereinafter, the "Concrete Facility") has fully demobilized from Parcels I and II of the Site and removed its existing concrete plant and associated materials, equipment, aggregate bins, and facilities;
- Excavation of approximately 31,930 in-situ cubic yards of MGP-impacted soil from within the remedial excavation limits on Parcel I to depths ranging from approximately 14 to 26 feet below existing grade;
- Excavation of approximately 9,490 in-situ cubic yards of MGP-impacted soil from within the remedial excavation limits on Parcel III to depths ranging from approximately 20 to 22 feet below existing grade;
- Decommissioning of several existing piezometers, groundwater monitoring wells, and passive dense non-aqueous phase liquid (DNAPL) recovery wells;
- Selective demolition of former building foundations, underground facilities, and former MGP structures located within the remedial excavation limits on Parcels I and III;
- Backfilling remedial excavation areas with suitable fill materials;
- Selective demolition of portions of existing Gowanus Canal bulkheads at the Site where necessary and required for the construction of a new bulkhead barrier wall;
- Construction of approximately 880 linear feet of new steel bulkhead barrier wall along the Gowanus Canal;
- Installation of several new piezometers and passive DNAPL recovery wells;
- Removal of demolition, excavation, and construction waste from the Site and disposal at appropriate, National Grid-approved facilities in accordance with applicable laws and regulations;
- On-Site treatment of construction wastewater and discharge (following treatment) to the Gowanus Canal in accordance with applicable laws and regulations; and

- Restoration of the Site to the grades and conditions shown or indicated in the RD.

The Specifications and Design Drawings for the Project are provided in Appendices A and B, respectively, of this RD.

This RD has been prepared in general conformance with Section 5.2 of NYSDEC's *Technical Guidance for Site Investigation and Remediation* (DER-10; NYSDEC 2010).

1.2 Report Organization

The remainder of this RD is organized into five sections as follows:

- Section 2 (Site Background), presents general information regarding existing (pre-remediation) conditions at the Site and in the surrounding off-Site area;
- Section 3 (Basis of Design), summarizes the technical basis and assumptions used in the design of the Project;
- Section 4 (Remediation Activities), summarizes the remedial construction activities to be performed as part of the Project;
- Section 5 (Schedule), presents the anticipated schedule for the implementation of the Project; and
- Section 6 (References), presents a list of reference documents used in the preparation of this RD.

2 SITE BACKGROUND

2.1 General

This section provides general information regarding existing (pre-remediation) conditions at the Site and in the surrounding off-Site area, including the investigations and evaluations conducted by National Grid and others in these areas.

2.2 Site Location and Description

The Site is generally located at the intersection of Smith and 5th Streets in the Carroll Gardens neighborhood of the Borough of Brooklyn, Kings County, New York (Figure 1). The Site is generally bounded by 5th Street, Hoyt Street, and privately-owned commercial properties to the north, Smith Street to the west, Huntington Street to the southwest, and the Gowanus Canal (a New York State Class SD waterbody) to the south and east (Figure 2). The area surrounding the Site is densely populated and includes a mix of commercial, industrial, and residential land uses. Gowanus Bay is located approximately 1.0 mile southeast of the Site, and New York Harbor is located approximately 1.2 miles west of the Site.

The Site encompasses an area of approximately 9.6 acres and comprises three contiguous properties, which are commonly referred to as “Parcel I” (Block 471, Lot 1), “Parcel II” (Block 471, Lot 100), and “Parcel III” (Block 471, Lot 200). Parcels I and II are owned by the City and, as of the date of this RD, are occupied by the Concrete Facility, which operates a concrete plant on Parcel II. Parcel I is also used by the Concrete Facility for employee parking, equipment staging, and material storage. Parcel III is currently owned by Smith Street Owner, LLC. The Site is enclosed by fencing and is generally secure from public access.

Parcel I is covered with concrete pavement (approximately 3.2 acres) and, along the northern and northwestern portions of the property (near Smith Street), gravel and debris with sparse vegetation (approximately 0.9 acre). Storm water infiltration is minimal in the gravel- and debris-covered portions of Parcel I due to shallow buried foundations and slabs associated with former MGP structures (e.g., gas holders, purifiers, etc.). Parcel II (approximately 1.7 acres) is covered entirely with concrete slabs and pavement, which vary in thickness from approximately 0.5 foot to approximately 4.5 feet. The footprint of the former warehouse on Parcel III (approximately 2.7 acres) is covered with gravel and debris with sparse vegetation. Asphalt pavement surrounds the former warehouse area to the northeast, east, and southeast (approximately 1.1 acres).

Surface topography at the Site slopes downward from the north to the south and southeast. Topographic elevations range from approximately 30.0 feet above the North American Vertical Datum of 1988 (NAVD88) near the intersection of Smith and 5th Streets to between approximately 8.0 feet and 12.0 feet NAVD88 along the Gowanus Canal. Storm water run-off at the Site generally drains from the central portion of Parcel I to the south and southeast, and ultimately reaches the Gowanus Canal via overland flow (Parcel II) or through outfalls in the existing bulkhead (Parcel III).

2.3 Site History

2.3.1 Operational History

The Site and surrounding area were originally part of the wetlands system adjacent to Gowanus Creek. The area was artificially filled as part of the construction of the Gowanus Canal in the 1860s. Soon after the completion of the canal, the Citizens Gas Company constructed a coal gasification plant on Parcels I and II. The Brooklyn Union Gas Company acquired the Site in 1895. The plant was converted to an oil gasification plant in 1952 and operated as such until its closure in the early 1960s. The Brooklyn Union Gas Company sold the MGP properties in 1969.

2.3.2 Regulatory History

KeySpan Corporation and NYSDEC entered into a Voluntary Cleanup Agreement (Index No. A2-0460-0502), effective August 31, 2002, for the investigation and remediation of Parcels I and II of the Site (formerly designated as Site No. V00360). The Voluntary Cleanup Agreement was terminated effective November 11, 2007, and NYSDEC and National Grid, the City, Vichar, Inc., and Harvic International Ltd. subsequently entered into a Brownfield Site Cleanup Agreement (Index No. A2-0610-0808), effective February 19, 2009, for the investigation and remediation of the Site (Parcels I, II, and III).

2.4 Previous Site Investigations and Evaluations

Several investigations and evaluations have been conducted at the Site and in the surrounding off-Site area to characterize existing (pre-remediation) conditions. The results of these investigations and evaluations, which serve as the basis for the remediation activities described herein, were presented in the following documents:

- *Environmental and Engineering Study, Assessing the Suitability of the Gowanus Canal Site for Public Housing and Recreational Usage* (Stone & Webster Engineering Corporation 1984);
- *Final Report, Vacant Property Site Assessment, Carroll Gardens, Brooklyn* (TRC Environmental Consultants, Inc. 1985);
- *Engineering Investigation at Inactive Hazardous Waste Sites, Phase I Investigations, Carroll Gardens, Site No: 224012, Borough of Brooklyn, Kings County* (EA Engineering, Science, and Technology, Inc. 1987);
- *Engineering Investigation at Inactive Hazardous Waste Sites, Phase II Investigations, Carroll Gardens, Site No: 224012, Borough of Brooklyn, Kings County* (Roux Associates, Inc. 1990);
- *Test Pit Soil Sampling and Drum Classification Results* (Metcalf & Eddy, Inc. 2005);
- *Final Remedial Investigation Report* (RI Report; GEI Consultants, Inc. [GEI] 2005);
- *Remedial Alternative Analysis* (KeySpan Corporation 2007);
- *Supplemental Remedial Investigation (SRI) Interim Data Summary* (National Grid 2009b);
- *Draft Gowanus Canal Remedial Investigation Report* (HDR, Inc. et al. 2011);

- *DNAPL Recovery Wells Pilot Test Report* (GEI 2011);
- *Supplemental DNAPL Investigation Findings and Memorialization of Related Design Parameters* (National Grid 2012);
- *Data Summary Report, Barrier Wall Pilot Test Program* (Barrier Wall Pilot Test Report; GEI 2015); and
- *Supplemental Design Investigation Report* (SDI Report; Arcadis 2016).

