RCRA REMEDIAL INVESTIGATION AND INTERIM REMEDIAL MEASURES SUMMARY

Honeywell

HONEYWELL RESINS & CHEMICALS LLC

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EXECUTIVE SUMMARY

The Honeywell Resins & Chemical Frankford Plant (hereafter referred to as Facility) is located in the Bridesburg section of Philadelphia, Pennsylvania (**Figure 1**) and occupies approximately 45 acres. The Facility has manufactured a variety of chemicals since 1884, but currently manufactures phenol, acetone, and alphamethylstyrene from cumene. During the period between 1884 to the present, the Facility has grown through the incorporation of surrounding properties from approximately 4.5 acres to its current size.

H.W. Jayne Company owned the Facility until 1896, when it was sold to the Barrett Manufacturing Company. In 1920, the Barrett Manufacturing Company became part of the Allied Chemical & Dye Corporation, which eventually became part of AlliedSignal Inc. and Honeywell International Inc. The Facility was bought by Sunoco in 1998, and in 2011, the Facility was bought by Honeywell Resins & Chemicals LLC, a subsidiary of Honeywell International Inc.

Late in 1981, the Facility discovered a layer of LNAPL floating on top of the water table beneath the site. Groundwater withdrawal to contain this layer commenced in June 1984. In September 1990, the USEPA issued the RCRA Permit for Corrective Action for the Plant. The Phase I RFI concluded that a layer of LNAPL underlies the central portion of the Plant and that soil contamination exists at the Plant (NUS, 1992).

In November 1992, the USEPA requested an Interim Measure to enhance the LNAPL recovery system at the Plant and subsequently modified the permit to incorporate enhancements. Between 1994 and 1995, nine additional product recovery wells were placed into service as a part of the LNAPL recovery system enhancement.

In February 1994, Brown and Root completed the Phase II RFI, which concluded that the extent of the shallow groundwater contamination had been defined with limited offsite migration of dissolved phase organic constituents. Shallow groundwater discharge was determined to be limited by groundwater withdrawal from the plant recovery wells as well as infiltration into the Plant sanitary sewer system.

An LNAPL collection trench was installed during December 2000 along 4th Street to intercept LNAPL migration to the south. The trench consists of three total fluids recovery wells to remove LNAPL mass and hydraulically contain the LNAPL plume. In March 2001, to mitigate LNAPL intrusion into the Wakeling Street sewer, the Facility installed a grout barrier on the east side and parallel with the sewer between 4th Street and 6th Street.

Between 2003 and 2004, Environmental Indicator Determinations concluded that current human exposures and migration of contaminated groundwater are both Under Control (a "YES" determination in both cases).

On May 15, 2001, the USEPA renewed the RCRA Corrective Action Permit, which is considered effective until the corrective action at the facility is completed. The continuing treatment and control of LNAPL were implemented under an Interim Measure and are anticipated to be, with upgrades, a significant component of the final remedy. In order for the site to make this transition, both the site cleanup goals and the post remediation care attainment process need to be developed. This document is intended to facilitate that development.

The USEPA has prepared Final Guidance on Completion of Corrective Action at RCRA facilities which states "it is appropriate to make a Correction Action Complete with Controls determination at a facility where the following milestones have been achieved: (1) A full set of corrective measures objectives has been defined; (2) the facility has completed construction and installation of the required remedial actions; (3) site-specific media cleanup objectives have been met; and (4) all that remains is performance of required operation and maintenance and monitoring actions, and/or compliance with and maintenance of any institutional controls."

1.0 INTRODUCTION

AMEC Environmental & Infrastructure (Amec) has prepared this Resource Conservation and Recovery Act (RCRA) Remedial Investigation and Interim Remedial Measures Summary for Honeywell Resins & Chemicals LLC (Honeywell) as a comprehensive review of submittals related to the facility RCRA permit for Corrective Action.

1.1 REPORT ORGANIZATION

The report is organized into eight sections, as described below, with supporting tables, figures, drawings, attachments, and appendices. Some of these sections provide background information presented in previous reports. This material is generally included in summary form with a reference to the source document(s).

Section 1.0 – Introduction – Contains the purpose and scope, background information, and describes the report organization.

Section 2.0 – Facility Background – Provides an overview of the Facility's operations, site regulatory framework, site geology, hydrogeology, site topography and drainage, and surface water bodies.

Section 3.0 – Summary of Remedial Investigation – Provides a summary of the RCRA Facility Investigation (RFI) Phase I & II reports, Baseline Groundwater Study, Environmental Indicator determinations, and Annual Groundwater Sampling events.

Section 4.0 – Current Site Conditions – Provides a summary of the most recent light non-aqueous phase liquid (LNAPL) measurements, groundwater sampling results, and vapor intrusion investigation.

Section 5.0 – DNAPL Investigation – Provides a summary of the ongoing Dense Non-Aqueous Phase Liquid (DNAPL) Investigation on the southwestern portion of the Facility.

Section 6.0 – Interim Remedial Actions – Provides an overview of completed and ongoing corrective measures along with the review of chosen measure for the consistence with the corrective action objectives.

Section 7.0 – References – Lists the reports and technical papers cited herein.

Section 8.0 – List of Acronyms and Abbreviations – Includes a list of acronyms and/or abbreviations used in this document.

1.2 RELEVANT FACILITY REGULATORY DOCUMENTS

The following reports and regulatory documents describe background environmental quality information and remedial activities relevant to the Facility.

Phase I RFI – Provides information regarding baseline soil and groundwater quality investigations; regional and facility geology and hydrogeology; characterization and delineation of LNAPL extent; potential human health and environmental risks evaluation; and evaluation of the feasibility of potential corrective measures (Halliburton NUS Environmental Corporation [NUS], 1991).

Final Report of the Conceptual Design Study for Free-Phase Product Recovery – Summarizes a study conducted to evaluate LNAPL recovery enhancement alternatives (Halliburton NUS, 1993).

Report of Free-Phase Product Recovery System Pilot Testing and Associated Work – Summarizes pilot study results and recommends a network of pumping wells to enhance LNAPL recovery (Brown and Root, 1993).

Phase II RFI –Provides additional investigation information regarding the delineation of the extent of shallow and deep groundwater contamination (Brown and Root, 1994).

Baseline Groundwater Study – Provides groundwater flow patterns, quality and distribution of residual dissolved and separate phase compounds (Resource Control Corporation [RES], 1999).

Environmental Indicator (EI) determinations – Provides information on the quality of the environment in relation to human exposures to contamination and the migration of contaminated groundwater (MWH Global, 2002 & 2004).

2.0 FACILITY BACKGROUND

2.1 SITE DESCRIPTION

The Facility is located in the Bridesburg section of Philadelphia, Pennsylvania (**Figure 1**) and occupies approximately 45 acres. It is bounded on the west by Margaret Street, on the north by Interstate 95, on the east by Bridge Street, and on the south by the Frankford Creek, the Frankford Creek sewer right of way, and Almond, Pratt, Belgrade, Ash, and Gaul Streets. Major site features are depicted in **Figure 2**.

Asphalt paving and buildings cover the majority of the Facility's surface. Most of the unpaved areas are covered with several inches of crushed stone or gravel. An extensive underground network of fire protection lines, sewer pipes (including storm and sanitary lines), gas mains, city water lines, and electrical duct and feeder corridors exist throughout the facility.

The Facility property is generally flat. Land surface elevations at the plant and surrounding properties range from 7 to 18 feet (North American Vertical Datum [NAVD] 88). The property gradually slopes to the south, toward the Frankford Creek. Immediately adjoining the Facility to the south is a densely populated residential area. A mixed residential and industrial area lies across Interstate 95 to the north of the Facility. **Figure 3** presents a detailed land usage map for the site and surrounding area.

2.2 SITE HISTORY

The Facility has manufactured organic chemicals since 1884. During the period between 1884 to the present, the Facility has grown through the incorporation of surrounding properties from approximately 4.5 acres to its current size of approximately 45 acres. **Figure 4** shows the growth of the Facility since the oldest available aerial photograph in 1930.

H.W. Jayne Company (Jayne Company) owned the Facility until 1896, when it was sold to the Barrett Manufacturing Company. In 1920, the Barrett Manufacturing Company became part of the Allied Chemical & Dye Corporation, which eventually

became part of AlliedSignal Inc. and Honeywell International Inc. The Facility later was bought by Sunoco in 1998, and in 2011 it was bought by Honeywell.

2.2.1 *Allied Chemical through AlliedSignal*

Operations at the Facility commenced in 1884 on a 4.5-acre lot by the Jayne Company, in conjunction with M. Ehret, Jr. and Company. The 1884 operations consisted of converting coal tar light oils and crude naphthalene to tar acid, solvent, and naphthalene products. Moth balls were made by hand. In 1896, the Jayne Company was bought by Barrett Manufacturing Company. By 1899, the Facility area had increased to 7 acres. Operations involved the production of purified phenol.

Between 1896 and 1916, new processes and products were introduced at the Facility. In 1916, the Facility area exceeded 17 acres. Operations in 1916 were bordered by Frankford Creek to the south, Margaret and Buckius Streets to the west, Bermuda and Stiles Streets to the north and Wakeling Street to the east. Products included benzene, toluene, naphthalene, anthracene, cresols (methylphenols), resorcinol, cresylic acid, nitrobenzene, nitrotoluene, nitronaphthalene, aniline, toluidine, naphthylamine, pyridine, carbazole, disinfectant oils, and semi-refined solvents and oils. During World War I, the Facility's product line was expanded to include the production of basic coal chemicals and derivatives required for the production of trinitrotoluene (TNT), picric acid, dyestuffs, and pharmaceuticals. By 1918, the Facility had expanded to include 76 buildings. The first phenol production unit at the Plant was constructed in 1918.

In 1920, Facility operations were limited to the separation and purification of coal chemicals found in carbolic oils and lights oils. The Facility's remaining products included refined benzene, toluene, and xylene; various semi-refined solvents; tar acids (phenol, cresols, and cresylic acids); pyridine, alpha-picoline, beta and gamma-picoline, lutidine, and collidine; crude and refined naphthalenes (including methylnaphthalene); and cumarene-indene resins. Processing of light oils and carbolic oils continued at the Facility until 1960 and 1972, respectively. During the late 1930s production of coal chemical derivatives and synthetics resumed at the Facility. From 1935 to 1945, 4-chloro-m-cresol was reportedly produced. Additionally, 1, 3, 5-xylenol production commenced at this time. This production was discontinued in 1971.

In 1937, the first phthalic anhydride unit was constructed at the Facility. Phthalic anhydride was produced from refined naphthalene. A second phthalic anhydride unit was installed at the Facility in 1942, and a third unit was constructed in 1955. By 1969, approximately 100 million pounds of phthalic anhydride were produced annually. During 1972, a fire in the phthalic anhydride production unit led to the cessation of phthalic anhydride manufacturing operations at the Facility.

In 1940, a second phenol unit using the sulfonation fusion process was placed into operation. This unit operated until 1953, when the Facility converted to the cumene-phenol process. In 1942, the Facility began converting some of its phthalic anhydride product into phthalate esters, using purchased alcohols (e.g., butanol and hexanol). The principal product during World War II was dibutyl phthalate.

After 1945, dioctyl phthalates (2-ethylhexyl, isooctyl, and capryl) became the main products produced. Adipate plasticizers were also produced prior to 1969, using solid adipic acid in place of phthalic anhydride. In 1971-1972, production of plasticizers at the Facility was terminated. In 1944, nicotinic acid (niacin) production from quinoline (a heavy tar base derivative) commenced. Production of quinoline was initiated simultaneously. Quinaldine and isoquinoline were also reportedly produced. In 1962, the nicotinic acid production was discontinued.