2.5 Existing Structures and Underground Facilities

2.5.1 Culver Viaduct

The Culver Viaduct, an elevated section of the Metropolitan Transit Authority's F and G subway lines, runs adjacent to the Site to the south and west. Spanning the Gowanus Canal at 9th Street, the structure supports four tracks, two subway lines (the F and G trains), and two stations, including the Smith and 9th Street stop which, at a height of 87.5 feet, is the highest subway station above ground level in the City. The concrete-encased steel structure is approximately one mile long and connects the Carroll Gardens and Park Slope neighborhoods. Originally constructed in 1933, the Culver Viaduct underwent a major rehabilitation between 2009 and 2013 to improve poor track drainage and repair deteriorated concrete sheathing.

2.5.2 Gowanus Canal Bulkheads

The existing bulkheads at the Site consist of (from north to south): (1) timber cribbing with an existing timber fender system outboard of the cribbing (approximately 200 linear feet); (2) a pile-supported concrete relief platform (approximately 285 linear feet); (3) timber cribbing (approximately 360 linear feet), and (4) steel sheet piling (with a tieback system) installed outboard of timber cribbing (approximately 40 linear feet). The approximate extent of the various bulkhead systems is depicted on Drawings G-101 and G-109 (Appendix B).

The bulkhead along the Gowanus Creek was constructed circa 1850 to the mid-1860s, which effectively turned the creek into the canal that is in existence today. The bulkhead at the Site was originally constructed as a timber crib wall (Hunter Research, Inc. et al. 2004). The original bulkhead has been upgraded and repaired several times through the years; however, details of many of these upgrades and repairs are not readily available. The most significant alteration or repair to the bulkhead at the Site was completed in 1922 when a large portion of the crib wall, generally at the southern end of Parcel II, collapsed into the Gowanus Canal. The damage was repaired by constructing a wooden deck supported on timber piles (relief platform) over the area of land that had slid into the canal. Subsequently, a concrete retaining wall was constructed on top of the deck. The original grade of the Site was then restored, and a pile-supported timber fender system was built out from the new bulkhead into the canal and faced to match the original crib wall in appearance. The timber fender system has since been removed, but historical records indicate that the timber piles, which formed the basis of this system, were cut-off at the mud line and still remain in place today. Based on the available construction documents,

the extant timber piles appear to be located up to approximately six feet into the canal from the concrete face of the bulkhead.

A separate timber fender system extending out into the Gowanus Canal still exists at the northern end of Parcel II on a portion of the existing timber crib bulkhead. This fender system is also supported on timber piles, which are visible during low tide.

A small portion of the original crib wall at the southern end of Parcel III has been reinforced by an anchored steel sheet pile bulkhead. The sheet pile bulkhead consists of a steel sheet pile headwall connected with two-inch diameter tie rods to steel H-pile anchors, which are located approximately 13 feet behind the headwall (GEI 2015).

2.5.3 Former MGP Structures

Initially, the MGP site was located between 5th Street and 6th Street on the northern portions of Parcels I and II. The initial MGP included three gas holders (hereinafter, "Holder No. 1", "Holder No. 2", and "Holder No. 3"), a retort house, and coal storage areas. The southern area of Parcel III was occupied by a chemical fertilizer production facility, which was not affiliated with the MGP. By 1904, a hydrogen gas holder (unnumbered) was located on Parcel I southeast of Holder No. 3, a purifier house was present on the northeast side of 6th Street, and a separator house and drip oil storage was located southwest of 6th Street.

The 1886 Sanborn map lists H.J. Baker and Brothers Chemical Fertilizers as the owner of the fertilizer plant and the 1904 Sanborn map identifies American Agricultural Chemical Company as the owner. The chemical fertilizer production facility closed sometime between 1904 and 1915 and Parcel III was further developed to include additional tar handling facilities and oil storage tanks. The unnumbered hydrogen gas holder on Parcel I was decommissioned during this period. By 1939, the plant had reached the extent of its construction. This included two new purifier houses and additional oil storage on Parcel I, a larger tar separator located on Parcel III, and the addition of two new gas holders – "Holder No. 4", which was constructed on Parcel IV (Block 468, Lot 25) near the corner of Hoyt and 5th Streets, and "Holder No. 5", which replaced Holder No. 1 and was constructed on Parcel I near the corner of Smith and 5th Streets. Between 1928 and 1948, a one-million-gallon oil tank was constructed on Parcel III and the two 86-foot diameter gas holders (Holder Nos. 2 and 3) on Parcel I were decommissioned as gas holders and converted for use as a tar dehydrator tank and tar separator tank, respectively. The plant retained this general configuration until the former MGP site was decommissioned and demolished in the early 1960s.

An historical site plan depicting the approximate locations of the former MGP structures is included as Drawing G-109 (Appendix B).

2.5.4 Bond-Lorraine Street Sewer

The Bond-Lorraine Street sewer is a City-owned, 72-inch inside-diameter, pile-supported combined sewer that passes beneath the Site from east to west through portions of Parcels I, II, and III. On Parcel II, the sewer alignment generally parallels the curve of the Gowanus Canal, and the distance between the southern edge of the sewer and the existing dock line ranges between approximately 30 and 40 feet. The sewer follows a relatively straight course through Parcel III and exits the Site at the corner of Smith and

Huntington Streets. Historical MGP drawings show a 10-foot wide easement on either side of the centerline of the sewer.

The overall width of the sewer is approximately 10 feet and the top of the sewer is generally located between elevations 4.1 feet and 5.6 feet NAVD88. The depth of the top of sewer below existing (pre-construction) ground surface varies with surface topography and depending on the construction type. The sewer is shallowest at the northeast end of Parcel II, where the depth to the top of the sewer is approximately 3.0 feet below existing (pre-construction) grade.

The original brick sewer was constructed circa 1892. Since that time, the sewer has undergone three major repairs at separate locations on the Site. Each of the repairs is summarized below in order from oldest to most recent.

2.5.4.1 1922 Replacement

In 1922, the timber crib bulkhead failed and resulted in damage to the sewer. The original brick sewer was removed and replaced with approximately 264 linear feet of 72-inch inside-diameter reinforced concrete culvert structure supported by timber piles.

2.5.4.2 1939 Replacement

A portion of the sewer, generally located beneath the former warehouse on Parcel III, was replaced in 1939 under the Work Projects Administration. The new section of sewer was built of reinforced concrete and was generally similar in construction to the section of sewer that had been previously replaced in 1922, with the exception of a flat ceiling. The inner width of this new section was also 72 inches.

2.5.4.3 1977 Repair

A portion of the original brick sewer partially collapsed, possibly due to operations at the concrete plant on Parcel II. The damaged section of sewer was repaired with the insertion of a 54-inch inside-diameter concrete section inside the original 72-inch brick pipe.

2.5.5 Gas Transmission Tunnel

During the early part of the 20th century, a tunnel was constructed under the Gowanus Canal to allow gas piping to pass under the canal. The construction of the tunnel was completed in 1924, and the gas lines routed through the tunnel are still in use today, providing critical gas supply to the Red Hook area of Brooklyn. The total length of the tunnel is 136 feet from center-to-center of shafts, with an oval cross section, 10 feet-8 inches in height, and 16 feet-1 inch in width. The tunnel is constructed from concrete sections, which are encased in 0.5-inch thick steel sheathing (Stiles 1926). The top of the steel sheathing for the tunnel is located at approximately elevation -23.6 feet NAVD88 and the depth of sediment over the tunnel varies between approximately 8 and 14 feet depending on location in the canal.

2.6 Site Geology and Hydrogeology

The regional geology within the area of the Site consists of the following units from shallowest to deepest:

- Fill;
- Native sands and marsh deposits;
- Upper Glacial Aquifer;
- Gardiners Clay;
- Jameco Gravel; and
- Fordham Gneiss.

The fill, native sands and marsh deposits, and Upper Glacial Aquifer are present throughout the majority of the Site. The Gardiners Clay is generally located beneath the Upper Glacial Aquifer, but was not observed in the eastern to central portion of Parcel I and the northwest portion of Parcel II during the remedial investigation (GEI 2005). The Gardiners Clay is considered to be a confining unit with vertical hydraulic conductivities ranging from 0.001 to 0.003 feet per day (United States Geological Survey 1999). The Jameco Gravel underlies either the Gardiners Clay, where present, or the Upper Glacial Aquifer. The Fordham Gneiss, a metamorphosed, medium- to coarse-grained igneous bedrock unit of Precambrian Age, was encountered during the remedial investigation at the Site between elevations -127.02 feet and -159.02 feet NAVD88.

Groundwater at the Site is present in the fill and underlying units. Recent alluvial and marsh deposits (meadow mat) are present between the fill and Upper Glacial Aquifer in most areas of the Site. The Upper Glacial Aquifer is generally unconfined; however, it can be locally confined by the presence of silt and clay layers within moraine deposits. Where the meadow mat is present, groundwater elevations are higher than where the mat is absent. Groundwater mounding is evident in the vicinity of the former gas holders on Parcel I along 5th Street. Shallow groundwater flow at the Site is generally toward the Gowanus Canal. Intermediate (Upper Glacial) and deep (Jameco) groundwater flow direction is generally west to southwest towards Upper New York Harbor. Groundwater at the Site is tidally influenced in the vicinity of the Gowanus Canal. The observed groundwater contours and interpolated groundwater flow directions are shown on Plates 7 through 12 of the RI Report.

The primary sources and sinks of groundwater in the area of the Site include the following:

- Recharge (precipitation);
- Surface water (Gowanus Canal, East River, and Gowanus Bay); and
- Regional aquifer.

Groundwater flows both into and out of the regional aquifer in the area of the Site, thus serving as both a source and a sink of groundwater. No evidence of significant utility infiltration/exfiltration has been observed at the Site.

Additional information regarding Site geology and hydrogeology is provided in the RI Report.

2.7 Nature and Extent of MGP-Related Impacts

As described in the Decision Document, soil and groundwater at and near the Site have been impacted by waste by-products of the gas manufacturing process – most notably, coal tar. Coal tar is a reddish-

brown to black DNAPL and contains a complex mixture of organic chemicals, including volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs). Chief among these compounds are benzene, toluene, ethylbenzene, and xylenes (collectively, "BTEX") and a more general class of SVOCs known as polycyclic aromatic hydrocarbons (PAHs). The specific PAHs of concern are acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, naphthalene, phenanthrene, and pyrene. The sum of the individual concentrations of these PAHs is hereinafter referred to as "total PAHs". Cyanide and metals, which can be associated with purifier waste and feedstock materials (e.g., coal, oil, etc.) used in the gas manufacturing process, have also been detected in soil and groundwater at the Site. Collectively, BTEX, PAHs, cyanide, and metals are considered the primary Site-related constituents of concern.

Information regarding the nature and extent of MGP-related impacts at the Site and analytical testing results for surface soil, subsurface soil, groundwater, and soil vapor samples collected at the Site and in the surrounding off-Site area (Operable Unit 2) were presented in the various reports prepared for the Site, most notably the RI Report (GEI 2005), *Supplemental Remedial Investigation (SRI) Interim Data Summary* (National Grid 2009b), *Supplemental DNAPL Investigation Findings and Memorialization of Related Design Parameters* (National Grid 2012), and SDI Report (Arcadis 2016).

3 BASIS OF DESIGN

3.1 General

This section provides a summary of the basis of design considerations that support the development of the RD for the upland remedial excavation areas, bulkhead barrier wall, and DNAPL recovery well network.

3.2 Remedial Excavation Areas

As outlined in the NYSDEC's remedy, the soil excavation areas focused on shallow soil and tar contaminated structures (deep excavation areas). The remediation of shallow impacted soil and deep excavation areas to address former structures is described further below.

A temporary wastewater treatment system has been designed to support the dewatering of the deep excavation areas. The dewatering rate for the excavation areas was evaluated using the Site groundwater flow model to determine steady state dewatering rates along with estimates based on Site observations and previous Site investigation activities. Based on these, the temporary wastewater treatment system was designed to treat a nominal flow rate of 200 gallons per minute (gpm). The treatment system components were selected based on existing Site groundwater data, previous experience at other MGP sites, and in order to meet SPDES discharge criteria for MGP-related compounds.

3.2.1 Shallow Impacted Soil

The Decision Document (NYSDEC 2007) includes requirements for removal of "contaminated soils…to a depth of approximately 8 feet below grade." The 8-foot depth was further clarified in a September 23, 2009 letter from National Grid to NYSDEC (National Grid 2009a), which indicated that the removal would "extend to (nominally) '8-feet' below street grade". Since the issuance of the Decision Document, a number of investigations have been performed and the scope of deep removal areas has been further refined based on all of the Site data, including data generated during the supplemental design investigation (SDI). A comparison of shallow soil impacts (observations of MGP-related visible impacts) identified during the various investigation activities to the limits of the deep soil excavation areas indicated that most of the areas of shallow soil impact will be removed as part of the deeper source area excavations at the Site. Other areas of shallow MGP-impacted soil within 8 feet below street grade (if any) that are encountered during future Site redevelopment will be addressed pursuant to the Decision Document and managed in accordance with a NYSDEC-approved Site Management Plan.

3.2.2 Deep Soil Excavation Areas

This RD provides details for deep soil excavation areas on Parcels I and III. As part of the RD, the excavation limits were updated based on the results of the SDI, previous investigations, historic information, and discussions with NYSDEC. In addition, the geotechnical data collected during the SDI and other Site information was used to design the excavation support systems as outlined further below.

Piping and structures containing visible MGP waste in the form of free-phase NAPL, NAPL coatings, or NAPL-saturated soils that are encountered within the top 8 feet of existing soil during the progress of the deep excavations on Parcels I and III will be excavated outside of the remedial excavation area(s) to the extent necessary, and where such excavation is not otherwise precluded by existing infrastructure (e.g., roads, active utilities, etc.), buildings, or facilities, to remove visible MGP-related impacts within and adjacent to them. This assumes that temporary shoring/shielding, and/or additional local permits/approvals will not be needed or required to address piping or structures encountered within 8 feet of existing grade that are located outside of the remedial excavation areas. MGP-impacted piping and structures, or portions thereof, that are encountered below or extend deeper than 8 feet below existing grade will remain in place. Existing piping and structures observed to be free of visible MGP waste will similarly remain in place.

Other deep MGP-impacted soils encountered during future Site redevelopment (if any) will be addressed pursuant to the Decision Document and managed in accordance with a NYSDEC-approved Site Management Plan.

3.2.2.1 Parcel I

The Parcel I deep soil excavation area was established to target "tar-contaminated MGP structures that remain in the subsurface along with their contents and the associated heavily-contaminated soils immediately surrounding them" as required by the NYSDEC's Decision Document. NAPL-impacted soil is located within and in the vicinity of Holder Nos. 2 and 3. Impacts inside the holder near the bottom are also present within Holder No. 5. Excavation at the unnumbered hydrogen gas holder was determined not to be necessary because the Site data (including the SDI and historic data) did not identify significant impacts. In addition, based on historic information, this holder is in close proximity to the high-pressure gas main along 5th Street such that installation of an excavation shoring system would not be feasible without affecting the adjacent gas main.

Based on this Site information, the excavation area for removal of "tar-contaminated" structures focuses on Holder Nos. 2 and 3 and the soils immediately adjacent to them. Materials within Holder No. 5 are addressed through removal within the holder (using best efforts without removing the sidewalls). The RD provides details regarding the excavation shoring and bracing system for the deep excavation work in the vicinity of Holder Nos. 2 and 3 to the limits shown down to the top of the foundation slabs (approximately elevations 3.0 feet and 2.0 feet NAVD88, respectively). The support system includes steel sheet piling along with internal bracing to allow the excavations to be completed safely. This method of support was selected over other methods (such as soil anchors) to avoid installation of bracing elements beneath existing streets and utilities. For Holder No. 5, the existing holder ring wall was evaluated to support the removal of the holder contents within the structure. Based on this evaluation, the holder ring wall itself was found not to be adequate to support the soil and construction loading. As a result, the RD includes the installation of a controlled low-strength material (CLSM) gravity wall inside of the holder ring wall to provide additional support that will be needed to remove the material inside of the holder.