About 1934, Frankford Creek was straightened, and the meander, or "horseshoe bend," within the Facility was removed and filled. Diversion of the Frankford Creek to its current configuration was completed in 1956 and construction of the Frankford Inlet sewer line and filling of the former creek bed on the Facility property was conducted soon after this, circa 1957.

Production of phenol and acetone by the cumene process was initiated at the Facility in early 1954. At this time, cumene was produced at the Facility by reacting propylene with benzene. By-products of the phenol process included alphamethylstyrene (AMS) and acetophenone. In 1954, an explosion damaged Phenol Production Unit No.1 and in 1955, a fire damaged the cumene production unit at the Facility. These units were rebuilt shortly thereafter. In 1960, a second synthetic cumene-phenol unit was placed into production and cumene production at the Plant ceased. A third cumene-phenol unit was added in 1964. In 1982, an explosion and fire damaged part of the phenol production facilities (Phenol Unit

No.1). These facilities were partially rebuilt in 1983. The cumene-phenol process is the only remaining production currently occurring at the Facility.

Prior to 1955, all Frankford facility wastewaters were treated and discharged to Frankford Creek. Beginning in 1955, the Plant began discharging its wastewaters to the Philadelphia Northeast Water Pollution Control Plant. Wastewaters are biologically treated at this plant.

In 1973, demolition began on outmoded, non-phenol-production facilities. This program continued through 1978. Late in 1981, the Facility discovered a layer of LNAPL floating on top of the water table beneath Phenol Process Unit No. 2. An LNAPL recovery system was installed in 1984 to remove free product. Between 1994 and 1995, additional recovery wells were placed into service.

2.2.2 Sunoco

Sunoco bought the Facility in 1998. The Facility continued manufacturing phenol, acetone, and AMS from cumene. The LNAPL recovery system continued recovering free product. A southern LNAPL recovery trench was installed in December 1999 along 4th Street, located to the north of the boiler house and south of the high-purity phenol unit. The LNAPL recovery trench was designed for total fluids, recovering free product and dissolved phase contamination.

2.2.3 Honeywell Resins & Chemicals LLC

Honeywell bought the Facility from Sunoco in 2011 and continues to produce phenol, acetone, and AMS from cumene. The Facility continues to operate and maintain the LNAPL recovery system.

2.3 SITE REGULATORY HISTORY

In September 1990, the U.S. Environmental Protection Agency (USEPA) issued the RCRA Permit for Corrective Action for the Plant. The permit requires an RFI for 12 Solid Waste Management Units (SWMUs) and two areas of concern (AOCs) at the Plant. The Phase I RFI concluded that a layer of LNAPL underlies the central portion of the Plant and that soil contamination exists at the Plant (NUS, 1992).

On November 9, 1992, the USEPA requested an Interim Measure to enhance the LNAPL recovery system at the Plant. On August 20, 1993, the Facility requested the

USEPA to modify its Permit for Corrective Action to incorporate enhancement of the LNAPL recovery system using active pumping to remove floating free product in recovery wells as an interim measure. Following a Conceptual Design Study and pilot testing, USEPA granted the Class 2 Permit modification on October 29, 1993.

Between 1994 and 1995, 15 additional product recovery and/or observation wells were placed into service as a part of the LNAPL recovery system enhancement. These wells are located along the north side of Main Street to the west of Wakeling Street, on both sides of Wakeling Street to the north of Main Street, and on the north side of 4th Street to the east of Wakeling Street. Nine of the 15 wells were fitted with compressed air, free product QED Seeker pumps, control units, a storage tank, and associated lines, valves, and tubing. LNAPL recovery system data and LNAPL thickness measurements were collected on quarterly basis from June 1994 and submitted in quarterly reports to the USEPA through December 1996, and semi-annual reports thereafter.

In February 1994, Brown and Root completed the Phase II RFI. The Phase II RFI concluded that the extent of the shallow groundwater contamination had been defined with limited offsite migration of dissolved phase organic constituents. Shallow groundwater discharge was determined to be limited by groundwater withdrawal from the plant recovery wells as well as infiltration into the Facility sanitary sewer system and City combined sewer system. The Phase II RFI found that shallow groundwater from only the southeastern corner of the Facility and south of the Frankford Inlet seeped into the inlet. The Phase II RFI further found that the extent of deep groundwater contamination had not been fully defined.

On May 15, 2001, USEPA renewed the RCRA Corrective Action Permit. The renewal is considered effective until the corrective action at the facility is completed.

On January 6, 2003, MWH submitted the EI Determination for Human Exposure to USEPA. It was concluded that the Current Human Exposures are Under Control at the facility (a "YES" determination).

Subsequently on September 24, 2004, MWH also submitted a groundwater EI, which concluded that Migration of Contaminated Groundwater is Under Control at the facility (a "YES" determination).

2.4 REGIONAL GEOLOGY

The Facility is located at the western edge of the Atlantic Coastal Plain Physiographic Province. The Atlantic Coastal Plain is an eastward-thickening wedge of predominantly unconsolidated sediments (i.e., gravel, sand, silt, and clay) extending from southeastern Pennsylvania across New Jersey. The western boundary of this clastic wedge is the Fall Line, which runs roughly in a northeast-to-southwest direction just west of the site. Site geological cross-sections of the Facility and nearby surrounding areas are shown in **Figures 5, 6 and 7**. These cross-sections are based upon site soil boring logs and are not intended to be an exact representation of the regional or site-specific geological conditions.

Underlying the unconsolidated sediments is crystalline basement rock of the Pre-Cretaceous Glenarm Series. These metamorphic rocks are of probable Lower Paleozoic age and may be of either sedimentary or igneous origin. They are fine to coarse-grained, crystalline, dense, hard, and foliated or banded rocks characterized by an excess of mica. The lithologies present include hornblende gneiss, granite gneiss, and a sequence of alternating micaceous schist and quartzite. The upper surface has been weathered to soft, gray, extremely micaceous clay (saprolite) that ranges from a few feet to several tens of feet in thickness and becomes firmer and more granular with increasing depth. The crystalline bedrock crops out northwest of the Fall Line and underlies the Coastal Plain sediments at generally increasing depths to the southeast. The southeastward-dipping surface of the bedrock has been channeled by the ancestral Schuylkill and Delaware Rivers and their major tributaries, including Frankford Creek, creating local variations in the elevation of the bedrock surface.

The basement bedrock complex is unconformable overlain in places by the Raritan Formation of Cretaceous age. In Pennsylvania, the Raritan Formation is represented by a sequence of non-marine deposits representing three cycles of deposition. Each cycle contains a basal layer of coarse-grained (sand and gravel) deposits that are covered by layers of silts and clays. These cycles consist, in ascending order, of the Farrington sand; lower clay, Sayreville sand, middle clay, Old Bridge sand, and upper clay members. Based on interpretations presented in Greenman, et al, (1961), the Old Bridge sand, Sayreville sand, and upper clay members of the Raritan Formation are not present in the area of the Facility. In the absence of the Sayreville sand, the lower and middle clay members are merged into

a single unit that is interpreted by Greenman et al. to be present in the subsurface throughout the area of the Facility. The Farrington sand member is interpreted by Greenman et al. to be present only beneath the southeastern most portion of the Facility, thickening toward the southeast. The Farrington sand member consists primarily of coarse sand and fine gravel that grade upward into medium to fine grained sand with a few beds of white clay. It varies in color from yellowish gray to pale yellowish brown. The sands and gravels are fairly well sorted. The thickness of the Farrington sand is generally less than 60 feet in Pennsylvania, and it thins rapidly toward the margins of its occurrence.

The lower clay member consists mainly of tough brick-red clay containing beds of soft gray, well-stratified clay, and thin lenses of fine-grained sand. The texture and composition of the lower clay are fairly uniform; however, the sequence and thickness of the beds may vary considerably. The thickness of the lower clay is mainly between 20 and 40 feet, except near the margins of its occurrence.

The middle clay member has a much less variable lithology than the lower clay member and consists mainly of tough red and white clay, with a uniformly massive texture. It may contain a few thin beds or lenses of fine-grained sand and locally may contain a conspicuous bed of lignite at the base. The thickness of the middle clay is similar to that of the lower clay; however, in the Philadelphia area, these two clay members are in direct contact and cannot be differentiated.

Both the Raritan Formation and the bedrock are unconformable overlain by Pleistocene age (Quaternary System) sediments within the Delaware River valley. These sediments, formerly referred to as the Cape May Formation, are now known as the Trenton gravel. They consist of gray to brown and pale reddish brown, very gravelly sand composed of medium- to coarse-grained, angular to rounded quartz sand grains, and pebbles, cobbles, and boulders of sandstone, siltstone, chert, quartzite, and mica schist. The Trenton Gravel is generally 30 to 40 feet thick and occurs at elevations of less than 20 or 30 feet above sea level. Much of the Trenton Gravel has been removed by erosion along the Delaware and Schuylkill Rivers.

Recent (post-Pleistocene) alluvial deposits overlie the older rocks and sediments beneath the channels and tidal flats of the Delaware River and its principal tributaries, including Frankford Creek. They are fine-grained, richly organic sediments consisting of dark gray mud, silt, and fine sand. In most locations, the

recent alluvial deposits are usually less than 10 feet thick and rarely more than 28 feet thick.

Soils in the area of the Facility are of the urban land - Howell Association. The Facility locale is in an area of nearly level to gently sloping soils formed in loamy and clayey material of mixed, old Coastal Plain sediment. Urban land consists of areas that are built up and occupied by urban structures. Howell and other soils have been obscured, smoothed, disturbed, filled in, or destroyed by the construction of urban facilities. Howell soils are deep and well drained, have a moderately low permeability, and consist of silt loam and silty, sandy, or gravelly clay loam [United States Department of Agriculture (USDA), 1985].

2.5 SITE GEOLOGY

Six deep and 90 shallow soil borings as well as 6 deep and 23 shallow monitoring well borings were drilled at the Facility during the RFI Phase I and II field work. In addition to the RFI Phase I and II borings, the Facility has undertaken numerous geotechnical investigations to determine the suitability of the soils and subsurface materials for the foundations of buildings and other structures. B&R Environmental identified 137 test borings that were drilled over between 1937 and 1990.

The geological model consists, in descending order, of three basic units: surficial fill deposits, unconsolidated sedimentary deposits, and the underlying saprolite and bedrock. The unconsolidated sedimentary deposits are further subdivided into a sand and gravel unit, a recent silt-clay unit, and an older silt-clay unit. The general configuration of the geologic interpretation and individual geologic units is illustrated by cross-sections (see **Figure 6 and 7** for the locations of the cross-sections). Cross-sections A-A' through C-C' (**Figure 6**) extend from northwest to northeast, roughly perpendicular to the geological contacts of the site. Cross-sections D-D' and E-E' (**Figure 7**) extend from west to east and are parallel to the geological contacts (strike) of the units at the site.

2.5.1 Surficial Fill Deposits

Lithologic descriptions from soil and monitoring well borings indicate that anywhere from 2 feet to over 20 feet of fill material are present at the Facility. The fill deposits are approximately 5 feet thick along the northern boundary of the Facility

and increase to more than 20 feet in thickness along the axis of the filled former creek bed and meanders of Frankford Creek.

The thickness and distribution of the fill deposits are also shown on the geologic cross-sections. Local areas of greater than average fill deposit thickness are expected to be present throughout the Facility. These areas would occur where excavations were made for the construction of buildings and the installation of sewers or other underground utility lines or structures. The gradual increase of the fill deposit thickness from the northern part of the Facility toward the southern part adjacent to the former Frankford Creek is consistent with the geographical setting of the Facility.