As requested by NYSDEC, the RD includes the retention of existing DNAPL recovery wells to the extent practical and/or installation of new temporary DNAPL recovery wells if necessary to the east of the Parcel I excavation area prior to initiating the overall remedial construction in this area. The existing recovery wells in this area will be gauged as a first step after the Concrete Facility removes the obstructions in this

area to provide access. The RD includes the installation of new temporary NAPL recovery wells in this area in the event that the existing recovery wells cannot be located or are not in satisfactory condition.

3.2.2.2 Parcel III

The Parcel III excavation area was developed based on observed NAPL-saturated soil up to elevation -10.0 feet NAVD88. To the west, the excavation area is located outside of the former foundation for the warehouse. To the east, the excavation limit is defined by the approximate extent of the existing timber crib bulkhead located along the Gowanus Canal. The RD provides details regarding the excavation shoring and bracing system including the steel sheet piling and internal bracing. The excavation area includes sequencing requirements to facilitate the loading of trucks beneath a pre-engineered enclosure.

3.3 Bulkhead Barrier Wall

The objectives of the bulkhead barrier wall are to (1) mitigate the potential migration of DNAPL from the Site to the Gowanus Canal and (2) retain upland soils both during and after the remediation of the Gowanus Canal. In addition, the bulkhead has been designed with consideration of existing Site conditions (outlined above) including the presence of the Bond-Lorraine Street Sewer, gas transmission tunnel, and various bulkhead types along the Site boundary. Other general design considerations included minimizing, to the extent practicable:

- Interference with the existing Bond-Lorraine Street sewer and gas transmission tunnel;
- Potential effects to the upland portions of the properties; and
- The projection of the new bulkhead barrier wall into the Gowanus Canal.

As shown on the Design Drawings (Appendix B), the bulkhead barrier wall at the Site will include two primary design configurations: (1) an anchored tieback wall (approximately 380 linear feet), consisting of a steel sheet pile headwall connected with tie rods to steel sheet pile anchors, which will be installed parallel to and between approximately 45 feet and 65 feet inland of the bulkhead headwall; and (2) a cantilevered combination wall (approximately 500 linear feet), consisting of steel king piles with intermediate steel sheet piles. The anchored tieback wall will generally be installed along Parcel III and the cantilevered combination wall will generally be installed along Parcel II, where the proximity of the pile-supported Bond-Lorraine Street sewer prevents the installation of an anchored tieback wall.

The bulkhead barrier wall will generally follow the western edge of the Gowanus Canal, from the Parcel II property line at the eastern edge of the Site to the northern edge of Huntington Street at the southwestern edge of the Site, and will terminate on both sides of the gas tunnel shaft. As previously discussed with NYSDEC, wing walls are not included in this RD based on the review of all the Site information and data by Arcadis. DNAPL transmissivity testing conducted at monitoring wells CGMW-41I and CGMW-43D and at recovery well CGRW-06I during the SDI showed a low potential for recoverability indicating that, where present, DNAPL in soil is relatively immobile (Arcadis 2016). Moreover, a review of existing data at the eastern (Parcel II) and southwestern (Parcel III) edges of the Site shows that DNAPL-saturated soils are limited in both horizontal and vertical extent in these areas, and generally are not present above elevation -40 feet NAVD88 (i.e., within the design requirements for the bulkhead barrier wall). Intermediate and

deep passive recovery wells will be monitored as part of the long-term NAPL monitoring program at the Site and additional wells can be installed if needed.

The bulkhead barrier wall will be constructed using shop-welded steel sheet pile pairs. A joint sealant, such as De Neef Swellseal WA or Adeka Ultraseal P-201, will be applied in the field to non-welded joints (i.e., between the interlocks of adjacent welded sheet pile pairs and at sheet pile-to-king pile and king pile-to-king pile connections). Bench-scale testing conducted as part of the barrier wall pilot test program (GEI 2015) confirmed the effectiveness of these joint sealants, together with the mechanical interlocks of the steel piles, to achieve the barrier wall joint permeability performance criteria of 1×10^{-6} centimeter per second. Steel sheet piles will be driven to a minimum elevation of -40.0 feet NAVD88 in order to (1) mitigate potential DNAPL migration from the Site to the Gowanus Canal and (2) retain upland soils both during and after the remediation of the Gowanus Canal. The king piles for the cantilevered combination wall will be driven to a minimum elevation of between -76.0 and -83.0 feet NAVD88, depending on location, for structural support.

It should be noted that National Grid's Gas Department has projects planned for 2018 (separate from the remediation activities described herein) to: (1) re-line the existing 30-inch diameter gas mains in the gas transmission tunnel; (2) install new pipe headers; (3) fill the tunnel with CLSM; and (4) fill the tunnel shafts with sand. As part of those projects, the top of the gas tunnel shaft will also be raised to match final grade. The work associated with the gas transmission tunnel and shaft will be completed by National Grid's Gas Department prior to the installation of the bulkhead barrier wall in this area in order to mitigate the pile driving-related vibration levels experienced by the gas mains located within the tunnel.

Summary and discussion of the various performance criteria evaluated as part of the bulkhead barrier wall design are presented in the subsections below and are summarized in Table 1.

3.3.1 Ground Surface and Canal Sediment Surface Elevations

The bulkhead barrier wall was designed based on the ground surface elevations along the existing bulkhead at the Site, which vary between approximately elevation 8.0 feet NAVD88 and approximately elevation 12.0 feet NAVD88. The assumed canal dredge elevation (-21.5 feet NAVD88) and final cap elevation (-16.0 feet NAVD88) were based on the remedial dredge elevation and navigational elevation, respectively, indicated in the Record of Decision for the Gowanus Canal Superfund Site (United States Environmental Protection Agency 2013) for the stretch of canal located adjacent to the Site.

3.3.2 Design Loads

In addition to lateral earth pressures, the following loads were considered in the design of the bulkhead barrier wall:

- Hydraulic loads;
- Surcharge loads;
- Seismic loads; and
- Wind, wave, and current loads.

Each of these loads is described in further detail below. It should be noted that mooring, breasting, and berthing loads are not expected to occur along the bulkhead barrier wall and were not considered in the design. If such loads are necessary to support other activities (such as future Site use, use of the Gowanus Canal, or remediation of the Gowanus Canal), other measures to accommodate these loads will need to be taken at that time by third parties.

3.3.2.1 Hydraulic Loads

Arcadis developed a groundwater flow model for the Site to evaluate the effects of groundwater mounding under post-remediation conditions (following future completion of the deep excavation areas and bulkhead barrier wall installation). As described in the *Groundwater Model Report* (Arcadis 2017b; provided in Appendix C of this RD), post-remediation conditions at the Site were simulated under steady-state average-, high-, and low-tide (corresponding to canal surface water elevations of 0.00 feet, 2.28 feet, and -2.77 feet NAVD88, respectively)[1]. The results of those simulations indicate that, compared to current (calibration) conditions, a maximum of between approximately 3.7 feet and 6.1 feet of groundwater mounding (depending on tide) is expected to occur along the bulkhead barrier wall at the Site; however, Site groundwater levels are not predicted to rise above ground surface under anticipated post-remediation conditions.

It should be noted that future activities and conditions unrelated to the Project have the potential to further increase groundwater mounding and reduce the thickness of the unsaturated zone at the Site and along the entirety of the Gowanus Canal including, but not limited to, the following:

- Remediation activities associated with the Gowanus Canal Superfund Site, including upgrades to existing bulkheads along the canal and the targeted in-situ solidification of sediments in Remediation Target Areas 1 and 2, the design of which has yet to be completed;
- Other bulkhead modifications or upgrades not necessarily associated with the remediation of the Gowanus Canal Superfund Site;
- Regional flood resiliency measures;
- Future redevelopment of the Site and surrounding area;
- Local and regional changes in surface cover types (e.g., infiltration galleries, permeable pavements, vegetated areas, etc.); and
- Sea level rise and increased precipitation resulting from climate change.

These future activities and conditions were not evaluated as part of the Site-related modeling efforts described in the *Groundwater Model Report* since the scope and details of such future activities and conditions are not known at this time. Since these future activities and conditions are expected to result in additional groundwater mounding at the Site, a passive hydraulic relief system has been incorporated into the RD. The hydraulic relief system, which generally consists of six-inch nominal diameter perforated high-density polyethylene piping and precast concrete manholes, will be installed on the upland side of

[1] Tidal elevations are referenced to National Oceanic and Atmospheric Administration Station 8518750, The Battery, New York, 1983 to 2001 epoch.

the bulkhead barrier wall to control groundwater mounding in the immediate vicinity of the wall. The hydraulic relief system was designed to: (1) maintain a maximum hydraulic head differential of approximately 9.0 feet[2] between the mounded groundwater elevation on the upland side of the bulkhead and the surface water elevation in the canal; (2) avoid interference with the tieback system on Parcel III; (3) provide sufficient cover over the piping (a minimum of one foot) based on final Site grades; and (4) maintain a self-cleaning flow velocity of 2 feet per second within the piping. Cleanouts have been included at the end of each run of piping to facilitate future system maintenance.

3.3.2.2 Surcharge Loads

The following uniform surcharge loads have been assumed along the upland side of the bulkhead barrier wall:

- During the remedial dredging operations in the Gowanus Canal (as part of the Gowanus Canal Superfund Site remedy), a uniform surcharge load of 250 pounds per square foot (psf) for construction loading (New York State Department of Transportation 2015); and
- Following the completion of the Gowanus Canal remediation activities, a uniform surcharge load of 100 psf for pedestrian loading, in combination with the pseudo-static seismic loading described in Section 3.3.2.3 below.

3.3.2.3 Seismic Loads

Section 1613.1 of the 2014 New York City Building Code (NYCBC) stipulates that structures be designed to resist the effects of earthquake motions in accordance with the *Minimum Design Loads for Buildings and Other Structures* (ASCE/SEI 7-10; American Society of Civil Engineers [ASCE] 2010). However, waterfront structures such as piers and bulkheads do not typically fall under the same criteria used for buildings. Section 1613.1 of the NYCBC provides exceptions. The following is stated under item 4:

> *"Structures that require special consideration of their response characteristics and environment that are not addressed by this code or ASCE 7-10 and for which other regulations provide seismic criteria, such as vehicular bridges, electrical transmission towers, hydraulic structures, buried utility lines and their appurtenances and nuclear reactors."*

Although waterfront structures are not specifically mentioned, various standards exist for the design of such structures. Examples include *Design: Piers and Wharves* (Unified Facilities Criteria UFC 4-152-01; United States Department of Defense 2017) and *Seismic Design of Piers and Wharves* (ASCE/COPRI 61-14; ASCE 2014). Many ports have their own standards. For example, the Port of Los Angeles uses criteria that are similar to ASCE/COPRI 61-14. Although ASCE/COPRI 61-14 does not explicitly address bulkheads, use of the design seismic events recommended in this standard was appropriate and used as the basis. Based on this standard, Arcadis evaluated the bulkhead barrier wall as part of the RD under a pseudo-static seismic condition corresponding to a 1 in 475-year event with a uniform live surcharge load

[2] Maximum hydraulic head differential represents the difference between the average invert elevation of the hydraulic relief piping (6.12 feet NAVD88) and mean lower low water in the canal (-2.77 feet NAVD88).

of 100 psf. Given the relatively short potential duration of the Gowanus Canal remedial dredging efforts immediately adjacent to the Site, the pseudo-static seismic condition was evaluated based on the assumed final cap elevation of -16.0 feet NAVD88.

3.3.2.4 Wind, Wave, and Current Loads

Wind, wave, and current loads were evaluated during the design of the bulkhead barrier wall and were determined not to govern the design loading. These loads would act in the opposite direction of the active loading on the bulkhead. Therefore, wind, wave, and current loads were not included in the final load combinations for the design of the bulkhead.

3.3.3 Corrosion Protection

The bulkhead barrier wall will be protected from corrosion through the use of: (1) sacrificial steel in the headwall piles, anchor piles, and tie rods; and (2) protective coatings on all steel materials. Headwall sheet piles and king piles will be coated on both the water and land sides with a shop-applied epoxy coating system. Tie rods, pile caps, hardware, and other miscellaneous steel materials will be hot-dipped galvanized.

3.4 DNAPL Recovery Well Network

Based on a review of existing conditions, DNAPL is present at depth in various areas of the Site. As required by the Decision Document, a network of existing and new DNAPL recovery wells are included in the RD to facilitate the continued monitoring and recovery (if possible) of NAPL following completion of the remediation activities. The DNAPL recovery well network includes a series of wells along the bulkhead barrier wall. New recovery wells will be constructed with 15-foot long sumps to support DNAPL collection and removal.

4 REMEDIATION ACTIVITIES

4.1 General

The primary components of the remedial activities are summarized below. The activities are not intended to establish a general construction sequence. It should be noted that the selected remediation contractor (hereinafter, the "Contractor") will propose the Project sequence and schedule as part of its bid proposal.

- Pre-Mobilization and Mobilization:
  - Securing access agreements to support the construction and monitoring activities. National Grid will secure access agreements to support the remediation activities on Parcels I, II, and III and to properties to support the monitoring program (including the structural surveys outlined below). The Contractor will be responsible for securing other access agreements (if any) to support their approach to completing the Project if such additional access agreements are necessary.
  - Performing pre-construction structural surveys of nearby structures and buildings. The pre-construction structural surveys will evaluate the existing conditions of the buildings adjacent to the Site.
  - Securing necessary permits to support the remediation activities.
  - Preparing and submitting Project submittals.
  - Mobilizing personnel, materials, and equipment to the Site.
  - Completing baseline monitoring activities (vibration monitoring and community air monitoring pursuant to the Community Air Monitoring Plan).
  - Completing utility clearance activities.
- Site Preparation:
  - Installing temporary controls such as erosion and sediment control measures, construction entrances, haul roads, material staging area(s), and equipment decontamination pads.
  - Installing Parcel I DNAPL recovery wells downgradient of the Parcel I deep excavation area as requested by NYSDEC. The recovery wells are being installed to facilitate potential DNAPL recovery during the excavation activities. Recovery wells may include a combination of existing and new recovery wells. The use of existing wells will be determined based on the ability to locate some of the existing wells (which are currently beneath the existing concrete plant operations) and the condition of the wells if they are located.
  - Protecting and repairing certain existing monitoring wells and recovery wells.
  - Decommissioning certain existing piezometers, monitoring wells, and recovery wells.
  - Removing certain existing chain-link fencing and gates.
  - Installing new chain-link fencing and gates to secure the Site.
  - Clearing and grubbing existing vegetation.

  - Relocating existing soil piles currently stored on Parcel III.

- Parcels I and III Deep Soil Excavations:
  - Excavating soil from within Holder No. 5 on Parcel I. As identified above, the existing holder wall will be supported by a CLSM gravity wall constructed inside of the holder wall.
  - Installing steel sheet piling to support the other deep excavation areas located on Parcels I and III. It is anticipated that excavation activities on the two parcels will be completed sequentially.
  - Installing a temporary fabric structure(s) over the deep excavation areas on Parcels I and III. The temporary structure(s) will be equipped with a temporary air treatment system, which will maintain a constant negative pressure within the temporary structure(s) and provide not less than six exchanges per hour of total air volume contained within the structure(s).
  - Constructing a temporary wastewater treatment system to treat water removed from the excavation areas. Treated water will be discharged to the Gowanus Canal in accordance with a SPDES discharge equivalency issued by NYSDEC.
  - Excavating deep excavation area soils. Deep excavation areas will proceed to the limits presented in the RD. As part of the excavation activities, soils that meet re-use criteria will be stockpiled and re-used as backfill. Foundations, piping, and other structures encountered within the excavation limits will be removed. Piping and structures containing visible MGP waste in the form of free-phase NAPL, NAPL coatings, or NAPL-saturated soils that are encountered within the top 8 feet of existing soil and extend horizontally beyond the excavation limits will be excavated to the extent necessary to remove visible MGP-related impacts within and adjacent to them, subject to the restrictions set forth in Section 3.2.2 of this RD. Soils requiring off-Site disposal will be transported to an appropriate disposal facility.
  - Backfilling deep excavation areas using debris and excavated material that is acceptable for re-use and imported backfill.
  - Removing temporary structures and restoring excavation areas.
- Installation of New Bulkhead Barrier Wall:
  - Pre-clearing the alignment of the bulkhead barrier wall to remove debris and other obstructions located within the soft sediment of the Gowanus Canal. The Contractor will provide temporary support measures for the existing bulkhead system to maintain its stability. In addition, the Contractor will install controls to control sheens and turbidity in the Gowanus Canal resulting from the pre-clearing activities or installation.
  - Demolishing existing structures such as the relieving platform, cribbing, and fender system to support installation of the bulkhead barrier wall system. The gas transmission tunnel and drop shaft will be filled with CLSM and sand, respectively, by National Grid's Gas Department prior to proceeding with demolition activities in the vicinity of the gas tunnel.
  - Driving steel sheet piles and steel king piles for the bulkhead headwall.
  - Installing the anchor wall and tie-back system for the southern portion of the bulkhead barrier wall.