The composition of the fill deposits encountered throughout the site is highly variable and includes natural soil and alluvial material and man-made debris and discarded materials. The natural alluvial and soil materials in the fill consist of silt, clay, sand, gravel, pebbles, and cobbles. The more common man-made debris and discarded materials in the fill deposits are crushed stone and rock fragments, brick and concrete fragments, coal, cinders, slag, tarry residues, and ashy material. Less common constituents of the fill include slate, tile, china, glass, plastic and shell fragments, wood, steel reinforcing bar, steel and copper wire, metal shavings, nails, black tarry sludge-like substances, cement grout, fibrous material similar to horse hair, and a white, tan, or brown crystalline solid suspected to contain naphthalene. Some fill components are present throughout the Facility, and others occur only in particular areas.

Grain size distribution analyses performed during the Phase I RFI indicated that the fill deposits are somewhat poorly to poorly sorted and show significant variation between sample locations.

2.5.2 Unconsolidated Alluvial Deposits

All the Phase I and II RFI soil borings and monitoring well installation borings that completely penetrated the surficial fill deposits encountered unconsolidated alluvial deposits. The lithologic descriptions available from these soil boring programs indicate that the unconsolidated alluvial deposits can be subdivided into three basic lithologic units: recent silt and clay deposits, older silt and clay deposits, and sand and gravel deposits. The three lithologic units of the unconsolidated alluvial deposits have been assigned based on similarities in lithology and the positions they occupy

relative to one another, to the overlying fill deposits, and to the underlying saprolite and bedrock.

2.5.2.1 Recent Silt and Clay Deposits

The recent silt and clay deposits are of post-Pleistocene geological age. They consist mainly of relatively homogeneous, soft and plastic deposits of silt and clay sized particles with significant amounts of natural organic matter deposited by Frankford Creek. These deposits are typically dark olive gray in color, although they may also be brown, grayish brown, or gray. Some fine- and very fine-grained sand or sandy layers may be present along with trace amounts of gravel or pebbles. The natural organic matter consists of leaves, stems, twigs, branches, and other plant material and appears as peat-like deposits where it is most prominent. Grain size distribution analyses of deposit show an average of 96.7 percent of the material from the recent silt and clay deposits was of silt and clay grain size (less than No. 200 sieve).

The sample of transitional material between the recent silt and clay and the underlying sand and gravel deposits was composed of 59.9 percent silt and clay grain size particles. The recent silt and clay deposits at the Facility occur in the area south of Main or Bermuda Streets, extending to the Frankford Inlet or just beyond the southern boundary of the former Frankford Creek.

The lower contact of the recent silt and clay is usually fairly distinct, with the transition from silt and clay to sand and gravel occurring over one to two feet or less. The upper contact of the recent silt and clay with the fill deposits may be either distinct or transitional. In some locations, the contact between fill materials and natural alluvial silt and clay is very sharp, occurring within intervals of a few inches to less than one inch. In other areas, the contact between fill materials and natural alluvial silt and clay appears as a zone of transition covering an interval of several inches to a few feet. This transition zone contains natural alluvial silts and clays, some fine to very fine grained sand, and man-made fill or waste materials that appear frequently to have been deposited in sedimentary fashion.

2.5.2.2 Older Silt and Clay Deposits

The older silt and clay deposits are of Pleistocene or Cretaceous age. All descriptions of these deposits come from the foundation test boring logs of several different contractors; the logs differ considerably in vintage and the type and degree of detail of lithologic descriptions.

The older silt and clay deposits are variously described as clay, silty clay, silty sandy clay, and clay with mica, fine sand, coarse sand, or gravel or as fine silt and sand, sandy clayey silt, and gravelly sandy clayey silt. The predominant colors are shades of brown and gray although these deposits have also been described as blue, blue and yellowish, reddish brown, green, orange, or black. The consistency of the older silt and clayey deposits is characterized as either stiff, medium dense, dense, very dense, or hard and as being non-plastic or having low plasticity. The presence of organic material is indicated in only one instance.

The older silt and clay deposits at the Facility occur in two distinct areas to the north of Main or Bermuda Streets. In all locations, the older silt and clay deposits are directly overlain by unconsolidated sand and gravel deposits.

2.5.2.3 Sand and Gravel Deposits

The sand and gravel deposits are of Pleistocene and possibly also of Cretaceous geological age. The deposits are a heterogeneous mixture of fine to coarse grained sand, fine to coarse gravel, rounded pebbles and cobbles, silt, and clay. They are typically brown or gray in color but may also be orange brown or reddish brown in places. Sand and gravel are the most common constituents of these deposits; however, significant amounts of silt and clay may be present. The pebbles and cobbles may consist of quartz, sandstone, siltstone, shale, chert, quartzite, gneiss, or schist. Grain size and degree of sorting vary considerably, both laterally and vertically within this unit. Some well-sorted layers of sand, silty clay or clay are present up to several inches, and possibly several feet, thick. The first few feet of the sand and gravel deposits atop the saprolite and bedrock are often characterized by a very dense or hard, compact, very poorly sorted layer of cobbles, pebbles, gravel, sand, silt, and clay.

Grain size distribution analyses were performed on two samples from the sand and gravel deposits during the Phase I RFI. One sample consisted of 2.8 percent fine gravel and coarse sand, 57.7 percent medium and fine sand, and 39.5 percent silt and clay. The other sample consisted of 21.9 percent fine gravel and coarse sand, 70.3 percent medium and fine sand, and 7.8 percent silt and clay. These limited data illustrate the heterogeneity of the sand and gravel deposits with regard to both grain size and degree of sorting.

The sand and gravel deposits occur throughout the entire site. Within the northern half of the Facility from the area of Main or Bermuda Streets northward and within the area south of the Frankford Inlet and former Frankford Creek, the sand and gravel deposits directly underlie the fill deposits. Between these two areas, the sand and gravel deposits underlie the recent silt and clay deposits. The sand and gravel deposits overlie either the saprolite and bedrock or the older silt and clay deposits were present. In a few small areas, the sand and gravel also occur overlying the saprolite and bedrock and underlying the older silt and clay deposits.

The sand and gravel deposits underlying the fill are typically from 15 to 40 feet thick, and those deposits underlying the recent silt and clay generally range from about 5 to 10 feet thick. The sand and gravel deposits between the bedrock and older silt and clay deposits are relatively thin, ranging from about 2 to less than 10 feet thick.

2.5.3 Saprolite and Bedrock

Saprolite and bedrock underlie the unconsolidated alluvial deposits at a depth of less than 50 feet throughout the site. The lowest saprolite and bedrock surface elevation encountered at -37.0 ft (NAVD 88) in the MW-302 boring located in the southwestern part of the Facility. The term saprolite used here refers to the most extensively chemically weathered bedrock in which most of the rock-forming minerals, with the exception of quartz and mica, have been weathered to clay minerals. The original fabric of the rock, including any banding, foliation, or other particular texture, remains the same in the saprolite. This type of saprolite is the same as the residual micaceous clay layer at the top of the bedrock mentioned in the regional geological description of the area by Greenman, et al, (1981).

The change from this type of saprolite to unweathered rock may occur as a gradual transition over a depth range of a few feet to over 10 to several tens of feet. The bedrock occurs most commonly as gray, dense or compact, decomposed mica schist consisting mainly of mica and quartz with some feldspar and lesser amounts of other accessory minerals. One of the deep foundation test borings penetrated over 60 feet of bedrock and described the material as mica schist and quartz, quartz with seams of mica, and mica with seams of quartz. Some banding and gneissic textures were evident in a few of the Phase II RFI saprolite samples.

2.6 REGIONAL HYDROGEOLOGY

Groundwater in the unconsolidated sediments of the area may occur under either water table or artesian conditions. The water table system is made up of unconfined and semi-artesian aquifers having common hydraulic head, similar hydrogeologic properties, and local sources of recharge. Groundwater in most of the Pleistocene and Recent age deposits as well as the Old Bridge sand member of the Raritan Formation occurs under water table conditions.

Groundwater in portions of the Farrington and Sayreville sand members of the Raritan Formation where the lower and middle clay members are absent or discontinuous may also occur under water table conditions. Artesian conditions do occur locally within Pleistocene deposits where they are overlain by silt and clay deposits of recent age, but these aquifers are still considered to be part of the overall water table system.

The Pleistocene alluvial deposits are part of the water table system and comprise the most extensive aquifer in the area of the Facility. The water-bearing properties of the sediments are highly variable due to their heterogeneous lithology. The highly permeable sand and gravel beds are capable of yielding large quantities of groundwater to wells. The Pleistocene sediments are favorably situated with respect to recharge and are thus subject to contamination from the surface. The Pleistocene deposits locally contain water under artesian conditions where they are overlain by less permeable confining beds of recent age.

Sediments of recent geological age are generally fine grained and less permeable than the sediments comprising the aquifers. Consequently, they are unimportant as a source of groundwater and, where present, constitute a leaky confining bed that tends to restrict the free exchange of water between the surface and groundwater bodies.

The artesian aquifer system comprises extensive confined aquifers with distinct hydraulic and hydrogeologic properties and with relatively remote sources of recharge. The artesian aquifer system is represented in Pennsylvania by the Farrington and Sayreville sand members of the Raritan Formation, along with the overlying lower and middle clay members. This aquifer system extends from a high-level recharge area east of Trenton, New Jersey southward and westward to low-

level discharge areas in the Delaware River valley. Hydraulic continuity of this aquifer system depends upon the physical continuity of the Raritan Formation members that comprise it.

The Farrington sand member of the Raritan Formation is a productive aquifer when present and of sufficient thickness. It generally functions as a separate hydrologic unit of the artesian aquifer system and is insulated from overlying water-bearing beds and surface water sources. A hypothetical representation of the piezometric surface of the Farrington sand, in the absence of pumping well influences, indicates a hydraulic gradient toward the northwest in the area of the Facility. This representation also indicates that the Farrington sand aquifer discharges groundwater to the overlying water table aquifer system in areas near the Facility where it is not confined by the lower and middle clay members (Greenman, et al., 1961). Whenever present, the lower and middle clay members of the Raritan Formation represent the upper confining layer of the artesian aquifer system of the area. This layer limits the movement of groundwater between the Farrington sand member and the water-bearing zones above. The Old Bridge sand, Sayreville sand, and upper clay members of the Raritan Formation are interpreted to be absent in the area of the Facility (Greenman, et al., 1961).

The crystalline bedrock and residual clay or saprolite that underlie the unconsolidated Coastal Plain sediments probably serve mainly as a lower confining layer retarding groundwater movement out of the overlying aquifers. Groundwater generally occurs under water table conditions in outcrop areas of the bedrock. Artesian conditions may occur locally where open fractures underlie the saprolite or the confining beds of the unconsolidated sediments. The basement bedrock complex can be expected to reliably yield small to moderate quantities of groundwater.

2.7 SITE HYDROGEOLOGY

Site hydrogeological interpretations were made in the Phase II RFI using data obtained from approximately 70 piezometers, recovery wells, and monitoring wells; observations, measurements, and information collected for sewer lines; and other underground utilities at the Facility. These data were used in conjunction with the site geological interpretation and the regional hydrogeologic setting to create a detailed interpretation that is consistent with all the currently available information.

2.7.1 Shallow Unconfined Aquifer

The shallow aquifer at the site is composed of the fill deposits and the sand and gravel deposits. Groundwater in this aquifer is unconfined (i.e., occurs under water table conditions). In the areas of the site containing recent silt and clay deposits, the shallow aquifer consists entirely of saturated fill deposits, and extends from the water table down to the top of the recent silt and clay layer. In the other areas of the site, the shallow aquifer consists of either saturated fill deposits and sand and gravel deposits or solely the sand and gravel deposits and extends from the water table surface down to the top of the saprolite and bedrock or the older silt and clay deposits.

The hydraulic properties of the shallow water table aquifer vary significantly throughout the site based on the heterogeneous nature of the fill deposits and the sand and gravel deposits that comprise the aquifer. The hydraulic conductivity values range from a low of 2.0×10^{-7} centimeters per second (cm/sec) in the silty, clayey fill deposits of MW-104 to a high of 8.7×10^{-2} cm/sec in the sand and gravel deposits of MW-102. The depth of the shallow water table surface varies from 2 to 13 feet below ground surface.

The Phase II RFI determined that only shallow groundwater from the southeastern corner of the Facility and from areas south of the Frankford inlet discharges to the inlet. The majority of the shallow groundwater within the Facility flows to discharge points also within the plant, including pumping recovery wells, suspected sanitary sewer infiltration points, and recharge zones for the deeper sand and gravel. Historical and current analytical results support this determination, indicating that there is little or no flow of contaminated shallow groundwater beyond the Facility boundary, except for a small area along Lefevre Street.

2.7.2 Recent Silt and Clay Aquitard

The recent silt and clay deposits at the site function as a semi-confining layer rather than as an aquifer. Visual observations, grain size distribution analyses, water-level measurements, and available geological references indicate that these deposits have low vertical permeability and that the movement of groundwater across or within the deposits is very limited. Undisturbed vertical permeability analyses from Shelby tube samples of the recent silt and clay deposits confirm the low vertical permeability of sediments.

2.7.3 Older Silt and Clay Aquitard

The older silt and clay deposits at the site are also expected to function as a semi-confining layer rather than as an aquifer. Lithologic descriptions of the fine-grained and/or poorly sorted nature of these deposits suggest that they have low permeability and that the movement of water across or within the deposits is restricted.

Where present, the older silt and clay deposits are expected to restrict the vertical movement of groundwater between the overlying sand and gravel deposits of the shallow water table aquifer and either the underlying saprolite and bedrock or the relatively thin underlying sand and gravel layers. Considering the rather limited extent of the older silt and clay deposits within the Facility, they are not expected to have a significant influence on the overall site hydrogeologic conditions.

2.7.4 Deeper Semi-Confined Aquifer

The deeper, semi-confined aquifer at the site is composed mainly of the sand and gravel deposits that occur between the saprolite and bedrock and the recent silt and clay deposits. Groundwater in this aquifer is partially confined by the underlying saprolite and bedrock and the overlying silt and clay deposits. The available Facility investigation geological data indicate that the semi-confined sand and gravel deposits beneath the recent silt and clay are laterally continuous, with an approximate average thickness of between 5 and 10 feet. The data also indicate that the semi-confined sand and gravel deposits are laterally continuous with the sand and gravel deposits of the water table aquifer at locations along the edges of the recent silt and clay deposits at the Facility.

The Phase II RFI posited that groundwater flow directions in the deeper, semi-confined aquifer within most of the Facility might be to the south and southeast, toward a major groundwater discharge point near deep monitoring well MW-306. This was supported by data from offsite wells that similarly flow toward the same discharge point.

2.8 SITE TOPOGRAPHY AND DRAINAGE

The Facility and nearby surrounding areas are generally flat to very gently sloping, with short, steeply sloping to vertical banks immediately adjacent to the Frankford Inlet. The principle exceptions to this generalization are the moderately to steeply

sloping embankments adjacent to Interstate 95 and the highway's on- and off-ramps, located north and west of the Facility. The land surface north of the former Frankford Creek and the existing Frankford Inlet generally slope from north to south toward the former creek bed and existing inlet. The land surface south of the former creek and existing inlet generally slopes from south to north. Land surface elevations at the Facility and surrounding areas range from 7.0 to 9.0 feet (NAVD 88) near the former creek bed and Frankford Inlet to as much as 15 to 18 feet in the northernmost portions of the Facility.

The Facility property south of Main Street and adjacent to the Frankford Inlet and the former Frankford Creek channel lies within 100-year floodplain. Facility flood elevation level is 10.4 ft. based on 1929 National Geodetic Vertical Datum (NGVD).

2.9 SURFACE WATER BODIES

Surface water runoff within the Facility is generally from north to south, from higher elevations adjacent to I-95 toward lower elevations adjacent to the Frankford Inlet and the former creekbed. Significant surface water run-on has been observed entering the Facility along Wakeling Street at the northern Facility boundary.

The Facility has installed controls and equipment to minimize the commingling of non-process and process area storm water. Surface water runoff throughout most of the Facility from areas west of Wakeling Street and/or north of Main Street is collected by sumps or drains entering either City of Philadelphia combined sewer lines or the Facility wastewater sewer system.

Surface water runoff in the southeastern part of the Facility, east of Wakeling Street and south of Main Street, is generally to the Frankford Inlet either by overland flow or through storm sewers that are permitted to discharge to the inlet.

The City of Philadelphia Frankford Inlet and Wakeling Street combined sewer lines may discharge to the Frankford Inlet during heavy precipitation events, via flood gates that are controlled by the City of Philadelphia Water Department. Local surface water bodies in the vicinity of the Facility include the Frankford Inlet adjacent to the southeastern boundary of the Facility and the Delaware River located approximately half a mile east of the Facility. The Frankford Inlet is an estuary of the Delaware River. The Delaware River flows to the southwest, toward the Delaware Bay.

The Frankford Inlet originates within the southeastern portion of the Facility. The inlet is formed by the remnants of the Frankford Creek channel when the remaining reaches within and beyond the western portion of the Facility were backfilled following the 1956 diversion of the creek. The Frankford Inlet receives National Pollutant Discharge Elimination System (NPDES) permitted wastewater and storm water discharges from the Facility, combined sewer system overflow from City of Philadelphia sewers, and storm water discharges from the former Rohm and Haas Delaware Valley plant and the Frankford Arsenal.

3.0 SUMMARY OF REMEDIAL INVESTIGATIONS

This section provides a summary of remedial investigations conducted at the Facility under the RCRA Corrective Action Permit. The initial investigations were categorized by SMWUs and AOCs. However, the Phase I RFI concluded that because vadose zone fill contamination is relatively continuous throughout the Facility, the area of contamination beneath the Plant should be considered as one study area for any further RCRA corrective action activities. Consequently, the facility pursued a site-wide approach to the cleanup, including the individual areas identified in this section.

3.1 PHASE I RCRA FACILITY INVESTIGATION (1992)

The Phase I RFI Report was prepared in response to the requirements outlined in the RCRA Corrective Action Permit issued by the USEPA in September 1990. The Permit required investigating 12 SWMUs and two AOCs. These SWMUs and AOCs were grouped into four study areas based on their similar unit operations, waste handling practices, and historical uses. The four study areas are listed below:

3.1.1 Study Area No. 1

Study Area 1 included the phenol water system (SWMU No. 46) and AOC-1. The phenol water system included underground piping, trenches, and sumps and contained phenol water, rinse waters, condensates, decanter water, and runoff waters. An LNAPL (cumene) plume was detected in the vicinity of phenol water system and was believed to have originated from a leaked phenolic waste water sump (NUS, 1991). This leak was repaired in 1983, and unit underground pipeline was replaced with above-ground piping. Three groundwater recovery wells were installed in the area for the LNAPL recovery (NUS, 1991).

3.1.1.1 Soil Remedial Investigation

Twenty-three soil borings were completed throughout the study area to determine the extent of the LNAPL plume. In addition, borings from other study areas were used to delineate the LNAPL extent. LNAPL presence and thicknesses were determined using visual observations, Photo Ionization Detector (PID) readings, and an oil/water interface probe. An LNAPL layer was found to the extent of approximately 720,000 square feet or 17 acres within the Facility boundaries.

Thickness of the layer ranged from 0 inches, where no LNAPL was found, to about 30 inches.

The range of the LNAPL volume within the layer at the Facility was estimated to be from 200,000 to 500,000 gallons. The LNAPL was believed to be predominantly cumene.

3.1.1.2 Groundwater Remedial investigation

Grab samples were collected from recovery and monitoring wells and analyzed for EPA Methods 8240 (Volatile Organic Analytes [VOAs]), 8270 (Base Neutral Analytes [BNAs]), 8080 (pesticide/ Polychlorinated biphenyls [PCBs]), 6020 (metals), and 8150 (herbicides). Contaminated shallow groundwater was identified beneath most of the site. The only area that appeared to be free of shallow groundwater contamination was the northern perimeter of the facility. Most of the compounds detected were associated with Facility process operations, including cresols, acetone, benzene, substituted benzenes, styrene, anthracene, biphenyl, acetophenone, naphthylamines, pyridine, phenols, methylstyrene, ethyl styrene, and methyl naphthalene.

Metals were also detected in groundwater samples including arsenic, beryllium, chromium, lead, manganese, and nickel.

3.1.2 Study Area No. 2

Study Area No. 2 consists of Naphthalene-Contaminated Soil (AOC-2) and Past Landfill Area A (SWMU No. 11), Past Landfill Area B (SWMU No. 12), and Former Creekbed (SWMU No. 42).

AOC-2 was believed to be contaminated with naphthalene (NUS, 1991). Approximately 840 cubic yards of soil was excavated and removed from this area. Past Landfill Area A was formerly used for temporary storage of approximately 700 tons of waste liquor (approximately 15 percent maleic acid, 3 percent phthalic acid, and 82 percent water). All visible wastes were reportedly removed before the area was capped with asphalt in 1991 (NUS, 1991). Past Landfill Area B was believed to be used for the temporary storage of phthalic acid, mother liquor or for tar acid, naphthalene, and tar base sludge disposal.

The Former Creekbed was filled in at some time between 1950 and 1957. The fill material, which may have included coal tar materials, incinerator ash, phthalates, or phenol-formaldehyde resins, has been partly excavated. Sections of it were paved over or covered by the refined acetone tank farm in 1990 (NUS, 1991).

3.1.2.1 AOC-2 Soil and Groundwater Remedial Investigation

Three soil samples were collected and analyzed for VOA, BNA, AMS, cumene, total organic carbon (TOC), and grain size analysis. Naphthalene crystal waste was reported in two of three borings at approximate depth of 3 feet. Naphthalene was also reported in two borings from the Former Creekbed SWMU, which indicated that the boundaries of the SWMUs/AOCs appear to overlap. Other compounds detected in subsurface soil included acetone, cumene, benzene, substituted benzenes, phenol, substituted phenols, Polycyclic Aromatic Hydrocarbons (PAHs), and phthalates. LNAPL was not detected in AOC-2 and TOC content in the collected samples ranged from 2.6 percent to 36.6 percent.

3.1.2.2 Past Landfill Area A Soil Remedial Investigation

Five soil samples were collected and analyzed for VOA, BNA, AMS, cumene, and TOC. Most of the compounds detected in these borings were associated with current and historic Facility process operations, including AMS, cumene, benzene, substituted benzenes, phthalates, and PAHs, including naphthalene. Tentatively Identified Compound (TICs) included alkylbenzenes (including trimethylbenzenes), methyl styrene, PAHs (including methyl naphthalene and other substituted naphthalenes), and phthalates. Ash and coal debris was reportedly observed in the boring and TOC content ranged from 0.15 percent to 3 percent. No LNAPL was encountered in any of the soil borings.

3.1.2.3 Past Landfill Area B Soil Remedial Investigation

Five soil samples were collected and analyzed for VOA, BNA, AMS, cumene, TOC, and grain size. Tar oil, fill material, and naphthalene waste were reportedly observed in the soil and the TOC content of soil samples ranged from 0.9 percent to 24 percent. Compounds detected in these soil samples included AMS, cumene, styrene, benzene, substituted benzenes, phenol, substituted phenols, and PAHs. Although the samples from this SWMU were collected from the vadose zone, the cumene and AMS detected likely are residual contamination from periods when the groundwater table (and LNAPL layer) was closer to the surface, since there are no reported uses of cumene/AMS in this SWMU vicinity. Naphthalene was detected up to 2.5 percent in one of the borings, which appeared to be a waste/fill mixture. TICs

included alkylbenzenes (including trimethylbenzenes), methyl styrene, PAHs including methyl naphthalene and other substituted naphthalenes, biphenyl and biphenyl compounds, substituted pyridines, substituted phenols, and quinoline compounds, all of which may be associated with previous Facility operations (NUS, 1991).