  - Installing jet-grout columns where the bulkhead barrier wall abuts the existing gas transmission tunnel shaft.
  - Installing piping, manholes, and cleanouts for the bulkhead barrier wall hydraulic relief system.
  - Backfilling behind the bulkhead barrier wall with suitable fill material.
  - Performing excavation dewatering (if necessary) to support installation of the bulkhead barrier wall system. Water removed from excavation areas will be directed to the temporary wastewater treatment system. Soils and debris requiring off-Site disposal will be transported and disposed of at an appropriate off-Site disposal facility.
  - Cutting off the tops of the steel piles at the elevations shown or indicated on the Design Drawings and installing a steel pile cap.
- Site Restoration:
  - Replacing the two existing catch basins on Parcel III. The new catch basins have been designed as a temporary measure to manage storm water run-off until such time as Parcel III is redeveloped and permanent storm water controls are established by the property owner/developer.
  - Installing new piezometers and DNAPL recovery wells along the bulkhead barrier wall.
  - Restoring the Parcel I deep excavation areas with new crushed stone surfacing and installing new asphalt pavement on Parcels II and III along the bulkhead barrier wall.
  - Reinstalling chain-link fencing and gates removed during the Site preparation activities.
  - Restoring other areas disturbed as part of the Site remediation activities.
- Demobilization:
  - Removing temporary construction facilities (e.g., field office trailers, material staging areas, decontamination pads, temporary haul roads, etc.) associated with the Site remedy.
  - Performing post-construction structural surveys of nearby structures and buildings. The post-construction structural surveys will evaluate the conditions of the buildings adjacent to the Site following construction activities.
  - Providing post-remediation submittals.
- Post-Remediation Activities:
  - Preparing a Final Engineering Report to summarize the remediation activities, the results of Project monitoring activities, and to provide as-built drawings for the Site remedy.
  - Preparing and implementing a Site Management Plan as required by NYSDEC's Decision Document.
  - Imposing institutional controls in the form of environmental easements as required by NYSDEC's Decision Document.

4.2 Citizen Participation and Public Outreach Activities

NYSDEC will prepare and distribute to the public a project fact sheet outlining the planned scope and anticipated start date of the Project. National Grid will also support NYSDEC with any public meetings or information sessions prior to and during the Project.

4.3 Site Controls and Community Air Monitoring

Community air monitoring activities will be conducted during disturbance of soil at the Site as outlined in the *Community Air Monitoring Plan* (Arcadis 2017a; provided in Appendix D of this RD). The monitoring requirements included in the *Community Air Monitoring Plan* were developed based on New York State Department of Health's Generic Community Air Monitoring Plan (which is included as Appendix 1A of DER-10). As part of the remedy, various engineering controls will be employed or made available to control dust and odors.

The primary measure for controlling dust will be the application of water on surfaces where heavy equipment is traveling (such as designated haul routes on-Site). Odor controls will include use of temporary enclosures over the deep excavation areas located on Parcels I and III. The temporary enclosures will be equipped with a temporary air treatment system equipped with organic treatment and particulate removal. Foam and foaming devices will be used during excavation work, if necessary, to control odors and VOC emissions.

5 SCHEDULE

As of the date of this RD, Parcels I and II of the Site are occupied by the Concrete Facility. Contractor procurement and implementation of the remedial action are predicated on the following:

- Complete demobilization of the Concrete Facility from Parcels I and II of the Site (including the existing concrete plant and associated materials, equipment, aggregate bins, and facilities);
- Regulatory agency approval of this RD; and
- Obtaining all necessary permits and access agreements.

The contractor procurement process is scheduled to commence when the following conditions are addressed: (1) regulatory agency approval of this RD and (2) complete demobilization of the Concrete Facility from Parcels I and II of the Site. Assuming that regulatory agency approval of this RD is received by the end of December 2017, and the Concrete Facility is completely demobilized from the Site by March 31, 2018, then mobilization for the remedial action would be anticipated to start in the fourth quarter of 2018. However, if there are any issues or delays related to any of the above items, or any significant modifications to the design, then this timeline is likely to be extended. Upon mobilization to the Site, the remedial action is anticipated to be implemented over a period of approximately 20 months.

6 REFERENCES

Arcadis. 2016. *Supplemental Design Investigation Report*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for National Grid. June.

Arcadis. 2017a. *Community Air Monitoring Plan*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for National Grid. November.

Arcadis. 2017b. *Groundwater Model Report*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for National Grid. November.

ASCE. 2010. *Minimum Design Loads for Buildings and Other Structures*. ASCE Standard ASCE/SEI 7-10. ASCE, Reston, Virginia.

ASCE. 2014. *Seismic Design of Piers and Wharves*. ASCE Standard ASCE/COPRI 61-14. ASCE, Reston, Virginia.

EA Engineering, Science, and Technology, Inc. 1987. *Engineering Investigation at Inactive Hazardous Waste Sites, Phase I Investigations, Carroll Gardens, Site No: 224012, Borough of Brooklyn, Kings County*. Prepared for NYSDEC. June.

GEI. 2005. *Final Remedial Investigation Report*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for KeySpan Corporation. October.

GEI. 2007. *Final Remedial Design Work Plan*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for KeySpan Corporation. September 14.

GEI. 2011a. *DNAPL Recovery Wells Pilot Test Report*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for National Grid. March 28.

GEI. 2011b. *Groundwater Model for Hydraulic Effect of Proposed Remedial Alternatives*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for National Grid. September 13.

GEI. 2015. *Data Summary Report, Barrier Wall Pilot Test Program*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. Prepared for National Grid. August.

HDR, Inc., CH2M Hill, and GRB Environmental Services, Inc. *Draft Gowanus Canal Remedial Investigation Report*. Gowanus Canal Superfund Site, Brooklyn, New York. Prepared for the United States Environmental Protection Agency. January.

Hunter Research, Inc., Raber Associates, and Northern Ecological Associates, Inc. 2004. *National Register of Historic Places Eligibility Evaluation and Cultural Resources Assessment for the Gowanus Canal*. Prepared for United States Army Corps of Engineers. May, Revised December.

KeySpan Corporation. 2007. *Remedial Alternative Analysis*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. March 22.

Metcalf & Eddy, Inc. 2005. *Test Pit Soil Sampling and Drum Classification Results*. Carroll Gardens (Public Place), Smith Street and Fifth Street, Brooklyn, New York. Prepared for the New York City Economic Development Corporation. May.

National Grid. 2009a. *Remedial Design Work Plan Initial Components Approach*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. September 23.

National Grid. 2009b. *Supplemental Remedial Investigation (SRI) Interim Data Summary*. Former Citizens Gas Works MGP Site, Brooklyn, New York. December 23.

National Grid. 2012. *Supplemental DNAPL Investigation Findings and Memorialization of Related Design Parameters*. Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. November 2.

New York State Department of Transportation. 2015. *Geotechnical Design Procedure for Flexible Wall Systems*. Geotechnical Design Procedure GDP-11, Revision #4. Office of Technical Services, Geotechnical Engineering Bureau. August.

NYSDEC. 2007. *Voluntary Cleanup Program Decision Document*. Operable Unit No. 1, Former Citizens Gas Works MGP Site, Carroll Gardens/Public Place, Brooklyn, New York. April 23.