3.1.2.4 Former Creekbed Soil Remedial Investigation

Seven soil samples were collected and analyzed for VOA, BNA, AMS, cumene, TOC, and grain size analysis. Oil stains and a coal tar layer were observed in the subsoil and TOC content of samples ranged from 0.2 percent to nine percent. Compounds detected included AMS, cumene, benzene, substituted benzenes, phenol, substituted phenols, phthalates, and PAHs, including naphthalene. Former Creekbed sample results were similar to adjoining SWMU No. 12 and AOC-2 samples, although concentrations and frequencies of detection were somewhat lower compared to adjoining SWMU/AOC. TICs included alkylbenzenes including trimethylbenzenes, PAHs including methyl naphthalene and other substituted naphthalenes, biphenyl compounds, substituted benzoic acid, quinoline compounds, and methylstyrene.

No groundwater contamination study was conducted on Study Area 2, but soil/waste contamination are expected to have migrated to the shallow groundwater.

3.1.3 Study Area No.3

Study Area No.3 consists of SWMU No. 19, 20, 21 and 30 (Past Dephenolizer I) and SWMU No. 49 (Naphthalene Tank Bottoms Area).

SWMU No. 19, the Past Dephenolizer I, was a steam-stripping column used to treat approximately 89,000 gallons per day (gpd) of wastewater. The wastewater reportedly contained an average of 30,000 to 40,000 micrograms per liter (µg/L) phenols and unspecified concentrations of sodium sulfate and acetone. The dephenolizer, feed tanks, and associated underground piping have been removed and the areas covered with gravel. The feed tank at SWMU No. 20 was reported to have leaked (Kearney, 1987).

SWMU No. 49, the Naphthalene Tank Bottoms Area was smaller than 200 cubic yards of naphthalene. Tank bottoms were reportedly spread, graded, and covered with stone (Flowers, 1990).

3.1.3.1 Remedial Investigation

Eight soil samples were collected and analyzed for VOA, BNA, AMS, cumene and TOC. A tar layer, oil, and demolition debris were reported in field observations. The TOC content of the study area samples ranged from one percent to four percent.

LNAPL was not detected in Study Area 3. Compounds detected in this study area included cumene (up to 570 milligrams per kilogram [mg/kg]) and naphthalene (up to 4,800 mg/kg) and other PAHs (up to 754 mg/kg). Cumene and AMS were not reportedly used in the vicinity of this study area. The detected cumene was predicted to be the result of underlying groundwater contamination and a fluctuating groundwater table. Substituted benzenes and substituted phenols were among the other chemicals detected.

TICs detected included alkyl benzenes (including tri methyl benzenes), PAHs (including methyl naphthalene and other substituted naphthalenes), substituted phenols, and methyl styrene, which can be associated with the history of production at the facility (NUS, 1991).

3.1.4 Study Area No. 4

Study Area No. 4 consists of SWMU No. 2 (Nonhazardous Drum Storage Area), SWMU No. 3 (Past Drum Storage Facility C), and SWMU No. 5 (Past Drum Storage Facility E).

SWMU No. 2, the Nonhazardous Drum Storage Area, consists of a paved area formerly used to store drummed hazardous and nonhazardous waste. These wastes may have included activated carbon sweepings, empty sample bottles, and ion exchange resins, which may have contained trace amounts of cumene, phenol, acetone, and AMS. This unit underwent RCRA closure and is currently used to store drummed nonhazardous waste and empty drums (NUS, 1991; Kearney, 1987).

SWMUs No. 3 and No. 5, Past Drum Storage Facility C and E, were reported to consist of a 1200 sq ft and 120,000 sq ft open hazardous waste drum storage area with a gravel base, respectively. The wastes stored onsite were reported to consist of 300 to 400 drums, which may have contained phenol, acetone, and AMS. These units were studied because of the possibility that spilled wastes could have contaminated soil and/or groundwater. Storage was discontinued prior to 1980 (NUS, 1991; Kearney, 1987).

3.1.4.1 Remedial Investigation

Three soil samples were collected from each SWMU and analyzed for VOA, BNA, AMS, cumene and TOC. No LNAPL stains or waste material in the sandy silt clay were observed in this area. Most of the compounds detected were associated with Facility process operations, includes cumene, phenol, PAHs, n-nitrosodiphenylamine, and phthalates (NUS, 1991).

3.2 PHASE II RCRA FACILITY INVESTIGATION (1994)

The first phase of the RFI concentrated on delineating the extent of detected LNAPL layer and soil contamination at the Facility. The Phase II RFI focused more on the nature and extent of groundwater contamination while supplementing the soil/fill contamination data.

3.2.1 Phase II Soil Investigation

The Phase II investigation included the placement of 33 borings that were advanced using hollow stem auger (HSA) drilling techniques (NSU 1994). Split-spoon sampling was conducted during this boring effort to obtain accurate lithologic samples. Five grab samples were obtained during the split-spoon sampling for chemical analysis.

Three samples were collected in the former Frankford Creek bed. Compounds detected in these samples included benzene, substituted benzenes, phthalates, and PAHs, including naphthalene. All compounds except benzene and toluene were detected within the ranges of chemical concentrations from analytical results of Phase I soil sampling. One grab sample collected from the MW-117 boring at a depth of 10 feet contained benzene and toluene at 16,000 mg/kg and 14,000 mg/kg, respectively. This sample was described as a hard black tar-like material, approximately two to three feet thick, with a sulfurous chemical odor.

Another sample was collected in an area north of the former phenol manufacturing area. The compounds detected included toluene (59 mg/kg), total xylenes (140 mg/kg), phenol (24 mg/kg), and naphthalene (320 mg/kg).

The last sample was collected outside the western Plant boundary at monitoring well MW-122. The sample was collected 13 feet below Lefevre Street, from a layer of soft brown crystalline material with some hair-like fibers and wood fragments. The

analytical results revealed that the sample contained 63 percent naphthalene and 1.7 percent 2-methlynaphthalene.

Five additional shallow soil borings were drilled along Lefevre Street and on the adjacent F.P. Woll property after the discovery of the naphthalenic crystalline material in the MW-122 boring. Split-spoon soil sampling was performed in order to visually identify the extent of the crystalline material. Two of the five borings encountered the naphthalenic crystalline material.

Based on these findings, 29 additional soil borings were installed by Geoprobe® direct push methods. Geoprobe® borings were drilled along Lefevre Street and on the adjacent F.P. Woll property to further delineate the extent of naphthalenic crystalline material. Two borings were installed inside the Facility boundary near the prior naphthalenic crystalline material discovery, and seven soil borings were drilled along the Plant boundary. Three of these seven borings and one boring within the Facility encountered naphthalenic crystalline material. The remaining borings were installed to better delineate the horizontal extent of the crystalline material.

3.2.2 Phase II Groundwater Investigation

3.2.2.1 Shallow Groundwater

During Stage I of the Phase II RFI, a network of 20 piezometers was installed to more clearly define the groundwater flow patterns beneath the site. Qualitative headspace screening of samples from these piezometers for volatile organic compounds (VOCs) was performed utilizing a portable field PID. The headspace screening data indicated probable volatile organic contamination west of the Facility along Lefevre Street. Very low (1 part per million [ppm]) volatile detections were noted along the southern and eastern property boundaries.

Groundwater samples were collected from 23 temporary drive point probes for onsite analysis in a mobile laboratory (i.e., rapid turnaround analysis) during Stage II. The six sample analytes were benzene, chlorobenzene, ethylbenzene, toluene, total xylenes, and cumene. The sample results provided a preliminary indication of the horizontal extent of shallow groundwater contamination. Except for an area along Margaret Street, shallow groundwater contamination appeared not to extend beyond the Facility boundary.

Twenty-four shallow groundwater samples were collected during Stage III. Sample locations included the three wells installed during the Phase I RFI, a groundwater seep along the north bank of the Frankford Inlet, and the 20 shallow wells installed during the Phase II RFI.

Phase II RFI shallow groundwater sample results indicated the extent of shallow groundwater contamination appeared to be delineated, mostly within the Facility. Fourteen shallow groundwater monitoring wells placed around the perimeter of the site were sampled. Only the MW-110 sample indicated significant groundwater contamination. The compounds detected in other perimeter wells were all detected at relatively low concentrations (i.e., less than 0.05 milligrams per liter [mg/L]).

Inside the Facility, benzene, toluene, xylenes, and/or ethyl benzene were detected at concentrations above 1 mg/L in samples from monitoring wells located in the western half of the site. During the sampling of monitoring well MW-103, significant oily and tarry residue clung to the sampling equipment. Small black to dark brown oily droplets were present in the sample. These droplets settled to the bottom of the container a few minutes after sampling, indicating the possible presence of DNAPL at this location.

The presence of acetone was only positively confirmed in one shallow groundwater sample from monitoring well MW-117, which is located approximately 200 feet south of the acetone tank car loading area and the former benzene-toluene-xylene process area.

Phenol was detected at concentrations greater than 1 mg/L in samples from several monitoring wells, with the highest levels of phenol detected in MW-117 and MW-103. No nearby source areas for these phenol detections were identified. Other detected compounds included naphthalene, cumene and metals.

TOCs, Biological Oxygen Demand (BOD), Total Dissolved Solids (TDSs), total hardness, total alkalinity, and dissolved solids analyses were conducted on all shallow groundwater samples. TOC analytical results indicated that a significant portion of the organic carbon present in the shallow groundwater is susceptible to biodegradation under ideal conditions. In the field, biodegradation is expected to be limited by the availability of oxygen and/or nutrients. Total hardness analytical results indicated that shallow groundwater hardness ranges from soft to very hard.

3.2.2.2 Deeper Groundwater

Thirty-one groundwater samples were collected and analyzed for VOA, BNA, AMS, cumene, TDS, total hardness and BOD. The chemicals detected included acetone, benzene, toluene, ethylbenzene, and total xylenes, phenol and substituted phenol compounds, naphthalene and other PAHs, cumene, and AMS. The only sample that did not contain contamination was the sample from monitoring well MW-304, which is located south of the former Frankford Creekbed and south of the deep low-level collector sewer.

TOC, BOD, TDS, total hardness, total alkalinity, and dissolved solids analyses were conducted on all deeper groundwater samples. TOC analytical results ranged from 2 mg/L to 62,000 mg/L. BOD analytical results ranged from less than 1 mg/L to greater than 770 mg/L. As discussed previously, the ratio of BOD to TOC serves as an indicator for biological degradation potential. Total hardness analytical results ranged from 110 mg/L to 1,800 mg/L. The total hardness results indicate that the majority of deep groundwater is hard to very hard. This conclusion is supported by the TDS and alkalinity results.

3.2.2.3 Sewer Line Data

All Facility stormwater discharges of water softener backwash, non-contact cooling water, process wastewater, recovered groundwater, and sanitary wastewater are permitted either by a City of Philadelphia Wastewater Discharge Permit or an NPDES permit. Facility process and sanitary sewers are depicted on **Figure 8**.

The City of Philadelphia permit allows discharging of process wastewater, recovered groundwater, sanitary wastewater, and contact stormwater to the Philadelphia Northeast Water Pollution Control Plant. Regulated discharges are via M sewer. Permit limitations include conventional parameters (e.g., pH and temperature), nonconventional parameters (phenol, acetone, cumene, benzene, and methanol), and the Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) categorical effluent standards.