NYSDEC. 2009. *CP-43: Groundwater Monitoring Well Decommissioning Policy*. Division of Environmental Remediation. November 3.

NYSDEC. 2010. *DER-10, Technical Guidance for Site Investigation and Remediation*. Division of Environmental Remediation. May.

Roux Associates, Inc. 1990. *Engineering Investigation at Inactive Hazardous Waste Sites, Phase II Investigations, Carroll Gardens, Site No: 224012, Borough of Brooklyn, Kings County*. Prepared for NYSDEC. September.

Stiles, L.S. 1926. Pipe Tunnel Under Gowanus Canal, Brooklyn, New York. In *Proceedings of the American Society of Civil Engineers*. New York, New York. January 20-22.

Stone & Webster Engineering Corporation. 1984. *Environmental and Engineering Study, Assessing the Suitability of the Gowanus Canal Site for Public Housing and Recreational Usage*. Prepared for the New York City Housing Partnership. December.

TRC Environmental Consultants, Inc. 1985. *Final Report, Vacant Property Site Assessment, Carroll Gardens, Brooklyn*. Prepared for NYCDEP. October.

United States Department of Defense. 2017. *Design: Piers and Wharves*. Unified Facilities Criteria UFC 4-152-01. January 19.

United States Environmental Protection Agency. 2013. *Record of Decision*. Gowanus Canal Superfund Site, Brooklyn, New York. September.

United States Geological Survey. 1999. *Simulation of Ground-Water Flow and Pumpage in Kings and Queens Counties, Long Island, New York*. Water-Resources Investigations Report 98-4071.

TABLES

Table 1
Summary of Bulkhead Barrier Wall Basis of Design
100% Remedial Design Report

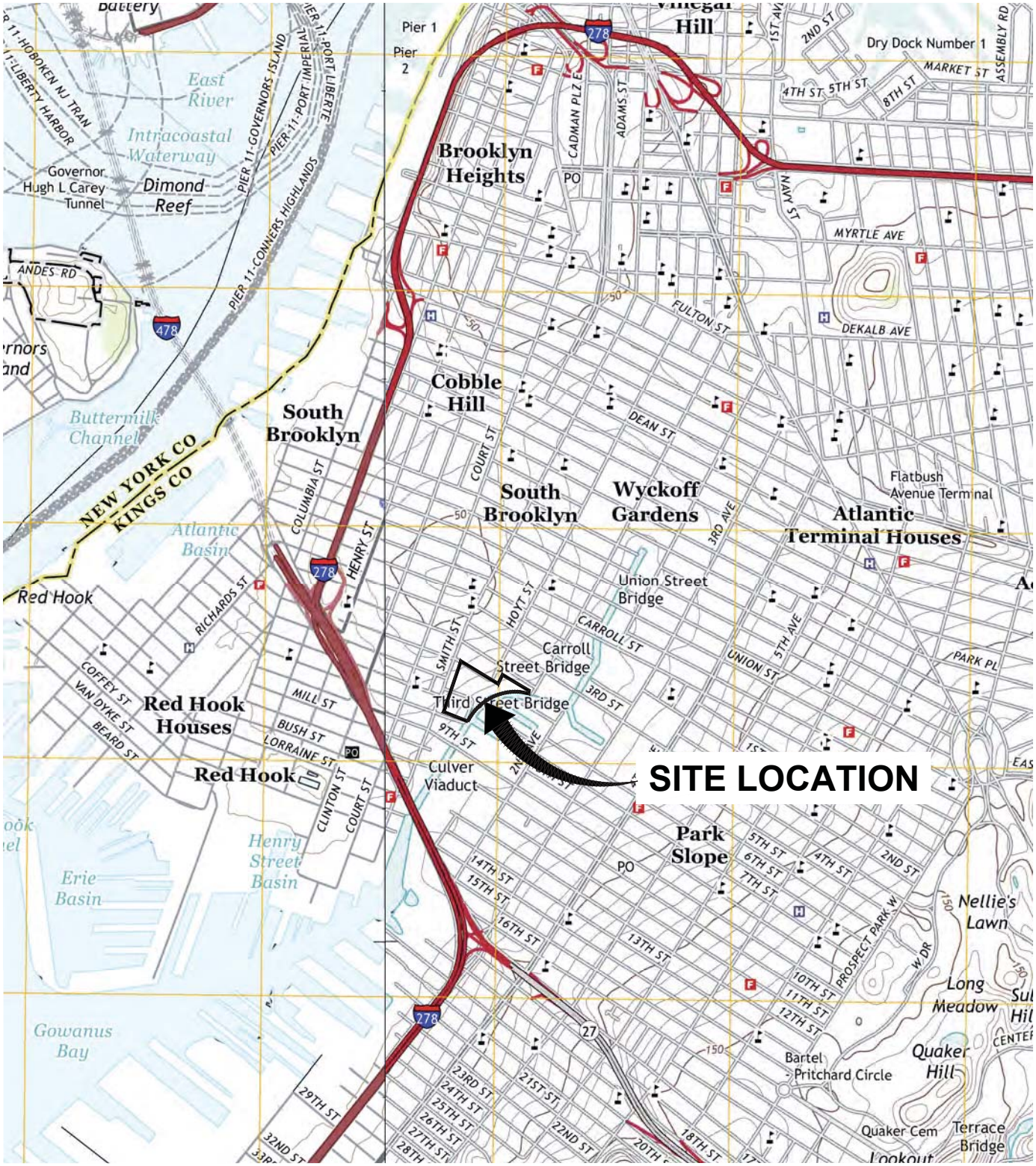
National Grid
Former Citizens Gas Works Manufactured Gas Plant Site
Carroll Gardens/Public Place
Borough of Brooklyn, Kings County, New York

Wall Alignment		Length of Wall (lf)	Wall Type	Design Analysis	Upland Ground Surface Elevation (ft NAVD88)	Canal Sediment Surface Elevation (ft NAVD88)	Maximum Hydraulic Head Differential[5] (ft)	Surcharge Load (lb/ft^2)
From	To							
0+00	3+49	348.80	Anchored Tieback Wall	Static-Drained	10.00	-22.50	8.89	250.00
				Static-Undrained	10.00	-22.50	8.89	250.00
				Pseudo-Static	10.00	-16.00	8.89	100.00
3+49	3+81	32.10	Anchored Tieback Wall	Static-Drained	12.00	-22.50	8.89	250.00
				Static-Undrained	12.00	-22.50	8.89	250.00
				Pseudo-Static	12.00	-16.00	8.89	100.00
3+81	3+99	18.00	Cantilevered Combination Wall	Static-Drained	12.00	-22.50	8.89	250.00
				Static-Undrained	12.00	-22.50	8.89	250.00
				Pseudo-Static	12.00	-16.00	8.89	100.00
3+99	4+41	42.40	Cantilevered Combination Wall	Static-Drained	12.00	-22.50	8.89	250.00
				Static-Undrained	12.00	-22.50	8.89	250.00
				Pseudo-Static	12.00	-16.00	8.89	100.00
4+41	4+68	26.60	Existing Gas Transmission Tunnel Shaft					
4+68	6+41	173.10	Cantilevered Combination Wall	Static-Drained	12.00	-22.50	8.89	250.00
				Static-Undrained	12.00	-22.50	8.89	250.00
				Pseudo-Static	12.00	-16.00	8.89	100.00
6+41	7+43	101.90	Cantilevered Combination Wall	Static-Drained	10.00	-22.50	8.89	250.00
				Static-Undrained	10.00	-22.50	8.89	250.00
				Pseudo-Static	10.00	-16.00	8.89	100.00
7+43	8+79	136.00	Cantilevered Combination Wall	Static-Drained	8.00	-22.50	8.89	250.00
				Static-Undrained	8.00	-22.50	8.89	250.00
				Pseudo-Static	8.00	-16.00	8.89	100.00

Notes:

1. lf, linear feet.
2. ft, feet.
3. NAVD88, North American Vertical Datum of 1988.
4. lb/ft^2, pounds per square foot.
5. Maximum hydraulic head differential represents the difference between the average invert elevation of the hydraulic relief piping (6.12 ft NAVD88) and mean lower low water in the Gowanus Canal (-2.77 ft NAVD88).

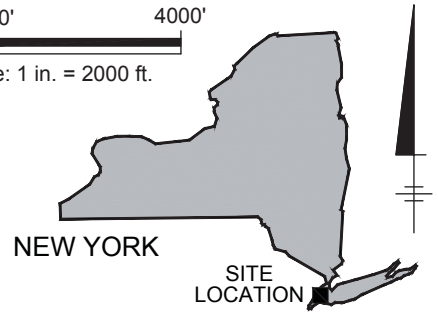
FIGURES



REFERENCE: BASE MAP USGS 7.5. MIN. TOPO. QUAD., BROOKLYN, NY, 2013, AND JERSEY CITY, NY-NJ, 2014.

0 2000' 4000'

Approximate Scale: 1 in. = 2000 ft.



NATIONAL GRID
FORMER CITIZENS GAS WORKS MANUFACTURED GAS PLANT SITE
BOROUGH OF BROOKLYN, KINGS COUNTY, NEW YORK
100% REMEDIAL DESIGN REPORT

SITE LOCATION MAP

ARCADIS Design & Consultancy for natural and built assets

FIGURE 1

CITY: SYRACUSE, NY DIV/GROUP: ENVCAD DB: B.GETTS, J. HARRIS PIC: T.YOUNG PM: M.BENOIT TM: A. GEORGE
C:\Users\jharris\Desktop\ENVCAD\RETURN-TO\SYRACUSE, NY\B0036726\0001\00003\DWG\100% REMEDIAL DESIGN REPORT\36726G01.dwg LAYOUT: 1 SAVED: 11/30/2017 2:48 PM ACADVER: 20.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 11/30/2017 2:49 PM
BY: HARRIS, JESS
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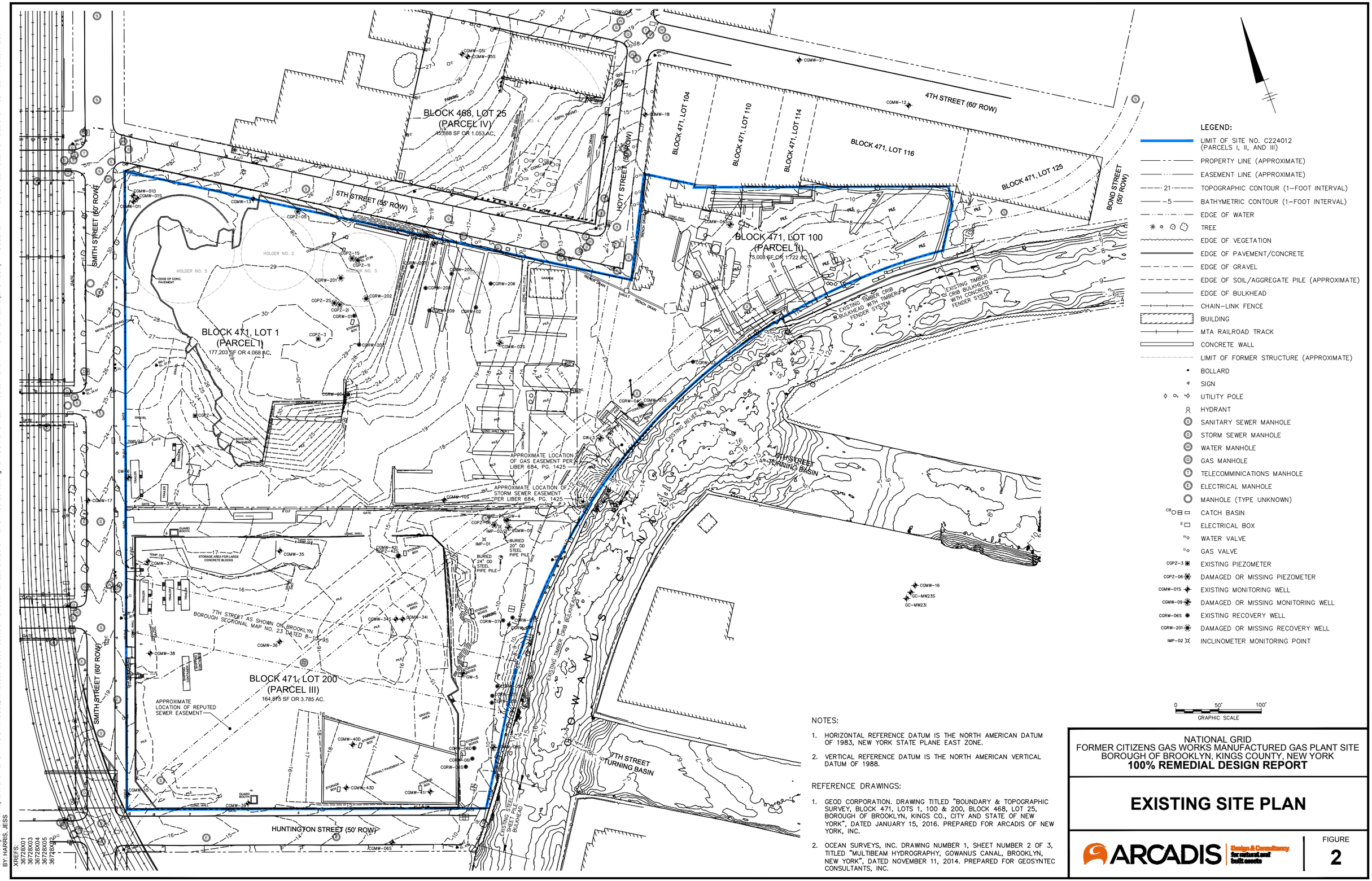
NJ_Jersey_City_20140403_TM_geo.jpg
NY_Brooklyn_20130328_TM_geo.jpg



NOTES:

1. HORIZONTAL REFERENCE DATUM IS THE NORTH AMERICAN DATUM OF 1983, NEW YORK STATE PLANE EAST ZONE.
2. VERTICAL REFERENCE DATUM IS THE NORTH AMERICAN VERTICAL DATUM OF 1988.

REFERENCE DRAWINGS:

1. GEOD CORPORATION. DRAWING TITLED "BOUNDARY & TOPOGRAPHIC SURVEY, BLOCK 471, LOTS 1, 100 & 200, BLOCK 468, LOT 25, BOROUGH OF BROOKLYN, KINGS CO., CITY AND STATE OF NEW YORK", DATED JANUARY 15, 2016. PREPARED FOR ARCADIS OF NEW YORK, INC.
2. OCEAN SURVEYS, INC. DRAWING NUMBER 1, SHEET NUMBER 2 OF 3, TITLED "MULTIBEAM HYDROGRAPHY, GOWANUS CANAL, BROOKLYN, NEW YORK", DATED NOVEMBER 11, 2014. PREPARED FOR GEOSYNTEC CONSULTANTS, INC.

NATIONAL GRID
FORMER CITIZENS GAS WORKS MANUFACTURED GAS PLANT SITE
BOROUGH OF BROOKLYN, KINGS COUNTY, NEW YORK
100% REMEDIAL DESIGN REPORT

EXISTING SITE PLAN

ARCADIS Design & Consultancy for natural and built assets

FIGURE
2

CITY: SYRACUSE,NY DIV/GROUP: IMDV DB: B. GETTS, K.SARTORI PIC: T. YOUNG PM: M.BENOIT TM: A. GEORGE LYR: ON=*;OFF=*REF*
C:\Users\jlharris\Desktop\ENVCAD\RETURN-TO\SYRACUSE_NY\B0036728\0001\00003\DWG\100% REMEDIAL DESIGN REPORT\36728P02.dwg LAYOUT: 2 SAVED: 11/30/2017 2:49 PM ACADVER: 20.1S (LMS TECH) PAGESETUP: ---- PLOTSTYLETABLE: PLTFULL.CTB PLOTTED: 11/30/2017 2:50 PM
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36728X01
36728X03
36728X04
36728X05
36728X06

Arcadis of New York, Inc.

One Lincoln Center

110 West Fayette Street

Suite 300

Syracuse, New York 13202

Tel 315 446 9120

Fax 315 449 0017

www.arcadis.com