O sewer sampling was performed in December 1993 as part of the NPDES permit requirement. Compounds detected included phenol (0.082 mg/L), naphthalene (0.010 mg/L), chloroform (0.014 mg/L), acetone (0.093 mg/L), and cumene (0.088 mg/L). These data indicated insignificant groundwater infiltration into O sewer.

The Facility also routinely sampled B sewer, E sewer, and W sewer water. The sampling was performed as part of an environmental monitoring program and was outside any permit requirements. Analytical data collected from samples of the W sewer revealed average phenol concentrations of 5.03 mg/L and an average mass flow rate of 0.25 pound per hour. Analytical data from samples of the B sewer effluent revealed average phenol concentrations of 13 mg/L and an average mass flow rate of 0.07 pound per hour. B sewer originates on the Facility. There are no process water discharges to it. Therefore, the measured phenol was believed to be due to groundwater infiltration. The E sewer analytical data indicated average phenol concentrations of 530 mg/L and an average mass flow rate of 1.1 pounds per hour. E sewer also originates on the Facility, and there are no process water discharges to this sewer. Therefore, the measured phenol was believed to be due to groundwater infiltration. Significant portions of E sewer were rebuilt after the Phase II RFI was completed and B sewer is scheduled for replacement in the near future.

3.2.2.4 Drinking Water Line Data

Fifteen samples of the drinking water were collected from fountains and other water stations (i.e., ice machines, restrooms, and sinks) along with a trip blank and were analyzed for inorganic contaminants, VOCs (EPA 524.2), semi volatile organic compounds [SVOC] (EPA Method 525), and coliform. The sample results indicated that the water supply was not affected by onsite contamination or Facility operations.

3.2.3 Health and Environmental Assessment including Vapor Intrusion

A health and environmental assessment was performed in accordance with the RFI Plan (NUS, 1991). The purpose of the assessment was to evaluate the potential risk associated with exposure to site chemicals by human and environmental receptors. Evaluation of risk includes identification of potential routes and mechanisms of exposure, identification of receptors, assessment of chemical toxicity, and quantization of exposures and the associated risks.

Although no direct contact to the groundwater discharged into the City combined sewers was expected to occur under normal circumstances, volatilization of groundwater chemicals was anticipated to result in exposure of human receptors via inhalation near manhole cover vents and at the discharge outfall at the sewage

treatment plant. Backflow of sewer vapors into residences is prevented by drain traps and similar plumbing fixtures.

A vapor emissions model was developed to estimate exposure concentrations for potential chemicals of concern via the inhalation route near the manhole cover vents at the intersection of Lefevre and Gaul Streets and at the sewage treatment plant outfall. The model was selected to quantify ambient vapor concentrations during releases, considering the primary release and transport mechanisms. Two potentially applicable sets of air quality criteria, occupational standards and proposed RCRA Subpart S action levels, were identified and were presented for comparison to the modeled vapor emission concentrations. These criteria were used as action levels to evaluate risk and not as "cleanup standards."

Air quality standards for occupational exposures are available for several chemicals for which chemical vapor emission modeling was performed. Based on the vapor emissions modeling performed for groundwater chemicals, none of the chemicals posed a significant occupational threat. RCRA Subpart S air quality action levels were proposed for only toluene and xylene. The toluene and xylene modeled concentrations were well below the corresponding proposed RCRA Subpart S action levels.

3.3 BASELINE GROUNDWATER STUDY (1999)

The Baseline Groundwater study was conducted to assess the groundwater flow patterns, groundwater quality, and distribution of residual dissolved and separate phase compounds. The study was performed by Resource Control Corporation (RCC) in December of 1998. Based on the results of these findings, RCC installed additional piezometers and test borings to minimize data gaps associated with delineation of separate phase product.

3.3.1 Groundwater Gauging Data

In December 1998, a total of 76 monitoring points were gauged to determine groundwater elevations as well as the horizontal and vertical extent of LNAPL and DNAPL. The monitoring points included wells, piezometers, recovery wells and a stream gauge for Frankford Creek.

The highest shallow groundwater elevations at the site appeared to be in the northern and western sections of the site with mounding conditions observed where surface influx of precipitation/runoff may be expected to influence the groundwater table. Intermediate to lower shallow groundwater elevations were observed in the eastern and southern sections of the site with the lowest elevations observed adjacent to the Frankford Creek. Elevation measurements adjacent to the creek inferred a groundwater flow to the south and east, towards the creek. The deep groundwater table elevation indicated deep groundwater flow towards the southeast, which was, for the most part, consistent with the results of the shallow water table aquifer.

LNAPL was found at a measurable thickness in 13 monitoring points. LNAPL thickness ranged from 0.02 feet to 2.28 feet. The plume appeared to occupy the central area of the Facility north of Main Street, subjacent to the cumene and phenol processing areas. DNAPL was exhibited in four of the monitoring points. However no thickness was determined since the screen intervals of the wells don't extend to the bedrock/overburden interface. Given this limitation, possible DNAPL thickness was assumed to range from 0.04 feet to over 5.0 feet.

A focused study was conducted to assess the influence of tidal fluctuations in Frankford Creek as it relates to the shallow water table aquifer in wells adjacent to the tributary. The results of this investigation indicated the water elevation fluctuates by 1.29 feet and 3.59 feet within well MW-109 and in the Frankford Creek surface water respectively.

3.3.2 Groundwater Analytical Results

A total of 29 groundwater samples were collected from Series 100, 200, and 300 monitoring/recovery wells and analyzed for VOA, BNA, AMS, cumene and Methyl Tertiary Butyl Ether (MTBE). This data is summarized below, but is included in **Table 1**.

3.3.2.1 Series 100 Shallow Monitoring Wells

VOCs were detected in 10 of the 17 series 100 wells. Those wells indicating the highest concentration of total VOCs included:

- MW -103 at over 1,200,000 µg/L (mostly acetone as noted above)
- MW-109 at 19,000 µg/L (cumene only)

- MW-119 at 8,051 µg/L.

BNAs were detected in all 17 series 100 wells. Those wells indicating the highest BNA concentrations were:

- MW-103 at 798,880 µg/L
- MW-119 at 4,227 µg/L
- MW-122 at 2,051 µg/L.

3.3.2.2 Series 200 Shallow Monitoring Wells

VOCs and BNAs were detected in all of the series 200 shallow monitoring wells that were sampled. Findings included:

- Total VOC concentrations ranged from 24,480 µg/L to 116,600 µg/L.
- MW-204 had the highest total BNA concentration at 412,310 µg/L.
- MW-204 had the highest naphthalene concentration at 96,000 µg/L.
- Phenol was found at an average concentration of 110,062 µg/L.

3.3.2.3 Series 300 Deep Monitoring Wells

VOCs and BNAs were detected in all series 300 wells sampled. Findings included:

- MW-305 had the highest total VOCs at 95,600 µg/L.
- MTBE was only analyzed in MW-303 and was not detected in that well.
- Phenol was detected at an average concentration of 210,842 µg/L with the highest dissolved phenol concentration found in any of the well series at the site detected in MW-305 at 1,200,000 µg/L.

3.3.3 LNAPL Investigation

The 25 soil borings were installed to an average depth of 15 feet below ground surface (bgs). Soil cores were collected from each boring and field-screened with a PID. Highest concentrations of volatile organic vapors observed within soil borings were exhibited where LNAPL and/or heavy sheens were noted, primarily adjacent to the process areas of the Facility.

Upon completion of the soil quality assessment, 14 piezometers were installed in those boring locations which indicated the presence of free-phase LNAPL or the potential for LNAPL to be present. LNAPL thickness readings from the new

piezometers indicated the major portion of the LNAPL plume appeared to occupy the central area of the Facility north of Main Street, adjacent to the cumene and phenol processing areas.

3.4 PUMPING DRAWDOWN ANALYSIS (2002)

After installation of the collection trench, Honeywell evaluated the technical rationale of installing an additional trench system north of the existing system in order to potentially augment the zone of hydraulic influence. To aid in the evaluation, Honeywell conducted strategic field activities to evaluate the hydraulic influence, and thus the performance of the southern trench to determine whether installation of a northern trench would significantly enhance LNAPL recovery.

The report recommended that each Ferret™ LNAPL pump could be replaced with a HammerHead™ total fluid pump. This would translate into a significant recovery increase from 0.1 gpm up to 10 gpm. This recommendation was later implemented, and the current trench system uses total fluid pumps.

Based on the performance of the LNAPL recovery system, the report concluded that a northern trench should not be installed for the following reasons:

- Little or no LNAPL is present upgradient of the proposed location;
- The installation of the northern trench may decrease the effectiveness of the southern trench; and
- The northern trench would not be effective at recovering the LNAPL in the vicinity of the groundwater mound based on the performance of the southern trench.

3.5 ENVIRONMENTAL INDICATOR DETERMINATIONS

EIs are measures used by the RCRA Corrective Action program to go beyond programmatic activity measures (e.g., reports received and approved, etc.) to track changes in the quality of the environment. The two EIs developed to date indicate the quality of the environment in relation to current human exposures to contamination and the migration of contaminated groundwater.

3.5.1 Human Health EI (2002)

Based on a review of the information contained in Human Health Environmental Indicators Determination, a "YES" determination was assigned, indicating current human exposures are under control at the facility.

3.5.2 Groundwater EI (2004)

Based on a review of the information contained in Groundwater Environmental Indicators Determination, a "YES" determination was assigned, indicating current migration of contaminated shallow and deep groundwater is under control at the facility.

3.5.3 Annual Groundwater Monitoring (2004-2012)

Subsequent to the Groundwater EI determination, a groundwater monitoring program was implemented at the site. The monitoring included annual sampling for VOCs and SVOCs of 17 boundary wells and 3 select interior wells as follows:

MW-102	MW-107	MW-112	MW-119	MW-301
MW-104	MW-108	MW-114	MW-121	MW-303
MW-105	MW-109	MW-115	MW-122	MW-304
MW-106	MW-110	MW-118	MW-123	MW-306

MW-119 was thought to be destroyed in 2006. During preparations to reinstall the well, the original well was found buried under several inches of gravel.

MW-114 was destroyed in 2008 during construction of new townhomes and street repairs. Due to several years of data indicating no detections of VOCs or SVOCs, in consultation with EPA it was determined that this well did not need to be reinstalled.

Prior to annual sampling, groundwater levels and other field parameters were measured. The elevation contours from June 2012 are presented on **Figure 9** and site wide redox potential contours presented on **Figure 14**.

Historical groundwater analytical data are presented in **Table 1**. The USEPA tap water Risk Based Criteria (RBC) are the most stringent set of criteria; however, since the RBCs are based on drinking water risk values and groundwater in this area is not used for drinking water purposes, the PA ACT 2 Medium Specific

Concentrations (MSCs) for residential nonuse aquifers were also used for comparison.

The following are findings related to the primary contaminants of concern (benzene, cumene, and naphthalene) during the June 2012 groundwater sampling event. Low level exceedances of other constituents are included in **Table 1**.

- The following wells exhibited no exceedances of RBCs or MSC non-use aquifer criteria: MW-104, MW-112, MW-115, and MW-123. Only naphthalene exceedances of the RBCs were detected in MW-105, MW-109, and MW-121, all of which have had sporadic exceedances of naphthalene in the past.
- Only one well, MW-118, exhibited exceedances of the MSC non-use aquifer criteria. Benzene was detected at 2610 µg/L, exceeding the RBC of 0.34 µg/L and the MSC of 500 µg/L. In addition, cumene was detected at 1880 µg/L, which exceeds the RBC of 66 µg/L, but is below the MSC of 50,000 µg/L. Naphthalene was detected at 161 µg/L, which exceeds the RBC of 0.65 µg/L, but is below the MSC of 30,000 µg/L. These results were inconsistent with historical MW-118 groundwater data, which previously had no detections of benzene and only low concentrations of naphthalene.
- MW-106: Benzene was detected at an estimated (J value) concentration of 3.5 µg/L and cumene was detected at a concentration 715 µg/L.
- MW-107: Benzene was detected at a concentration of 16.7 µg/L. There were a number of exceedances for the RBCs for SVOCs including a naphthalene concentration of 1680 µg/L. These findings are consistent with historic sampling events.
- MW-108: Chloroform and trichloroethene (TCE) were detected at concentrations exceeding the RBC. MW-108 is located in the furthest upgradient area of the plant, TCE was detected only in this well, and chloroform was detected only in one other upgradient well, so these compounds are not site-related.
- MW-110: Benzene was detected at a concentration of 141 µg/L, cumene was detected at 99.3 µg/L, and naphthalene was detected at an estimated concentration of 2.4 µg/L. Previous years of groundwater sampling results

showed a number of exceedances of VOCs and SVOCs, though a decreasing concentration trend has been apparent since 2003.

- MW-122: Benzene was detected at a concentration of 30.3 µg/L. In addition, several SVOC RBC exceedances were noted, including a naphthalene concentration of 20,500 µg/L. Results are consistent with previous sampling rounds and no apparent trend is exhibited.
- Series 300: Each deep aquifer well (MW-301, MW-303, MW-304, and MW-306) had several low level exceedances, but all results were consistent with previous sampling rounds. MW-301 had concentrations of cumene of 7390 µg/L and benzene of 5.7 µg/L.

During annual groundwater level measurements, LNAPL thickness was also measured in each well. **Figure 12** shows the extents of the LNAPL plume since the monitoring program started. In general, the plume appears to have contracted from 2004 through 2010 due to the interim measure described in Section 5.0.

3.6 ENVIRONMENTAL DATA RESOURCES (EDR) SEARCH (2011)

To address offsite contamination to the north and northwest, an updated Environmental Data Resource search was conducted. Sites within one mile of the Frankford Plant are depicted on **Figure 15.**

Upgradient sites in the north/northwest direction include a Roadway Express Trucking company, several automobile repair shops, and several gasoline stations. Sites immediately adjacent to the plant include a Mobil gas station and Frankford Auto Repair directly north.

Downgradient sites to the southwest nearest to the plant include a 7-Eleven gas station and the former Rohm and Haas Chemical Plant.

3.7 EMAIL DATA SUBMITTAL (2011)

After a meeting between Honeywell, Sunoco, and the USEPA in April 2011, the USEPA requested via email information to fill in several data gaps regarding site-wide investigation.

Honeywell responded to the USEPA in an email submittal, dated July 11, 2011, and attached in **Appendix A**. The contents of the submittal are summarized as follows:

- Addressed the extents of the naphthalene plume and incomplete delineation to the north/northwest.
- Provided data from the series 300 deep wells to show impacts to the lower aquifer. Also noted that DNAPL is still being delineated around MW-302.
- Provided operational data for the trench collection system in 2011.
- Addressed vapor intrusion (VI) pathways on- and offsite. Indicated that VI was investigated in onsite buildings in 2005. Also noted that all residences adjacent to the site are to the south, where concentrations of VOCs in monitoring wells are either at estimated concentrations below the detection limit or not detected at all.
- Provided a 3D site conceptual model of the LNAPL plume.
- Provided a schedule of RCRA corrective action steps leading to construction complete.
- Confirmed that benzene is the primary constituent of concern, with naphthalene and cumene as secondary constituents of concern.

4.0 CURRENT SITE CONDITIONS

4.1 LNAPL DELINEATION (2013)

In May 2013, 10 temporary well points (TWPs) were installed to further delineate the extent of the LNAPL plume. Each TWP was installed to an average depth of 15 feet bgs. Soil cores were collected from each boring and field-screened with a PID. Highest concentrations of volatile organic vapors observed within soil borings were exhibited where LNAPL and/or heavy sheens were noted, primarily adjacent to the process areas of the plant.

LNAPL thicknesses at each TWP, along with thicknesses in all onsite wells, are presented in **Table 2**. As shown on **Figure 13,** the LNAPL plume has contracted further in most areas compared to the 2010 contours depicted on **Figure 12**, except to the northeast, where the plume may migrate offsite for a short distance under the I-95 on-ramp. Both of these differences from the earlier contours are likely a result of the additional data points collected to further delineate the plume.

4.2 SHALLOW GROUNDWATER INVESTIGATION (2013)

In December 2013, 20 shallow wells were sampled for VOCs and SVOCs. In addition to the 15 shallow wells sampled annually and noted in Section 3.5.3, the following five wells were sampled to fill data gaps:

- MW-101 - provides additional site interior data to improve iso-contouring
- MW-201 - provides additional site interior data to improve iso-contouring
- MW-111 – replaces data lost from the abandonment of MW-114
- MW-113 – provide additional perimeter data to the south
- MW-116 – provide additional perimeter data to the south

Analytical data from this sampling round are presented in **Table 4**. Sample results were evaluated in comparison to the MSCs for residential non-use aquifers. The following are findings related to VOC and SVOC concentrations in wells during this event:

- The following wells exhibited no exceedances of the MSCs for residential non-use aquifer criteria: MW-101, MW-102, MW-104, MW-105, MW-106, MW-

108, MW-109, MW-111, MW-112, MW-113, MW-115, MW-116, MW-119, MW-121, and MW-123.

- Benzene exceedances of the MSC were encountered in perimeter wells MW-110 (13,700 µg/L) and MW-118 (2,980 µg/L). Benzene concentrations in these wells were historically either in a decreasing trend (MW-110) or non-detect (MW-118) until 2012. As this portion of the facility is mostly administrative, recent spills are unlikely. In addition, wells closer to the main plant area (MW-119 and MW-201) show much lower benzene concentrations, indicating that this benzene contamination originates at an offsite upgradient area.
- A benzene exceedance of the MSC was also encountered in interior well MW-201, which is expected, as this well is close to the LNAPL plume.
- There were no cumene (known as isopropylbenzene in lab documents) or naphthalene exceedances of the MSC.
- 2-Methylnaphthalene exceedances of the MSCs were discovered in interior wells MW-107 (763 µg/L) and MW-201 (1,610 µg/L), as well as in perimeter well MW-122 (2,270 µg/L). The MW-122 exceedance is due to the crystal naphthalene material previously delineated under Lefevre Street. Naphthalene concentrations are also elevated in this well, though not above the MSC.

The extents of the benzene and naphthalene plumes are depicted on **Figures 10 and 11**, respectively. While the naphthalene plume appears mostly closed to the northwest, the benzene plume is open in the same direction due to the high concentrations previously discussed in MW-110. As noted, it appears that this contamination originates offsite.

4.3 VAPOR INTRUSION EVALUATION (2014)

4.3.1 Offsite

The facility is surrounded by a number of residential and commercial buildings, so data from the December 2013 groundwater sampling event was evaluated using the Pennsylvania Department of Environmental Protection (PADEP) guidance document on vapor intrusion (PADEP, 2004). As presented in **Table 5,** VOC concentrations in perimeter and offsite wells were compared to the USEPA-PA default residential volatilization to indoor air screening levels. The only exceedance

of these screening levels was a benzene concentration of 13,700 µg/L in the offsite well MW-110. As previously noted, benzene contamination in this well is attributable to an offsite source. More importantly, no exceedances (and very few detections) of VOCs were encountered at any of the southern boundary wells which border residential neighborhoods, therefore offsite vapor intrusion from Facility contamination is not a concern.

4.3.2 Onsite

Since there are also several occupied buildings onsite, data for all of the onsite wells sampled was also compared to the USEPA-PA default nonresidential Permissible Exposure Limits (PEL) for volatilization to indoor air. No contaminants were detected in exceedances of these screening levels; however, wells containing LNAPL were not sampled. Further evaluations regarding the potential for this pathway to be complete will be conducted.

5.0 DNAPL INVESTIGATION

A laboratory fingerprint analysis collected in 2010 confirmed that the DNAPL present in monitoring well MW-302 is a coal tar material. In 2011, a DNAPL investigation was initiated, which focused on vertical and horizontal delineation of the material located at MW-302.

The following work has been completed to date. Honeywell will report results of the pilot studies to the USEPA upon selection of a remediation method in the third quarter of 2014.

5.1 DNAPL PROFILING (2011)

In June and October 2011, 29 soil borings were advanced using the Green Optical Screening Tool (TarGOST) screening technology at depths ranging from approximately 38 to 54 feet bgs via a Geoprobe® to screen and characterize the DNAPL plume across the southeast boundary of the Plant. The locations of the monitoring wells and borings are presented in the attached **Figure 16**.

The deepest distinct single DNAPL layer generally ranged from approximately 39 feet to 42 feet bgs, was generally oriented in an east to west direction south of the RCRA pad area and along the southern border of the Plant. A slightly shallower distinct single DNAPL layer, generally ranged from approximately 35 feet to 37 feet bgs, was oriented in an east to west direction along the RCRA pad and appears to become shallower progressing northward. The data indicate that shallow intermittent layers of LNAPL/DNAPL were present and generally ranged from approximately 16 feet to 21 feet bgs and were oriented in an east to west direction just north of the RCRA pad.

The weathered bedrock ranged from approximately 41 to 52 feet bgs with a slight downward dip encountered in the area proximate to well MW-302 along the southern border of the plant. These depths were based on probe refusal depths. This dip appears to be limited to the plant as off-property borings located south of MW-302 across Gaul Street indicate probe refusal at approximately 41 feet bgs. Previous documents have reported that the downward dip in the bedrock may be associated with the former Frankford Inlet stream bottom.

The data also indicate that the weathered bedrock zone below the source area and the off-property borings along Casmir Street has not been impacted with DNAPL below the source area based on the TarGOST screening results.

5.2 CONFIRMATORY SOIL BORING AND SAMPLING (2011)

A soil boring and confirmatory fixed-base laboratory soil sampling program was completed in June and October 2011 to refine the DNAPL profiling results, establish the composition and location of the DNAPL and to obtain continuous boring data to assess the formation lithology and stratigraphy.

The soil sampling data indicate that elevated concentrations of benzene, ethylbenzene and total xylenes, and/or SVOCs (primarily anthracene, benz(a)pyrene, carbazole, chrysene, dibenzofuran, 2-methylnaphthalene, naphthalene, and phenol) were present above the MSCs at various borings within the DNAPL source area. The primary target analyte list metal concentrations above the MSCs include arsenic, cobalt, lead, and manganese. The detected contaminants are typically associated with manufactured gas plant related coal tar derivatives and similar in nature to the DNAPL present in existing well MW-302.

The data also indicate that the weathered bedrock zone has not been impacted with DNAPL based on the field observations and field PID screening results.

5.3 SOIL BORING INVESTIGATION DATA AND DNAPL WELL INSTALLATION (2012)

In March 2012, 11 soil borings were advanced to approximately 45 feet bgs via HSA drilling methods to perform confirmatory subsurface soil investigation, to complete vertical delineation, and to more accurately define the DNAPL source area.

The soil stratigraphic information indicate that the DNAPL resides in the native soil layers consisting of a coarse to fine-grained, gray brown micaceous sand and fine gravel with a trace of silt. This formation is located in the saturated zone and ranges in thickness from approximately 17 feet to 40 feet bgs within the DNAPL source area. The shallow weathered bedrock generally ranges in thickness from approximately 41 feet to 45 feet bgs and is composed of green to gray mica, gneiss and schist saprolite of the Wissahickon formation.

The soil sampling investigation data indicate that elevated concentrations of benzene, ethylbenzene and toluene (BET) and/or SVOCs (similar to the contaminants detected in the Geoprobe® data) were present above the MSCs at various borings within the DNAPL source. The primary metal concentrations detected above the MSCs include arsenic, lead, and manganese.

Additionally, four deep unconsolidated groundwater/DNAPL monitoring wells (MW-310D through MW-313D), were installed to monitor the DNAPL thickness and characterize the dissolved-phase contaminants. The well screened intervals were placed in the deep overburden zone where the TarGOST borings and field observations confirmed the presence of DNAPL at depths of 37 to 42 feet bgs, such that they straddled the DNAPL bearing zones.

5.4 DNAPL WELL MONITORING (2012)

Newly installed wells MW-310D through MW-313D were gauged in June, August and September 2012 using an oil/water interface probe to collect DNAPL measurements. Strong odors were noted at the wellheads; however, DNAPL was not detected at wells MW-310D through MW-313D during any of the 2012 gauging events. Field observations and measurements have confirmed that DNAPL remains at MW-302 with historic thicknesses ranging from approximately 4 to 7 feet thick.

The lack of DNAPL in the wells indicate the DNAPL materials may be mobile (i.e., will move into well if soil conditions around the well are NAPL-saturated) but these materials do not appear to be migrating.

On September 10, 2012, groundwater samples were collected from MW-302, MW-310D, MW-311D, MW-312D and MW-313D, using low-flow purging/sampling methods. The data indicate that one or more of the following targeted compounds of concern were detected above the PADEP Maximum Contaminant Levels (PA MCLs) during the September 2012 sampling event: Benzene, anthracene, benzo(a) anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, 2-methylnaphthalene, phenanthrene, pyrene and iron.

5.5 IN-SITU PILOT STUDIES (2013)

The In-Situ Geochemical Soil Stabilization (ISGS) pilot study (using catalyzed sodium permanganate) was implemented from May 13 to May 17, 2013. The pilot study injection program consisted of the following primary elements:

- 5,000 square feet;
- 16 temporary injection points;
- 2 targeted treatment intervals ranging from 36 to 38 feet bgs and 39 to 41 feet bgs;
- 125 gallons of chemical solution were injected at each treatment zone;
- 250 gallons of solution per injection point;
- Approximately 4,000 gallons of ISGS solution was injected;
- Estimated effective radius of injection influence 10 to 12 feet; and
- Bottom-up injections.

An In-Situ Thermal Remediation (ISTR®) pilot study is planned for 2013 to assess the feasibility of this technology to treat the existing DNAPL source area. The results of the ISGS and ISTR will be directly compared to assess the overall cost-effectiveness of each technology for possible full-scale application.

6.0 INTERIM REMEDIAL ACTIONS

6.1 LNAPL RECOVERY SYSTEM (1984)

The presence of an LNAPL plume was first observed in 1981 on top of the water table beneath Phenol Process Unit No. 2. The LNAPL (mainly cumene) plume was believed to have originated from a leak in the phenol water system at the phenolic waste water sump (CP2; NUS, 1991). This leak was repaired in 1983, and all the underground piping was converted to above-ground piping.

Five recovery wells were installed in 1984 as a part of LNAPL recovery system. Three recovery wells removed dissolved-phase contaminants as well as the free product from the phenol process area.

6.2 INTERIM MEASURE TO ENHANCE COLLECTION SYSTEM (1990-1995)

After completion of the RFI Phase I, the Facility voluntarily conducted a conceptual design study to evaluate potential LNAPL recovery enhancement alternatives ("Final Report of the Conceptual Design Study for Free-Phase Product Recovery," Halliburton NUS, February 1993). The results of the study concluded that active LNAPL-only recovery systems and passive LNAPL recovery systems presented the two best alternatives for system enhancement.

On November 9, 1992, the USEPA requested an Interim Measure to enhance the existing LNAPL recovery system (USEPA, November 1992). Based on pilot study results, it was recommended that a network of active pumping wells be installed to enhance the LNAPL recovery system ("Report of Free-Phase Product Recovery System Pilot Testing and Associated Work," B&R Environmental, July 1993).

The Facility requested that the USEPA modify its corrective action permit to incorporate enhancement of the LNAPL recovery system using active pumping as an Interim Measure (AlliedSignal, August 1993). The USEPA granted the Class II Permit modification on October 29, 1993 (USEPA, October 1993).

The LNAPL recovery systems installed in June 1994 included two multiple well pumping systems and two single well pumping systems, one of which was expanded to a multiple well system in July 1995. These systems have been subsequently

modified or decommissioned based on LNAPL thickness measurements and LNAPL production results. Detailed descriptions of the systems are included in the Semi-Annual Reports submitted to the USEPA since 1994. Quarterly production and average production rates from each LNAPL recovery system for all quarters of operation are presented in **Table 3**.

Currently, only one multiple well recovery system remains active. This system includes wells MW-205, MW-219, and MW-220, which are shown on **Figure 17**.

6.3 COLLECTION TRENCH RECOVERY SYSTEM (2000)

An LNAPL collection trench was installed during December 2000 along 4th Street located north of the boiler house and south of the high-purity phenol unit (**Figure 17**). The trench was installed as three separate segments due to underground utility limitations. Each segment contains a recovery well. The collection trench and recovery wells are designed for the operation of a permanent, continuous-pumping LNAPL recovery system. Preliminary test pumping of LNAPL and water from collection trench recovery wells was performed in January 2000. Prior to final installation and startup of the continuous system, manual LNAPL removal at regular intervals from the trench wells began in April 2000 and continued until the permanent system was installed in March 2001. Startup pumping of the recovery system began in April 2001, and continuous pumping of this system began in July 2001. Recovered free product is separated from pumped groundwater while the latter is processed through the facility wastewater treatment plant.

Monthly gauging events are completed to ensure system drawdown and oil-water separator operation. The scope of work for the gauging events consists of collecting depth to water and depth to product data from each recovery well and associated wells listed below:

MW-101	MW-218	RC-19	RC-21B	H-04
MW-108	MW-219	RC-20	RC-22	R-07
MW-202	RC-16	RC-21	H-01	R-08
MW-203	RC-17	RC-21A	H-03	R-09
MW-211	RC-18			

In addition to the monitoring of plume thickness and drawdown effects, monthly operations, maintenance and monitoring (OM&M) visits are made to ensure the operation of the system. The events consist of the following:

- Observe and record the overall condition of the system including pumps, tubing, vaults and other components;
- Measure the pumping rate at each recovery pump;
- Obtain instantaneous readings from the flow meters and system pressure gauges and check control settings;
- Compare the results of the pumping rate test to the flow meter recorded and observed flows; and
- Review monthly flow and recovery data provided by plant personnel.

6.4 WAKELING STREET SEWER GROUT WALL (2001)

In March 2001, to mitigate LNAPL product intrusion into the Wakeling Street sewer, the Facility installed a grout barrier on the east side and parallel with the sewer between 4th Street and 6th Street (see **Figure 17**). The barrier is a 3- to 6-foot thick grout curtain which penetrates the subsurface approximately 6 feet below grade at the southern end near 4th Street, and becomes shallower by 1 to 2 feet as the trench is extended north. Due to underground utilities, an approximate 50-foot gap exists in the barrier, located adjacent to VT-105.

6.4.1 Follow-On Wakeling Street Sewer Inspections (2001-2004)

From June 2001 through June 2004, seven follow-on inspections of the Wakeling Street sewer were performed to evaluate the effectiveness of the grout wall in preventing LNAPL intrusion in the sewer.

During each inspection, photographs and PID readings were collected at alignment stations set up along the east and west walls of the sewer. Data from each station was then compared to previous inspections to determine the presence of new LNAPL intrusions. In addition, water and LNAPL levels were measured in five pairs of piezometers installed along the grout wall, one well in each pair inside the wall and one well outside the wall.

During the seventh and final inspection in June 2004, no product was measured in the piezometers downgradient (west) of the grout wall. This, in addition to essentially no change in the amount of staining evident within the sewer and no

product observed by the quarterly inspections, demonstrated that the wall was performing as intended.

Though additional inspections of the Wakeling Street sewers have not been conducted, the piezometer pairs along the wall are measured on a monthly basis and do not indicate LNAPL on the sewer side of the grout wall.

6.5 PUMP DRAWDOWN ANALYSIS (2002)

After startup of continuous pumping of the collection trench recovery system and installation of the grout wall, a pump drawdown analysis was conducted to measure the hydraulic influence of the system and to further delineate the LNAPL plume.

Delineation efforts of the LNAPL yielded two distinct plumes, one on the western and one on the northeastern section of the site. The LNAPL volume estimate was 209,332 gallons encompassing 194,788 square feet, with the majority occupying the northeastern section of the site, upgradient from the trench system.

Regarding the drawdown analysis, the report made the following conclusions:

- Data demonstrated that the pumping trench system is influencing the LNAPL plume.
- The grout barrier adjacent to the Wakeling Street sewer line and the extension along 4th Street intercepts the shallow table. The relatively no-flow boundary may contribute to achieving the necessary drawdown in the trenches by shifting the hydraulic gradient toward the trenches.
- A northern trench (proposed at the time) was not recommended, as it would only interfere with the effectiveness of the existing trench system.

To maximize LNAPL capture, the report also recommended drawdown by replacing the Ferret LNAPL pumps with HammerHead total fluid pumps. The total fluid pumps were subsequently installed and currently pump at a rate of approximately 3 to 6 gallons per minute, while achieving a drawdown in each recovery well of at least 4 feet.

7.0 REFERENCES

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8.0 LIST OF ACRONYMS AND ABBREVIATIONS

Amec	AMEC Environment & Infrastructure, Inc.
AMS	Alphamethylstyrene
AOC	Area of Concern
BET	Benzene, Ethylbenzene, Toluene
bgs	Below Ground Surface
BNA	Base Neutral Analytes
BOD	Biological Oxygen Demand
cm/sec	Centimeter per Second
DNAPL	Dense Non-Aqueous Phase Liquid
EI	Environmental Indicator
Facility	Frankford Plant
gpd	Gallon per Day
HSA	Hollow Stem Auger
Honeywell	Honeywell Resins & Chemicals LLC
IM	Interim Measures
ISGS	*In-Situ* Geochemical Soil Stablization
ISTR	*In-Situ* Thermal Remediation
LNAPL	Light Non-Aqueous Phase Liquid
MSC	Medium Specific Concentration
MSL	Mean Sea Level
MTBE	Methyl Tertiary Butyl Ether
MSC	Medium Specific Concentration
µg/L	Microgram per Liter
mg/L	Milligram per Liter
mg/kg	Milligram per Kilogram
NAPL	Non-Aqueous Phase Liquid
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System

OCPSF	Organic Chemicals, Plastics, and Synthetic Fibers
OM&M	Operations, Maintenance, and Monitoring
PADEP	Pennsylvania Department of Environmental Protection
PA MCL	Pennsylvania Department of Environmental Protection Maximum Contaminant Levels
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PEL	Permissible Exposure Limits
PID	Photo Ionization Detector
ppm	Parts per Million
RBC	Risk Based Criteria
RCRA	Resource Conservation and Recovery Act
RFI	Resource Conservation and Recovery Act Facility Investigation
SVOC	Semi Volatile Organic Compound
SWMU	Solid Waste Management Unit
TCE	Trichloroethene
TDS	Total Dissolved Solids
TICs	Tentatively Identified Compounds
TOC	Total Organic Carbon
TNT	Trinitrotoluene
TWP	Temporary Well Points
USEPA	U.S. Environmental Protection Agency
VI	Vapor Intrusion
VOA	Volatile Organic Analytes
VOC	Volatile Organic Compound